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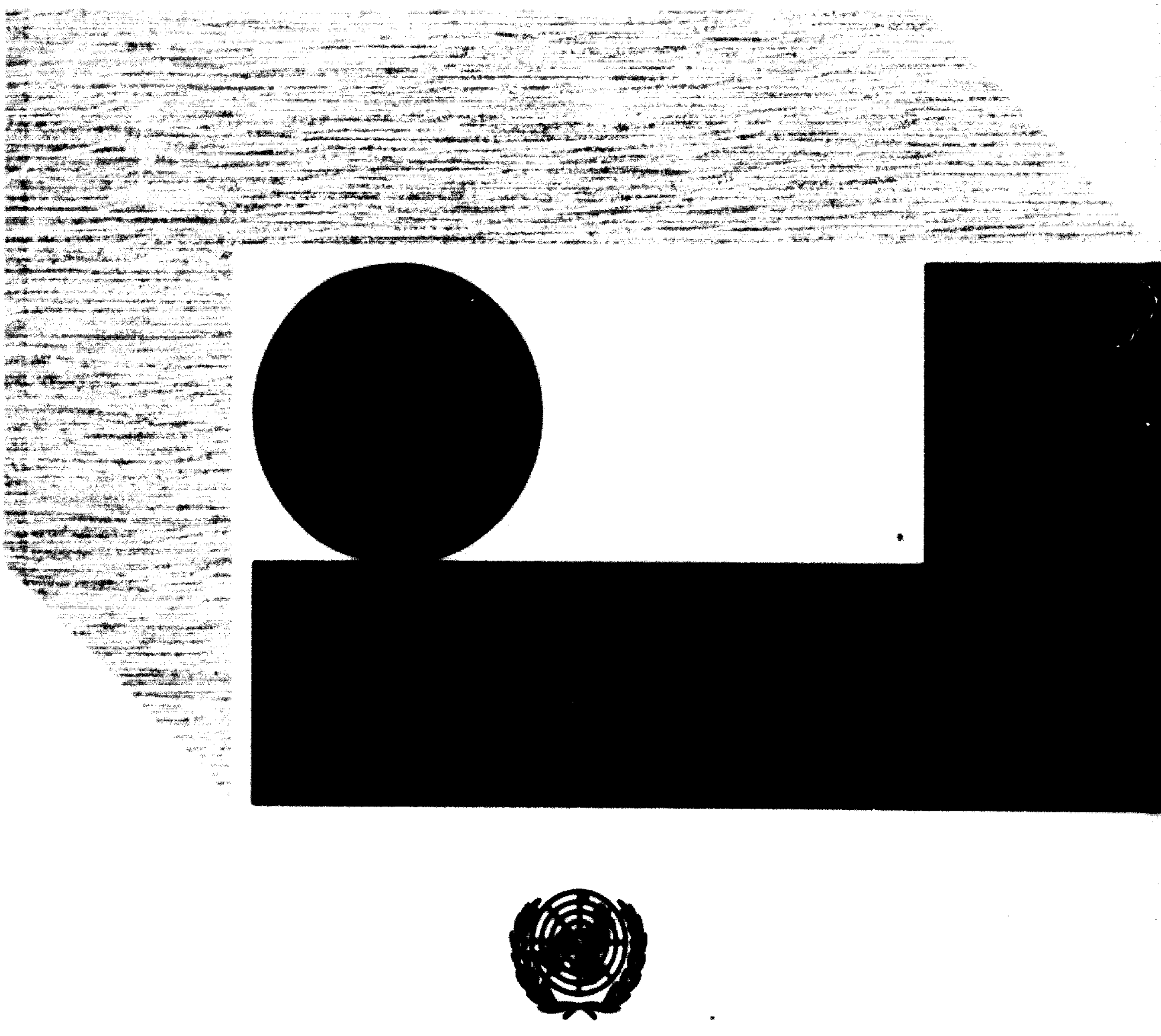
WOOD AS A PACKAGING MATERIAL IN THE DEVELOPING COUNTRIES



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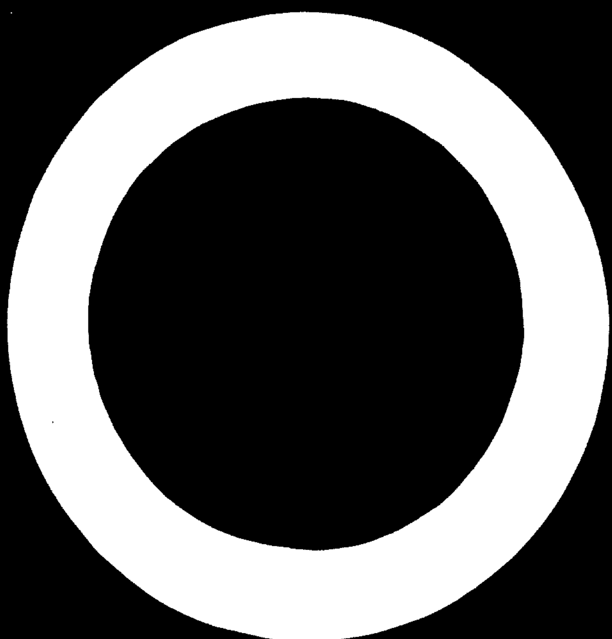

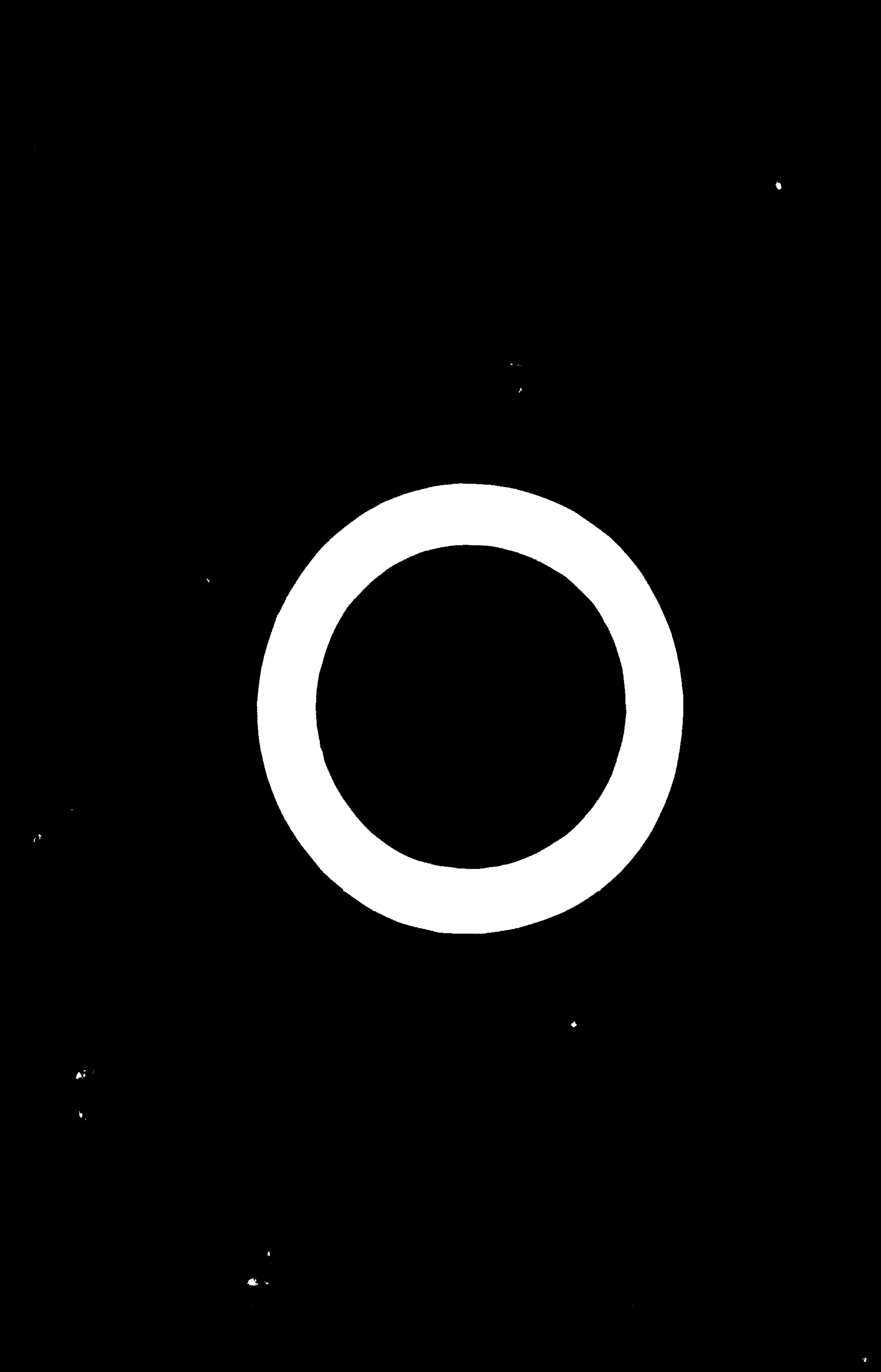

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COUNTRIES

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION
VIENNA

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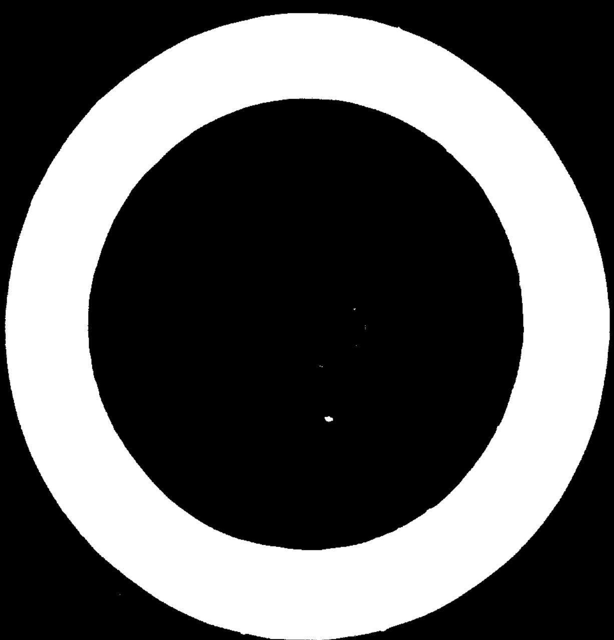
Preface

The industrial development of any country brings with it an increase in the production of consumer goods, and above all an increase in the transport of such goods to both domestic markets and markets abroad. As development progresses, these goods are shipped over longer distances, and the importance of transport, and hence of packaging, increases accordingly.

This study, dealing with the various types of wooden containers available today and their uses, was prepared by Mr. Bernard Hochart, serving as consultant to UNIDO. At that time Mr. Hochart was Chief of the Departments of Packaging and Agriculture of the Centre Technique du Bois, Paris, and is at present the Chief of the Wood and Furniture Industries Section of the Centre. The views and opinions expressed in this publication are those of the consultant and do not necessarily reflect the views of the secretariat of UNIDO.



CONTENTS

EXPLANATORY NOTES

Reference to dollars ($) is to United States dollars.

Reference to tons is to metric tons.

ABBREVIATIONS

ECE	United Nations Economic Commission for Europe
ISO	International Organization for Standardization
OECD	Organisation for Economic Co-operation and Development

Chapter 1

RECENT DEVELOPMENTS IN PACKAGING

The primary role of packaging is to permit goods to be stored and transported and to preserve them in the best possible condition. Other roles of packaging are to permit goods to be sold in convenient amounts in retail stores and to advertise goods at the place where they are sold, in particular in self-service stores. Packaging materials of wood are associated for the most part with the first role of packaging (storage and transport). They are not so well adapted to the other roles (wrapping of goods for retail sale and advertising).

Wood has been used to pack goods for transport since ancient times; it is known to have been used for this purpose in the time of the Pharaohs, some 4,000 years ago. Paradoxically, the long career of wood as a packing material may be a handicap to it at present. as it cannot take advantage of the prejudice for novelty which, to many people, is synonymous with a modern outlook. In many instances wooden packaging is considered to be out of date. eclipsed by packaging made of competing materials, such as cardboard, metals or plastics. Nevertheless, wooden packaging has developed considerably, and wooden packing cases of one type or another can be used for all kinds of goods and all methods of transport.

The development of the use of wood for packing depends, to be sure, on a country's degree of industrialization, but it also depends on the country's forest resources.

When the entire field of packing, including the wrapping of goods for retail sale, is considered, it will be observed that the percentage accounted for by wood has greatly diminished because new techniques of presentation and prepackaging have led to the use of new materials, mainly as sale in packaged form has replaced sale in bulk. Thus, in industrialized countries, the proportion of the total value of packagings accounted for by wood is between 6 and 12 per cent. The proportion accounted for by wood in the field of transport packaging, however, represents between one third and one half of the total value, depending on the country. This is an important point. Although the growth rate of wooden crates is lower than that for most of the competing materials, this is due primarily to the growth of the additional roles of packaging mentioned above. Wooden packaging materials are still needed for the storage and transport of goods and are thus an essential element in development.

Many packing problems arising in developing countries in connexion with the transport of agricultural products within the domestic market and the export of agricultural or manufactured products are being solved successfully through the use of wood, regardless of the level of industrialization of a country, for the manufacture of wooden crates can progress from the artisan stage to the industrial stage and can be continuously adapted to the country's needs.

Fruit and vegetables are an important sector in agriculture. For transport, they are packed in both wooden and cardboard containers. The use of wood and cardboard for transport packaging in selected countries and in Latin America as a whole is shown below.

	Wood (%)	*Cardboard (%)*
Algeria	100	0
Australia	60	40
Belgium	80	20
Bulgaria	95	5
France	90	10
Greece	90	10
Israel	80	20
Italy	90	10
Latin America	95	5
Morocco	95	5
Netherlands	50	50
New Zealand	60	40
South Africa	60	40
Switzerland	100	0
Tunisia	95	5
Turkey	95	5
United Kingdom	60	40
United States	50	50
Yugoslavia	98	2

When goods are transported by sea in conventional cargo ships, 50–80 per cent of the products are packed in wooden containers.

Medium-sized nailed sawnwood crates with a capacity of less than one cubic metre are being replaced by the following:

(a) Light packing cases made of sliced or peeled veneers stapled together (used in particular for agricultural products);

(b) Wirebound packing cases consisting of peeled veneers assembled and reinforced by stapled iron wire (used both for agricultural products, particularly citrus fruits, and industrial products);

(c) Large crates or cases whose degree of utilization depends on the facilities available for handling them.

As the industrial development of a country proceeds, three possible approaches to packaging present themselves:

(a) Palletization;

(b) Containerization (use of containers);

(c) Development and use of one-way packing cases.

Palletization

Palletization is a system of storing or transporting goods by means of pallets. A number of packing cases are assembled on an element called a pallet, which makes it possible to handle a considerable weight (about one ton) in a single action instead of having to handle the cases individually. Palletization is easy to arrange when goods are to be stored and handled in warehouses, as the warehouses can be planned and fitted out with this in mind. Pallets of the size and type most suitable for the packages and products to be handled can be selected, or the packages can be made to conform to the pallets. The appropriate handling equipment (forklift trucks, pallet trucks) can likewise be adapted to requirements. In these conditions, the profitability of the investment can be calculated fairly easily, and the enterprise making the investment benefits from it directly.

It is much more difficult, however, to carry out the palletization of transport operations and to calculate the profitability of this venture. The palletization of transport operations makes it possible to transfer products from their places of production to their place of consumption in unbroken load units, and it is this unbroken transport that is the main attraction of palletization. At all stages, however, there must be full compatibility between the palletized loads and the handling facilities.

The pallets used must be well adapted to the wagons, trucks and ships in which they are transported, and the carriers must likewise be well adapted to accommodate the pallets: their floors must be sufficiently strong to bear a forklift truck, and it must be possible to drive a forklift truck into the interior of the carrier or to unload the pallets from the ground.

The packing cases must be adapted to the pallets from the point of view of both size and type. The dimensions of the cases must be sub-multiples of the pallet dimensions. Although it is relatively easy to work out the size of palletizable packing cases for small products, such as fruit and vegetables, it is much more difficult to do this for bulky industrial products. For these products the packing cases must be designed to withstand stresses of a different type from those to which small packing cases are subjected. The shocks resulting from dropping will be replaced by compression stresses resulting from stacking: the packing cases can thus be made lighter in one respect, but they must have a higher resistance to crushing.

All the links in the chain of distribution must be provided with loading, storage and handling facilities that permit the transport and above all the handling of palletized loads. Considerable investment must therefore be envisaged to ensure that palletized loads can be sent without being divided up from one end of the chain to the other.

If, on delivery, the packing cases had to be unloaded one by one, there would obviously be only disadvantages in transporting goods on pallets because of the extra weight and the loss of space etc. This situation could occur because the investment needed at each of the links in the commercial chain is not necessarily proportional to the advantage which the link in question can derive from it; thus, there may be no incentive to make arrangements for palletization at one of the links if the investment involved is greater than the profit which that link is likely to derive. In this situation the chain would be broken and consequently the advantages of palletization reduced for the other links in the chain. Thus, an over-all plan must be drawn up covering the standardization of the vehicles, pallets, packing cases etc. as well as the financing of the costs, which should either be assumed in full or in part by the authorities or else shared among the business sectors concerned. Palletization is bound to become a necessity sooner or later, so it is essential to plan ahead for it and implement the measures required for its success.

Four possible systems of palletization are described below.

(a) System using one-way pallets, which make one journey only and are then destroyed on arrival. This system can be adopted for exports. For the domestic market, one-way pallets raise the same problem as one-way packing cases, which will be considered later.

(b) System based on reusable pallets belonging to a particular enterprise. This system makes it possible to place on the market an adequate quantity of pallets that exactly meet the requirements of the enterprise and to keep a relatively easy check on the utilization and return of the pallets. This system, however, makes the standardization of pallets difficult, and problems arise in the warehouse because of the wide variety of pallets in use which must be sorted before they can be sent back. The return of the pallets empty, which is a feature of this system, adds to the cost.

(c) System based on reusable pallets that are the common property of several users of groups of users. This system, which involves the establishment of multiple pools, makes possible a certain degree of standardization; but there is a danger that the pallet specialization by the groups may increase the difficulties encountered in dealing with privately owned pallets and pallets from a national pool.

(d) The common utilization of pallets at the national level through the establishment of a single pool. The principle of the system is to decide on one (or possibly two) models of pallets of precisely defined dimensions and manufacturing characteristics. Each member of the pool buys a supply of pallets, depending on his needs (tonnages stored and dispatched by him).

These pallets are checked on receipt by a representative of the pool, in order to ensure that they are in accordance with specifications. When a user dispatches a certain number of pallets with a consignment, he receives an equivalent number in return. On arrival at their destination, his own pallets are passed on empty to another user. This system permits the standardization of pallets at the national level, thus simplifying operations, securing the best possible return on the investment, and doing away with the need for the sorting and return of empty pallets to their owners. The system presupposes the existence of a central administrative body, which may be either a transport firm or a government department. Difficulties will be encountered in keeping track of the stocks and movements of the pallets. To avoid the complete disappearance of pallets, sophisticated accounting machines must be used.

Containerization

Containerization is a system of packing goods in specially designed containers that can be shipped without any breaking of the load by one or more means of transport. The container is a permanent packing unit and must therefore be sufficiently strong to permit repeated use. It is equipped with various features to make it easy to handle, particularly when being transferred from one means of transport to another and is designed to be easy to fill and empty. Its interior volume must be at least 1 m^3.

The containers most frequently used at the international level conform to the recommendations of the International Organization for Standardization (ISO) and have the following characteristics:

Height:	8 feet (2.44 m)		
Width:	8 feet (2.44 m)		
Length:	40 feet (12.19 m)	30 feet (9.14 m)	20 feet (6.10 m)
Maximum gross weight:	30 tons	25 tons	20 tons

Containerization is undoubtedly a world-wide practice that is here to stay, but to an even greater extent than palletization it requires decisions at the highest national levels and extremely large, simultaneous initial investments. Everything must be designed around and for the container: the ships, the docks, the cranes, the wagons or trucks and the warehouses. A container costs between $1,000 and $4,000, and a dockside crane designed for handling containers costs between $400,000 and $1 million.

To justify the investments involved in containerization, the tonnage of goods transported must be sufficiently high, and the investments must be concentrated on a few well-chosen ports. It is estimated that by 1975 over 80 per cent of all packed goods transported across the North Atlantic will be packed in containers. Containers can be profitably used only if the movement of goods is regular and in balance, that is, if the tonnage of packed goods sent through a port corresponds more or less to the tonnage of packed goods received.

Containerization will certainly be introduced into the international trade of developing countries, but investments will have to be made very gradually; containerization can be extended to the domestic market only very slowly.

The use of containers will bring about a number of modifications in the packaging field. To make use of the containers that are being returned, it will be necessary to pack them with goods that were formerly transported in bulk. To use the capacity of containers to best advantage, it will be necessary to move towards types of packaging where the useful volume is as high as possible with relation to the over-all volume (i.e. wirebound cases or cartons).

Development and use of one-way packing cases

In contrast to the reusable packing case that is designed with sufficient strength and durability for repeated use, a packing case made for a one-way trip is just strong enough to ensure that its contents arrive at the final destination in good condition, after which the packing case is discarded.

For the export trade, the problem of deciding which type of packing case to use scarcely arises, as there is very little likelihood that the packing case dispatched will ever be sent back in view of the high costs and difficulties that its recovery would involve. For the internal market, however, the problem of deciding whether to use one-way packing cases or reusable cases does arise.

Use of the one-way packing case brings some undeniable advantages: each case is hygienic because it is new (an important consideration when perishable goods are involved); it protects goods adequately during transport; and it greatly facilitates trading operations. However, its price must be amortized in a single journey, and the cost of manufacturing a packing case obviously does not increase in proportion to the number of journeys it is capable of making. The use of one-way packing cases does make it possible to calculate with certainty the proportion of the final selling price accounted for by the cost of packing.

Except on its first journey, a reusable packing case must be considered "used" and should be checked each time it is to be used to make sure that it is still in satisfactory condition. Of course, in practice this is never done. Even if such checking were possible it would be practically impossible to clean such cases. Reusable cases quickly become dirty and drab, and their unappetizing appearance adversely affects the presentation of the goods packed in them. These cases are subject to wear and tear, and they must be repaired before they deteriorate to a state where they must be scrapped. It has been estimated that the cost of repairing a packing case eventually amounts to as much as its initial cost. This problem of repair is often at the root of disputes and litigation between successive users of the packing case. On the other hand, reusable packings have the indisputable advantage of being amortized over a number of journeys, although it must not be forgotten that they have to be recovered and returned to their place of use.

Many attempts have been made to determine the comparative cost of one-way and reusable cases, but all such calculations are largely theoretical, as it is impossible in practice to obtain precise figures. The cost of one-way packing cases can be determined fairly accurately; but this is impossible to do for reusable cases, since the cost of the operations of sorting, dispatch and return, the cost of losses of packing cases etc. cannot be determined. However, it is possible to establish that:

(a) Reusable packing cases are often still used, even in the most highly industrialized countries, for transfers of goods within a closed commercial circuit, that is, transfers between factories in the same group or between enterprises linked together commercially.

(b) The development of the use of one-way packing cases is directly linked with the level of the *per capita* gross domestic product. One-way packing cases are, in general, used in countries where the *per capita* gross domestic product is over $1,200, whereas reusable packing cases are almost the general rule in countries with a *per capita* gross domestic product of less than $500. In countries with a *per capita* gross domestic product of between $500 and $1,200, the trend towards the use of one-way packing cases becomes more and more marked as the gross domestic product rises. The transition from reusable to one-way packing cases takes place, to a certain extent, at the expense of wooden cases because almost 100 per cent of reusable packing cases are made of wood, whereas only somewhere between 20 and 30 per cent of the one-way packing cases used on the domestic market are wooden. Nevertheless, as the transition from reusable packing cases to one-way packing cases also means that more one-way wooden packing cases are used, the total number of wooden packing cases increases.

It is thus easy to see how important wooden packing cases are in the developing countries because they are the packing cases used for the transfer of goods during the period of development, and they contribute to that development by making possible an increase in trade. Moreover, wooden packing cases can be used for exports of both agricultural and manufactured goods.

Chapter 2

CHARACTERISTICS OF SPECIES USED IN THE PACKING INDUSTRY

In principle, all European specifications permit any species of wood to be used for packing cases, but in practice only a few species are used (poplar, pine or beech). The choice of the species to be used will be determined above all by the quantity available and its market value.

The packing industry is a large consumer of timber; it has been estimated that of the total timber used for all purposes 10–20 per cent, depending on the country, is used for packing cases. Thus, substantial forest resources are essential to the packing industry.

The cost of the raw material accounts for a large part of the total cost of a packing case. Coming as it does at the end of a series of manufacturing or production operations, packing is always considered "too expensive", so the cheapest wood possible is usually chosen for this operation.

From the technical point of view, the choice of the type of wood to be used will depend upon the ease of working of the wood, its resistance to shocks, its resistance to the extraction of nails, its odour, its density, its resistance to decay, and its quality. No type of wood is the best for all uses, but most of the main species of commercial timbers can be used, subject to the observations and reservations discussed below.

Ease of working

Wood for packaging must be capable of being sawn rapidly without the need to take special precautions. Depending on the final use to which it is to be put, the requirements for ease of working vary. For sawnwood cases, crates and pallets, wood must be capable of being sawn, planed and shaped easily without the use of special tools such as stellite tipped saws or tools with tungsten carbide inserts.

Species such as Colombian mahogany, angelique or Brazilian rosewood, which contain foreign matter (e.g. silica) should be avoided. Species containing a great deal of resin, which rapidly fouls the tools, should also be avoided.

For light packing cases, wirebound cases and plywood packing wood that can be peeled (or possibly sliced) easily is best. As a rough guide, all species used for the manufacture of plywood can be used for these types of packing cases. It is not necessary to use the large peeling machines designed for the production of plywood, however, since the dimensions of the pieces to be cut are generally small. Hence, small-diameter wood (30–40 cm) can be used.

Density

The density of wood, which is easy to determine, is undoubtedly a very important characteristic because it gives a fairly reliable idea of the general strength of the wood and of its resistance to the extraction of nails. Density also indicates approximately how much shrinkage—and hence distortion—is likely to take place during drying. The use of high-density wood is advisable when high resistance to shocks is required, and above all when high resistance to the extraction of nails is called for. On the other hand, this type of wood has a strong tendency to distortion, and it is difficult to drive nails into it; nails tend to split the wood or to bend, so that it is necessary to drill preliminary holes before nailing. Wood with a density of over 750 kg/m^3 should not normally be used for packaging. On the other hand, it is not advisable to use woods whose density is less than 400 kg/m^3, for they will not have sufficient mechanical strength.

Decisions on the use of woods with a density of between 400 and 800 kg/m^3 (approximately) will depend on the type of case or case components that are to be made. Within this density range, it is best to use high-density woods (650–750 kg/m^3) to make components that are subjected to considerable shocks or nail-extraction forces, such as the edge planks and spacers of pallets, the bearing members of the floors of crates, the uprights and outer lengthwise members of crates, the battens of nailed cases and plywood cases, and the battens of wirebound cases. Woods of lower density (400–600 kg/m^3) should preferably be used for the manufacture of components that do not have to undergo very high stresses, such as the intermediate uprights and lengthwise members of crates, the cladding of crates, the panels of cases, and the sides and laths of wirebound cases and light packing cases.

Mechanical strength

It would be useful to draw up a complete table of all the species that are available in large quantities and to determine the most important characteristics of each species with an average density of between approximately 400 and 750 kg/m^3. The characteristics of wood for packing cases should fall within the following limits:

Density: 400–750 kg/m^3

Bending strength:

- Breaking strain: 600–1,400 kg/cm^2
- Modulus of elasticity: 80,000–140,000 kg/cm^2

Compressive strength:

- Breaking load: 350–600 kg/cm^2
- Resilience: 0.30–0.80 kg/cm^2

Other factors, such as those considered below, also enter into the mechanical strength of wood.

Humidity

The wood of living trees contains an enormous amount of water, which is lost after felling and particularly after sawing. For most uses of wood as a packing material, and particularly for using wood to make crates, reusable cases and pallets, and wirebound cases, almost all this water must be removed.

Humidity is present in the inner cavities of the wood and in the cell walls. When the water has evaporated from the cavities, but the cell walls are still saturated, the wood is said to have reached the point of fibre saturation, this point actually corresponding generally to a moisture content of about 30 per cent. When the humidity falls below this saturation point, the wood begins to shrink. The wood stops drying when it has reached equilibrium with the temperature and relative humidity conditions of the surrounding air. This equilibrium point varies from 10–25 per cent, depending on climatic conditions.

When wood dries, its fibres begin to stiffen, so that its resistance to static stresses increases while its resistance to dynamic stresses diminishes. The resistance to static stresses and to the extraction of nails may be as much as 30 per cent greater for dry wood than for green wood.

Knots

Knots are sections of branches appearing on the surface of a piece of wood. They interrupt the direction of the grain and give rise to local areas of cross-grain with marked slope. Some types of knots reduce the strength of the wood they are in more than others. A distinction should therefore be made between healthy knots, which adhere strongly to the surrounding wood, and black, rotten, loose knots.

The effect of a knot on the strength of the piece of wood in which it exists depends on its proportion to the cross section of the wood. The maximum permissible dimensions of knots must therefore be determined in the light of the width of the wood in which they are found. Knots reduce the tensile strength more than the compressive or shear strength. The position they occupy with respect to the length of the piece of wood must be taken into consideration if the wood is to be subjected to bending stresses.

Slope of grain

The slope of the grain is the direction of the wood fibres with respect to the longitudinal axis of a piece of wood. When the fibres are not parallel to the longitudinal axis, the wood is said to have a slanting grain. The slope represented by the angle between the general direction of the grain and the longitudinal axis of the piece of wood is expressed as a percentage. Slight local deviations in the grain are usually ignored. A grain slanting very markedly, however, causes a considerable reduction in the strength of the piece. Thus, a slope of 10 per cent in a piece of wood subjected to bending stresses causes a reduction in bending strength of 40 per cent, while a slope of 15 per cent causes a reduction of 60 per cent, and it is therefore necessary to reduce the working loads normally assigned in order to compensate for this loss of strength. Furthermore, pieces of wood with a slanting grain have a tendency to warp when subjected to variations in humidity. The permissible slope of the grain must therefore be limited to a certain level for pieces of wood subjected to strain, such as crate framework members, the battens of sawnwood and plywood cases, and the battens of wirebound cases.

Rot

Rot, which causes wood to disintegrate, is a result of the action of wood-destructive fungi. It seriously affects the strength properties, including resistance to extraction of nails, and may reduce these properties to zero: it is therefore totally unacceptable.

Blueing

The blue colouring of the sapwood of certain types of wood, notably tropical resinous and broadleaf woods, is caused by a fungus. In itself it does not affect the strength of the wood, but the conditions that promote the growth of this fungus are also ideal for the growth of destructive fungi, and blueing may well mark the beginning of rot.

Attack by insects

Some types of wood while in the green or dry state are subject to attack by insects or larvae. The sapwood of certain broadleaf timbers is subject to attack by lyctus beetles and deathwatch beetles. Small wormholes, and especially the dead black punctures resulting from the emergence of these insects from the green wood, have only a slight effect on the strength of the wood; and if the wood is otherwise sound it is quite suitable for the manufacture of packing cases. If the wood has been heavily attacked, however, and especially if the larvae or insects are still in the wood, as is shown by active punctures, the wood will eventually be destroyed by the pests and thus should not be used.

Wane

Wane is either the presence of bark or the absence of wood (as a result of removal of previously existing bark) on the edges of a piece of wood. They cause a diminution of the strength of the piece of wood because of the diminution of its cross section. They are a less serious fault in cladding or filling elements than in frame elements, battens or lintels.

Splits

Splits are internal or external separations along the grain of wood caused by stress resulting from shrinkage in drying. These splits reduce the shear strength and moreover often arise at the point at which a nail enters, thus considerably reducing the strength of nailed elements. Few splits may be tolerated. Certain phenomena caused by bad drying, such as case hardening, which brings about the formation of cavities inside the wood, lead to such a diminution of strength that the wood in which the condition occurs must be discarded.

Resistance to attacks by fungi and insects

Since the strength of wood that has been attacked by fungi or insects is considerably reduced, such wood should not be used in the manufacture of packing cases. However, sound wood can be attacked while it is being used. There is normally little risk that one-way packing cases will be attacked so severely in the course of their one and only journey that their strength will be impaired.

For reusable packing cases, however, the problem is obviously different, because such cases are designed to last for several years. It should be noted that reusable packing cases are unlikely to be contaminated by insects during their actual shipping (transport and handling). Likewise, reusable cases in which the wood has reached a state of humidity equilibrium below 20–22 per cent are unlikely to be attacked by fungi.

Empty or full cases may be attacked by insects during storage if the climatic conditions are such that the equilibrium state of the wood is dry, or by fungi if the equilibrium state of wood has a moisture content of more than 20 per cent or if cases remain in contact with the ground. Theoretically, it is therefore necessary either to use wood having a particularly high natural resistance to attack (which would eliminate the sapwood from most species) or to treat the wood with a preservative that is effective against fungi and insects, including termites, and will not leach. The preservative must also be compatible with the goods being transported; its composition must be such that it will have no harmful chemical action on the goods. This problem often arises in the packing of metal goods and above all in the packing of perishable products. Most countries have laid down rules concerning the products that may be placed in contact with foodstuffs, and these regulations prohibit the use of almost all the most common wood preservatives, especially those based on arsenic or bromine.

As mentioned above, wood intended for packing cases must be as cheap as possible. The systematic elimination of the sapwood or the treatment of wood with preservatives raises its price considerably. Moreover, the treatment with preservatives must be carried out on the machined packing components rather than on the unprocessed sawnwood.

A study carried out in the United States has shown that the life of a wooden case that was given no preservative treatment and was exposed to unfavourable weathering conditions was 5 years, while the life of a similar case exposed to the same conditions after preservative treatment varied from 5 to 11 years, depending on the treatment used. Most packing cases, however, do not have a life of more than 5 years if they are used regularly for transport and handling. Five years is the life generally assumed for bottle cases and wooden pallets. The life of packing cases designed for storage is undoubtedly more than 5 years, and it may be as much as 10 years or more.

Thus, the risk of destruction of packing cases by fungi or insects, which needs to be taken into consideration only when packing cases are likely to be stored under bad conditions, must be weighed against the cost of preservative treatment, which increases the cost of the raw material by 25–30 per cent. The decision to use a preservative will depend to a very large extent on the climatic conditions of a country and even on the conditions of a region of a country. No treatment may be needed in countries with a temperate climate, while certain categories of cases may need to be treated in countries with a tropical or subtropical climate.

Compatibility and odour

The question has often been raised whether untreated wood is likely to have any influence on the keeping properties of the product packed in it. Practically all known woods have a pH of less than 7, and their pH is generally between 6 and 4.5. As far as is known, of all woods whose pH has been studied, only balsa has a pH over 7 (its pH is 8).

The fact that the pH of wood is less than 7 indicates that wood is naturally acid. In itself, this acidity is independent of the humidity of the wood, but the humidity does permit the acid agents to migrate towards the exterior of the wood. Thus, the lower the pH of a wood is and the more humid the wood is, the more possibility there will be that the acidity will exert some kind of action on a product packed in the wood.

The humidity of wood is, of course, itself a corrosive agent when it is in contact with metal. Frequently, in drying, damp woods give off water vapour inside packing cases; this vapour condenses on metal parts and operates as an active corrosive agent. This phenomenon is particularly common when elements made of humid wood are enclosed inside airtight wrappings such as plastic sheet or cocoons. Thus, for packing cases or pallets designed for the transport of metal goods, it is advisable to select wood with the highest possible pH and to dry it thoroughly.

The humidity and acidity of wood have the further effect of attacking the nails required for the assembly of packing cases. The life of one-way packing cases is normally so short that the corrosive action does not affect the nails or staples enough to reduce seriously the strength of the assemblies. For reusable packing cases, however, the problem is quite different, and cases are frequently found in which the nails have been completely rusted away. To prevent this from happening, the nails should be galvanized or phosphated before use; such treatment also increases the resistance of the nails to extraction by 20–30 per cent.

Apart from their humidity and acidity, certain woods may exude substances such as tannins, staining substances, essences, resins, or oleoresins that damage the contents to some extent. Such woods should generally not be used, or should be used only if they do not come into contact with the merchandise.

Some woods tend to transmit a taste or odour to perishable goods, especially those susceptible of rapid spoilage, such as butter. This tendency depends on the species and on its humidity. As the humidity of the wood diminishes, the level of the odour also diminishes, and some woods give off no odour whatever at humidities below 20 per cent, whereas others do so whatever their humidity. Before it is decided not to use a certain species, the relationship between the level of the odour given off by the wood and the length of time the merchandise is likely to spend in the case should be considered, with storage conditions also taken into account.

When merchandise is kept in a packing case only for the time necessary for transport, there is scarcely any risk of transmission of odour to the goods, but when goods are stored for a long period or in a confined space (cold storage of butter or apples), the risk of transmission of odours is great. The use of aromatic woods or very resinous woods such as cedar, larch, pitch pine and Oregon pine should therefore be avoided when prolonged storage is envisaged.

A final aspect of compatibility concerns hygiene. The question arises whether the wood of packing cases can become contaminated and transmit harmful germs. As far as is known, the types of insects that attack wood have never been found to be harmful to man nor to transmit the germs of any disease. Nor are the types of fungi that grow on wood harmful to man, except that their spores may cause allergies when breathed. The only serious risk would appear to be that these fungi might be transferred to the goods packed in the wood. If this happened, the goods could nevertheless be consumed without any danger within a short period, but they would deteriorate and rapidly become unsuitable for consumption. The growth of such fungi would thus reduce the keeping time of the goods. Certain goods, such as fish, transmit to wood microflora and bacteria that produce indole or H_2S, and these agents develop in the wood and are retransmitted to other fish when the packing case is used again. These microflora and bacteria are not harmful to man either, but they likewise diminish the keeping time of the fish. It is therefore preferable to take out of circulation any packing cases for food products on which fungi have developed and to cleanse reusable cases intended for fish.

Chapter 3

TYPES OF WOODEN PACKING CASES

A manufacturer of packing cases generally has at his disposal many species of wood with very different characteristics, and he can thus design and execute numerous types of packing cases specially adapted to storage, handling and transport conditions by making the best use of the mechanical properties of the various species. The types of packing cases that can be made from wood are as varied as the material itself. To analyse them it is necessary to classify them, although any classification is bound to be somewhat arbitrary, since the distinctions between different categories are not always specific and the categories are not all of equal importance.

Crates

A crate is a large, generally oblong, wooden packing case made of a framework of pieces of wood assembled to form a rigid enclosure to protect the contents during shipping and storage. The sides of the crate may be filled in with panelling or left open. Crates are used for shipping all types of industrial goods. Their total weight may vary from 1 ton to over 30 tons, and their dimensions are limited only by the capacity of the transport and handling facilities. Crates enable a large, heavy object or a number of objects to be handled as a single unit; they cost less, for a given effective volume, than several small cases. They are essential for shipping fully assembled machine tools.

A crate consists of a base and four vertical walls. In the United States, a crate serves as a three-dimensional framework beam. For this reason, it is often called a frame beam (see figure 1). The product to be crated is placed on the base and attached firmly to it by bolts, heavy screws or metal straps, while the vertical walls and the top are placed on top of this base like a bell-shaped cover for a plate of cheese, without their coming into contact with the contents. The crate itself, independent of its contents, must resist all the compressive stresses resulting from stacking, bending stresses and lateral crushing stresses arising during handling with slings. In this design, the crate can be considered a frame element, the calculations for which must be made in the light of the size and weight distribution of the contents and the well-known formulae on strength of materials.

In Europe it is customary to take the contents as the real starting point, and the crate is built around them, taking maximum advantage of the possibilities of using

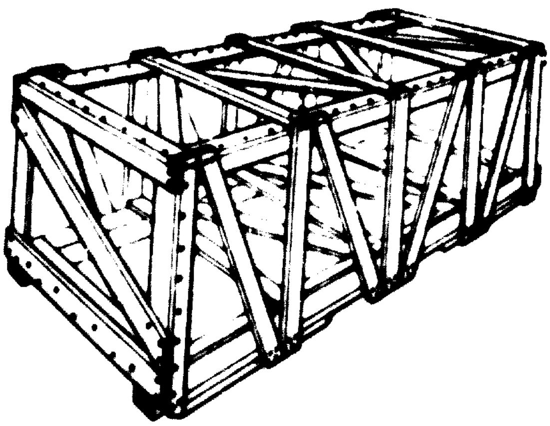


Figure 1 Frame beam crate

the contents as a support through a system of rigid wooden struts and packing piece so that the contents and the crate finally form a single unit (hence the name "unitary crate"). To be able to use this system, the contents themselves must be capable of resisting the external stresses that will be transmitted to them through the struts and packing pieces.

This design makes it possible to construct crates having smaller exterior dimensions, for contents of a given size, than beam crates. Theoretically they also require less wood, but the various calculations necessary for constructing unitary crates are very complicated, and in practice the cross section of the wood to be used for their various elements is usually decided by rule of thumb.

The struts and packing pieces that rest at one end on the contents of the crate and at the other end on the crate framework itself must be placed at precise points in order to distribute the external stresses sufficiently well to avoid damage to the crate or its contents during storage and handling. Thus, the placing and design of these pieces must be carried out by highly skilled workers having long professional experience and a thorough knowledge of the packing trade.

When the contents of the crate cannot themselves bear the stresses resulting from shocks or compression, the rigid struts and packing pieces are replaced by a flexible packing of wood fibre (loose or in sheets or rolls covered with kraft paper), sponge rubber or plastic foam pads, or more sophisticated shock-absorbing systems. Straw is generally ruled out for sanitary reasons.

Whatever the design used, all crates consist of a base, four vertical walls and a top. The base is the main element of the crate and must be sufficiently rigid to absorb most of the bending stresses. It can be made in accordance with two very different designs.

Skid bases are made of two or more one-piece lengths of wood of large cross section wood (deals), the "skids", running lengthwise under the crate. On top of and at right angles to these beams, a crosspiece of fairly large cross section is fixed at each end of the beam to receive the end of the crate (the vertical wall), and a number of other crosspieces, whose number and cross section are determined by the size and weight distribution of the contents, are fixed across the beams to support the contents. Finally, planks or plywood elements are fixed between the various crosspieces to provide, if necessary, some degree of sealing against dust and water (see figure 2).

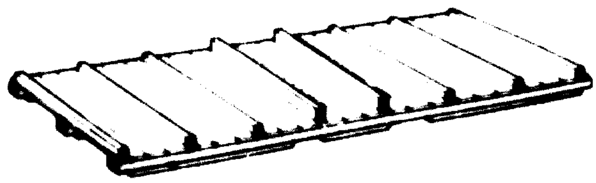


Figure 2. Skid base

This type of base is quite easy to make and requires relatively little labour, but wood of large cross section and considerable length is required for the skids. Such special sizes of sawnwood are sometimes difficult to obtain. Skids can also be made from shorter pieces of wood joined together, but the various methods of doing this are difficult and costly.

Box-type bases are made of thin pieces of wood (30–60 mm thick) laid out to form a frame consisting of two lengthwise elements and two cross elements and then doubled towards the inside of the base with other pieces of wood of the same cross section. Additional crosspieces (possibly double) are then fitted where they are needed depending on the size and weight distribution of the contents of the crate. Finally, further elements are fitted longitudinally between these crosspieces to effect suitable bracing of the base (see figure 3). This type of base has the advantage that it requires only relatively thin wood, which is much easier to find than the wood of large cross section needed for skid bases, but these box-type bases are much more difficult to make and involve much more work.

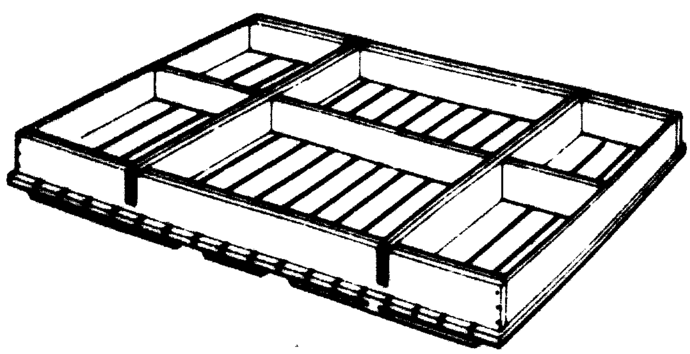


Figure 3. Box-type base

The vertical walls of the crates (the ends and sides) are made of uprights, lengthwise pieces, diagonals and spacers whose cross section, number and position depend on the over-all weight of the crate and above all on its dimensions. The top of the crate consists of a frame of scantlings with intermediate strengthening cross members designed to support weight from above (smaller cases may be piled on top of the crate) and to withstand the lateral crushing stresses caused by the slings during handling.

The walls and top of the crate need not be solid if the contents do not require any particular protection; that is, the crate may consist simply of the framework, the elements of which are nailed or bolted together. When the contents require a certain degree of protection, the frame elements of a panel are simply juxtaposed, and a cladding of boards or plywood is nailed to them, thus fastening them together.

The decision whether to use boards or plywood for cladding is primarily an economic one, although it depends to some extent on technical considerations as well. Boards are a cheap material for cladding, but their fitting involves a great deal of work. They tend to dry out and thus to shrink, leaving a certain amount of space between them, which reduces the resistance of the panel to diagonal distortion. Even when fitted together with tongues and grooves, boards are not waterproof, for water can very easily filter in between adjoining boards and thus penetrate the crate. The vertical panels can be lined with a sheet of tarred paper or plastic film, but if the same technique is used on the top of the crate, the water filters in and forms pockets in the barrier sheeting, which sooner or later bursts. To ensure watertightness, therefore, the tops of crates must be made of two crossed layers of boarding with a sheet of barrier material between them.

Plywood is considerably more expensive than boards as a cladding material, even though it needs to be only half as thick as boarding to give the same over-all strength to a crate. The precutting and assembly of plywood require much less labour, however. The economic desirability of plywood will therefore depend on the ratio between the cost of boards, the cost of plywood and the cost of labour. From the technical point of view, plywood requires more uprights but fewer bracing members than boards, and it has the advantage of being practically waterproof.

For a developing country, it would appear that the first crates would be made with cladding entirely of boarding, followed soon afterwards by crates with plywood tops; and finally, as the country develops, crates would be made with cladding entirely of plywood.

Like all other types of packing cases, crates may be of the one-way type or may be reusable. European-type crates are almost always one-way crates and their panels are assembled with nails. American-type crates may be one-way crates (if so, they are assembled with nails) or reusable crates. If the reusable crates do not have to be dismantled for empty return, they are assembled with nails; but more often than not such dismantling is necessary, and the panels are therefore attached to each other by bolts as long as it is possible to reach into the crate, and finally with heavy screws for the last panel.

Nailed sawnwood boxes and cases

The mass-produced, prefabricated box designed for the domestic transport of manufactured goods and finished products from soap, wine and tinned goods to machine parts and electrical appliances is normally the first type of packing case to be replaced by other types such as wirebound cases, plywood cases or cardboard boxes.

The nailed sawnwood box is the oldest type of wooden packing case, and it has not undergone any substantial development since it was first produced. Because of lack of imagination, box makers do not use all the possibilities at their disposal. Although many different types of nailed sawnwood boxes can be made, such boxes can nevertheless be grouped in four main categories corresponding to four basic designs.

Type 1 Simple box

The simplest type of box has no strengthening battens on any of its panels and cannot be made in a large size. It is difficult to make such boxes more than 30 cm high, for each panel must be made either in one piece or from two or three elements assembled together by means of dovetail joints, glued tongues and grooves, or glued scarf joints (see figure 4).

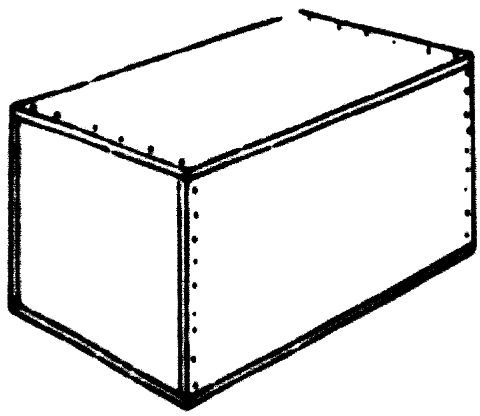


Figure 4. Simple box

The sides overlap the ends of the box, and the bottom and top overlap both the sides and the ends. The sides are nailed into the end grain of the ends of the box, whereas the top and bottom are nailed into the side grain of the box ends. Nailing into the end grain of wood gives about 50 per cent less resistance to extraction of the nails than nailing into the cross grain, and this is a particular weak point of this type of box.

Nevertheless, the high ratio of the useful interior volume of these boxes to their exterior volume makes this type of box a good one to use for reducing transport costs, especially when the freight charges are calculated on volume (e.g. sea transport). This type of box is limited to the shipping of weights not exceeding 40 kg.

Type 2–Case with framed ends

The second type of case consists of four flat panels forming the sides, top and bottom, each made of one or more boards that may simply be juxtaposed but are more usually fixed together by dovetails or tongues and grooves, and two panels framed with four battens, which form the ends of the case. These battens may be laid out in several ways, but the usual way consists of two vertical battens perpendicular to the boards making up the end panel and slightly shorter than the height of the panel, and two horizontal battens placed along the top and bottom edges of the panel between the vertical battens (see figure 5).

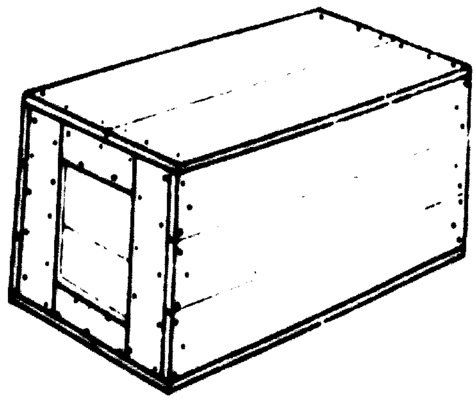


Figure 5. Case with framed ends

The framing of the end panels can also be carried out in the opposite manner: i.e. by first of all fixing two horizontal battens slightly shorter than the width of the end panel and then placing two vertical battens along the vertical edges of the panel between the horizontal battens.

Finally, if the case has battened ends, the strengthening of the ends can be carried out by means of four battens of equal length mounted so that each batten has one end in one of the four corners of the end panel of the case. The sides of the case cover the edges of the end panels and the strengthening battens, while the top and bottom of the box cover the edges of the side panels and of the end panels and battens. The nails are staggered so that all, or at any rate more than half, of the nails are in the side grain of the wood. This type of case is designed for the transport of goods weighing up to about 150 kg.

Type 3 – Case with vertical battened ends

The third type of case consists of four flat panels forming the sides, bottom and top, just like type 2, and two flat end panels with two vertical battens fixed at right angles to the boards making up the panels. These battens are slightly shorter than the total height of the end panels plus the thickness of the top and bottom panels (see figure 6).

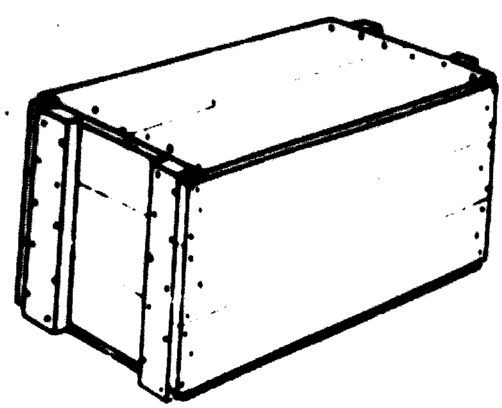


Figure 6. Case with vertical battened ends

The side panels cover the end panels and battens, while the top and bottom panels cover the edges of the side panels and of the end panels and fit within the ends of the strengthening battens. These battens are normally placed on the outside of the ends, but in certain special circumstances they can be fixed inside the end panels, if the nature of the contents permits this, and the over-all volume of the case can be reduced. If this is done, the battens must, of course, be no longer than the interior height of the case.

This design with interior battens is much used for the manufacture of reusable cases for fruit and vegetables. The battens are of triangular section in order to avoid damage to the contents, and the boards making up the side panels are spaced slightly apart from each other so as to form horizontal slots permitting ventilation of the contents. When used for fruit and vegetables, this type of case is rarely provided with a top. Cases of type 3 can be used for the transport of goods weighing up to about 120 kg.

The weakness of cases of types 2 and 3 comes from the method of nailing the sides, top and bottom towards the middle of the end panels, for in the event of a shock the strain exerted by the contents is not distributed over the whole panel, but is concentrated towards the middle of it, and the nails fixing the middle boards of the side, top or bottom panels to the end panels are subjected to heavier extractive stresses than the nails fastening the edge boards. There is thus a tendency for the nails of the middle boards to be pulled out. To overcome this disadvantage, the panels can be made in one piece, so that the strains that tend to pull out the nails will be better distributed. It is therefore preferable to make the panels by attaching the boards at the edges by means of dovetails, glued tongues and grooves, or glued scarf joints. These methods are relatively costly, but are nevertheless worthy of consideration because they make it possible to reduce substantially the thickness of the wood used.

Type 4–Hooped case

The fourth type of case is made of four side, top and bottom panels, each provided with at least two strengthening battens (more than two if the length of the panel makes this necessary), and two end panels identical either with those of type 2 (case with framed ends) or type 3 (case with vertical battened ends). The panels are normally made of boards simply laid next to each other, but the boards can be fixed to each other by dovetails or tongues and grooves if it is desired to seal the panels to some extent (see figure 7).

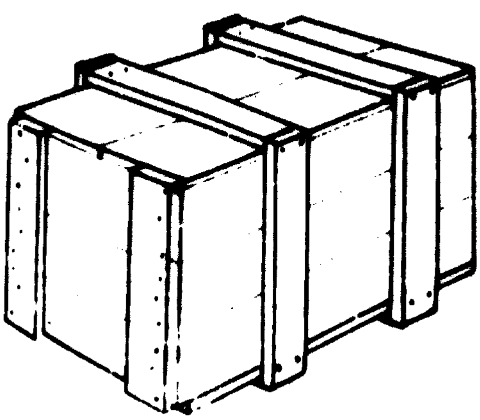


Figure 7. Hooped case

The battens fixed on the sides, top and bottom of the case (the "hoops") are located about one quarter of the total length of the case from the end. If a third set of hoops is added, the end hoops are placed one sixth of the total length of the case from the ends, while the additional hoop is located equidistant from the first two. The strengthening battens of the sides, top and bottom thus form a series of hoops round the case.

The side panels cover the end panels and their strengthening battens, and the strengthening battens of the side panels cover the edges of the top and bottom panels and the ends of their strengthening battens. The top and bottom panels fit inside the strengthening battens of the side panels and cover the edges of the side panels and end panels. If the cases have framed-type end panels, the top and bottom panels will also cover the framing battens; if the cases have vertical battened ends, the top and bottom panels will fit within the ends of the battens. This type of case can be used to transport goods weighing up to 250 kg.

Every well-designed packing case should be free of weak points: that is, if the packing case breaks it should do so at different points, and not always at the same point or points. It has been observed that the weak point of nailed sawnwood boxes is always the attachment of the panels to each other, but this is generally due to faulty manufacturing.

In fact, it is quite possible to achieve a balance between the strength of the wood used to make cases and the strength of the attachment of the panels to each other. To begin with, it is necessary to use nails that are longer than those generally employed (e.g. 55 X 2.7 mm nails instead of 45 X 2.4 mm nails for a battened-end case designed to carry 100 kg of goods). On the other hand, it is possible to use thinner wood by using thin nails (e.g. 55 X 2.2 mm), which have less tendency to split the wood and are essential if it is desired to nail edgewise into wood less than 15 mm thick. Finally, and most importantly, the strength of attachment can be considerably increased by using what are known as "improved" nails, nails that have been given special chemical or mechanical treatment. The galvanizing or phosphating of nails not only protects them against corrosion, but also increases the strength of attachment by some 20 per cent.

Many different types of nails can be obtained through mechanical treatment of ordinary nails. The two types that give the most advantages, however, are nails impressed with a large number of annular ridges and especially the strength of attachment of box panels to be improved by 100 per cent; the use of such nails should therefore be extended as rapidly as possible, especially thin, spiral-grooved nails, which are valuable for the attachment of thin boards. While these nails are best for attaching the panels to each other, smooth nails can be used for attaching battens to the panels, as the nails are always clinched at the ends in this construction.

A further important factor in the strength of cases is their shape, for the longer a case is the weaker it will be for a given set of manufacturing characteristics. Moreover, for a given useful volume, an elongated case uses more wood than a cubic one. The weight that can be transported in a given case varies as a function of the shape coefficient (ratio of the case's smallest interior dimension to its largest interior dimension). Thus, a given case with a shape coefficient of 0.25 can carry 100 kg, while a similar case with a shape coefficient of 1.0 can carry 180 kg. There is thus every advantage in making cases in shapes as close to that of a cube as possible.

Bottle cases

A bottle case is a lidless box divided into compartments by partitions (see figure 8).

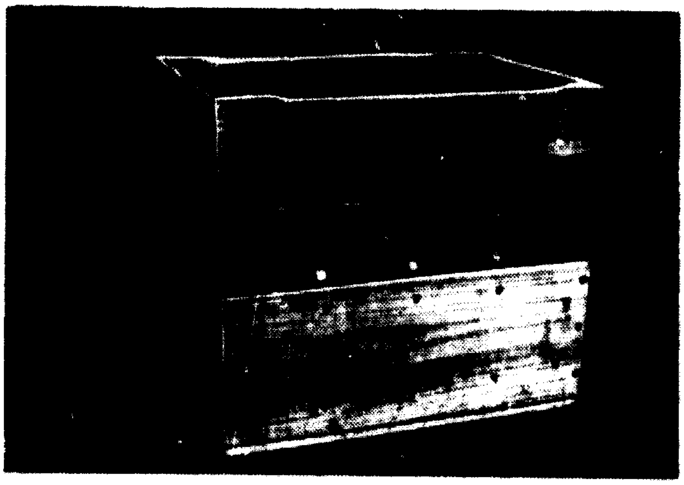


Figure 8. Bottle case

The dimensions of bottle cases will depend on the size of the bottles to be accommodated. To achieve standardization of the cases, it is necessary first to standardize the diameters and heights of the bottles. Bottle cases differ in the number of compartments they contain. Cases for one-litre bottles generally have 10, 12 or 15 compartments.

Cases for 10 bottles are the most common, for they make it easy to count the number of bottles in stock or sold; but their long, narrow shape is not rational, since they are not steady when stacked and their shape leads to an excessively high consumption of wood in proportion to the number of bottles they contain. Cases holding 15 bottles are much more rationally designed, but they may weigh 30 kg when full, and are therefore hard to handle, especially for female labour. Cases designed for 12 bottles are a compromise between the two. They have the advantages of both 10- and 15-bottle cases, for their compact shape makes them easy to stack and they do not weigh more than 25 kg when full. Production should undoubtedly be oriented towards this type of case.

For small bottles of 33–50 centilitres capacity, cases holding 24 bottles can be used. For some particularly strong small bottles, such as beer bottles or Coca-Cola bottles, it is possible to do away with the partitions altogether, thus making possible savings on the manufacture of the cases and reducing their over-all dimensions.

Bottle cases consist of:

(a) A bottom, generally made up of two skids and four cross members. Equally good results can be obtained, however, by replacing this type of bottom with one composed of two lengthwise boards.

(b) Two sides consisting of a broad lower board and a narrow upper board. The narrow upper board is subjected to considerable strains and thus should be made of particularly strong wood.

(c) Two ends consisting of a broad lower board, a narrow upper board and two uprights, which should also be made of strong wood.

(d) Partitions that may be made of sawnwood or fibreboard. When the cases are filled by hand, these partitions should have a flat, horizontal upper surface. When the cases are filled automatically, the top of the partitions should be V-shaped so that each point where the partition strips cross is rather dome-shaped, thus ensuring that the bottles will fall into place properly and not remain stuck in the upper part of the case.

Bottle cases can be made of soft wood (density 0.40–0.60), but to achieve some evenness of strength, the uprights and the narrow upper boards at the sides should be made of harder wood (density 0.60–0.75).

Pallets and pallet bins

A pallet is a movable platform on which a certain quantity of goods can be placed together to form a "load unit" for handling, transport or storage and which is moved with the aid of mechanical handling devices such as pallet trucks or forklift trucks. A pallet consists of two decks connected by spacers. A pallet bin consists of a pallet with at least three vertical walls, which may be fixed, folding or removable and which permit a pallet or another pallet bin to be stacked on top. Pallets and pallet bins provide an effective means of improving handling and storage.

Pallets and pallet bins may be designed in many different ways according to requirements.

Entries

An entry is a free space into which the fork of a forklift truck or a pallet truck can be inserted in a given direction. Pallets and pallet bins fall into three types, depending on their design and number of entries.

Pallets with two entries are designed so that the forks or forklift trucks or pallet trucks can be inserted into them on two opposite sides. Such pallets consist of an upper deck, three or four scantlings acting as spacers, and a lower deck (see figure 9).

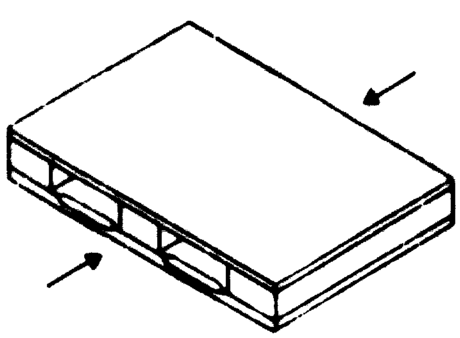


Figure 9. Double-entry pallet

Such pallets are particularly simple to make and are generally very strong, but because they can be picked up only from two opposite sides their use is restricted. In particular, when vehicles are being loaded, the pallets must be placed parallel to each other, and it is not possible to juggle their two base dimensions, which would often permit better utilization of the space in a vehicle or in a warehouse. Thus, for example, an ISO container with an internal width of 2.33 m cannot be loaded with two 100 X 120 m two-entry pallets because the two pallets side by side would measure 2.40 m. Such a container can, however, be loaded with two four-entry pallets, one lengthwise and the other crosswise (total length 2.20 m).

Pallets with four entries are so designed as to permit the insertion of the forks of forklift trucks or pallet trucks on all four sides. Such pallets are made of an upper deck attached to three cross members at right angles to the boards by clinched nails; nine spacer blocks (three per cross member); and a lower surface consisting of three sole boards nailed under the spacer blocks parallel to the boards in the upper deck (see figure 10). These four-entry pallets can be used much more flexibly than the two-entry pallets, but they are longer and more difficult to manufacture, and are much more fragile because in one direction their resistance to bending is provided only by the three crosspieces.

A third type of pallet has 2 + 2 entries.

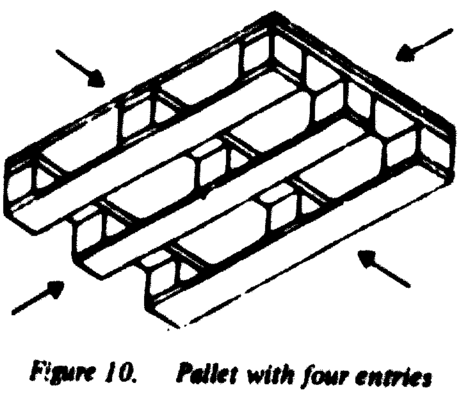


Figure 10. Pallet with four entries

Pallets with two and four entries are designed to be picked up from two or four sides, respectively, by the forks of forklift trucks and pallet trucks. A passage only 50 mm high is required for the forks of forklift trucks, but the forks of pallet trucks require a passage about 100 mm high. Pallets with 2 + 2 entries are therefore so designed as to permit the entry of the forks of pallet trucks on two opposite sides, while permitting the entry of the forks of forklift trucks on all four sides.

Pallets with 2 + 2 entries consist of an upper deck, scantlings forming the spacing members, and an underside consisting of three sole boards. In their lower parts the scantlings have two cut-outs 30–35 mm high and as wide as the distance between the sole boards of the underside. These pallets are as strong as two-entry pallets, and their possibilities of utilization, while inferior to those of four-entry pallets, are better than those of two-entry pallets. The scantlings have to be cut out, however, and this naturally involves an additional operation.

Composition of the boarding

In all pallets, it is the upper boarding that supports the load. Reusable pallets designed for very varied loads must have upper boarding capable of accommodating any load that may be placed on the pallet; this boarding is therefore composed of sawnwood planks with only a small space (less than 50 mm) between them, or else a solid panel of plywood. One-way pallets, on the other hand, are designed for the handling of products of a given shape, size and weight. Their upper boarding can therefore be designed to suit the load exactly and may be either solid or composed of planks with small or large spaces between them.

The underside of pallets may be single-faced, double-faced or reversible. Single-face pallets actually do not have an underfloor, as the upper boarding is fixed to scantlings or blocks designed to rest directly on the ground. These pallets are not designed for stacking, unless the top of the palletized loads on which they are to be placed itself consists of a panel or a special framework of some kind designed to permit stacking. Most pallets, however, are double-faced, that is, their underfloor is designed to permit stacking. Some of them are non-reversible, and their underfloor differs from their upper boarding in that it is composed of three sawnwood planks whose bearing surface is equal to at least 40% of the total area of the upper boarding. These planks are separated by spaces large enough to enable the wheels of pallet trucks run under the pallet to rest on the ground. The planks are chamfered at each end to facilitate the entry of the pallet truck forks. Reversible pallets have identical upper boarding and underfloors, either of which can be used for receiving the load. Except in a few rather unusual types of one-way pallet, reversible pallets have two sets of boarding, both of which have little or no space between the planks, and they cannot therefore be handled with pallet trucks.

Flanges

Pallets or pallet bins may have boarding ending flush with the spacer scantlings; ordinary pallets or pallet bins are of this type. Some pallets or pallet bins, however, are so designed that one or both of their sets of boarding project outside the spacers at each side, and these pallets or pallet bins are called flanged pallets (see figure 11).

These flanges, provided only on two opposite sides of the pallet, facilitate the handling of pallets by slings, which is a very common method of handling in sea transport; hence, flanged pallets are found primarily in this sector. To grip plain

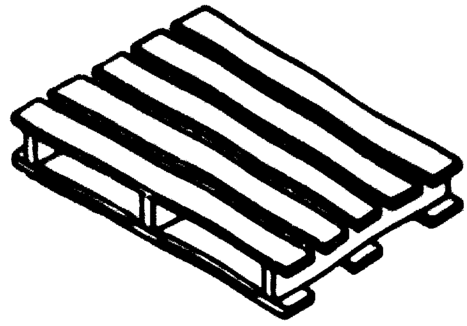


Figure 11. Flanged pallet

pallets with ordinary slings, considerable strain must be imposed on the edge planks, and this often causes damage. Flanged pallets, particularly four-entry flanged pallets, are very flexible in the direction in which they are gripped by the sling; they should not be handled with ordinary slings, but rather with rigid bars suspended from slings.

Superstructure

Between ordinary flat pallets and pallet bins with four vertical walls and a top there is a wide range of possible designs.

Pillar pallets are provided with fixed or removable vertical elements, usually made of metal, which are designed to support pallets placed one on top of the other without the pallet above resting on the goods loaded on the one below.

Spacer-wall pallets consist of ordinary flat pallets provided with peripheral edge walls that can be placed on top of each other (see figure 12). These spacer walls may

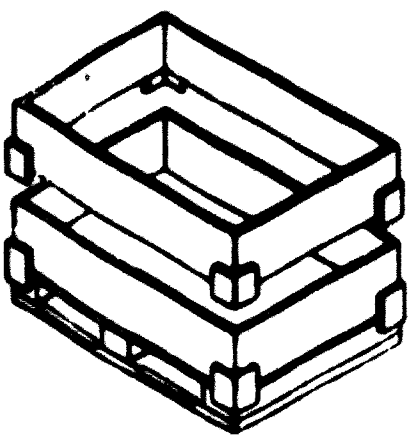


Figure 12. Spacer-wall pallet

simply be frames having the same external dimensions of the pallet and thus making it into a sort of pallet bin. Spacer-wall pallets may also take the form of real cases or crates designed for a specific use so as to combine the concepts of a tote box and a pallet. When this is so, the cases are used on the production line of one manufacturer to receive the manufactured product, very often in compartments or cradles, and the cases are then stacked on a pallet for transport to another manufacturer who distributes them to his production lines, where they serve as supply boxes. This procedure enables the product to be transferred from one production line to another in the most efficient way.

Pallet bins proper always have three vertical walls, but usually four (see figure 13). The fourth wall is often removable so as to facilitate loading and unloading, especially when the bin is used for component storage.

For empty return it would seem desirable to use pallet bins with removable or folding walls in order to save space in the transport vehicles. However, the design and development of such pallet bins is complicated and costly. The pallet bins themselves are always very fragile. The fixing elements of the walls are almost always quickly broken, so that the pallet bin becomes unusable, or else the distortion of the panels

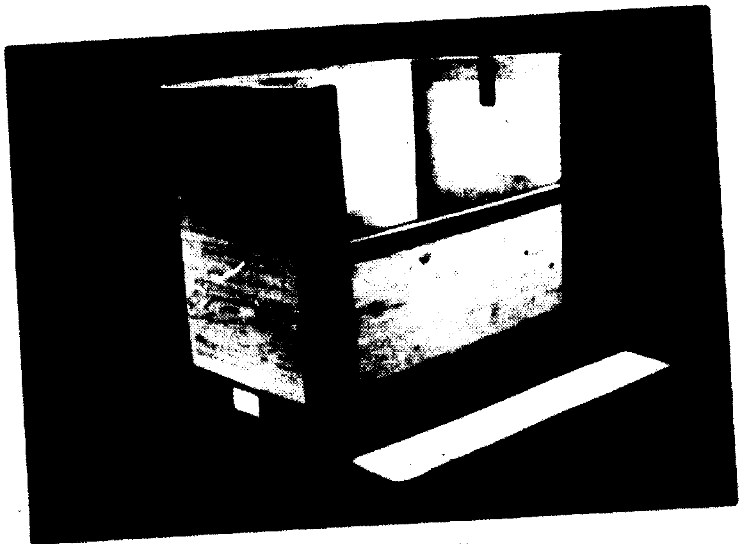


Figure 13. Wall pallet case

resulting from rough handling makes it impossible to assemble or dismantle the pallet bin. Pallet bins that can be dismantled or folded have certain advantages (for storage or return when empty), but these are often outweighed by their disadvantages: high cost of manufacture; necessity for assembly and dismantling for each trip, which requires considerable labour; and fragility. A careful study should be made to determine whether the use of such pallet bins is economic.

Two important points must be considered in the construction of all pallets and pallet bins: their means of assembly and their uniformity of strength.

Assembly can be carried out by means of bolts, nails or staples. For a long time assembly by means of bolts was considered the method that gave pallets the greatest strength, but in fact the strength of bolted pallets or pallet bins is not superior to that of pallets assembled by other methods. Furthermore, this method requires preliminary drilling operations to make holes for the bolts and to countersink the heads and nuts, and it also requires more labour during assembly than nailing. Bolting should be used only for the manufacture of pallet bins that are designed to be dismantled.

Assembly by means of smooth nails, except for flat assemblies where the points of the nails can be clinched, does not give sufficient strength, so pallets and pallet bins are normally assembled by means of spiral-grooved nails.

Assembly by means of staples is generally quicker than nailing because of the high operating speeds of the stapling machines, and it gives very good results. However, it is not possible to use staples longer than 60 mm, and for this reason this method is used at present only for the manufacture of one-way pallets.

Pallets, like packing cases, ideally should have no weak points. Although the use of spiral-grooved nails makes it possible to balance, more or less, the strength of the wood and the strength of the fastenings, some parts of pallets are nevertheless subjected to considerably greater strains than others. Thus, the entry boards of pallets are subjected to blows from the heels of the forklift truck forks, while the corner pillars of pallet bins are subjected to compressive forces resulting from stacking. These parts should therefore be made of harder wood, whereas the other parts may be made of soft wood. It is not always easy to obtain woods of different species, not for technical reasons, but for reasons of supply. If such a difficulty arises, then the whole pallet or pallet bin can be made of a single species. Species of hardwood may be easier to obtain than species of softwood. If so, the entire pallet or pallet bin can be made of the hardwood. As far as possible, and in most economic situations, it is preferable to use two different types of wood.

Plywood and fibreboard packing cases

Because of their intrinsic properties and other advantages, the plywood and fibreboard packing cases developed in industrialized countries are becoming increasingly popular elsewhere. Plywood forms solid, warp-free panels because it is made up of thin layers of wood glued one on top of the other with the grain in each layer running perpendicular to the grain in the adjoining layer. Packing cases made of plywood are as solid and rigid as high-quality sawnwood packing cases, yet they are also light and save space.

Fibreboard is made of wood fibres or fibres of other ligno-cellulosic materials held together mainly by felting but also with the aid of binders. It takes the form either of insulating panels, which are compressed only slightly or not at all and which are not used in packaging, or of compressed panels, termed semi-hard, hard or extra hard panels, which can be used in the same way as plywood.

The weight of a plywood packing case is between a quarter and half that of a traditional wooden case; obviously, the volume is not reduced to the same extent, but nevertheless the saving of a few centimetres on each of the three dimensions is important when transport charges are based on volume. For small and medium-sized cases, the saving of total exterior volume for a given interior useful volume may amount to 10–20%. Because of their advantages with respect to weight and volume as well as their great strength, plywood or fibreboard packing cases should be seriously considered for use in developing countries, despite the higher cost of manufacturing them.

The appearance of panels for packing cases, particularly plywood panels, is of no importance as far as their utility is concerned. Panels with superficial faults, such as knots on their outside surfaces, can very well be used for cases; but those with structural faults that would weaken them, such as open joints, must be rejected.

The type of glue chosen will depend on the conditions under which the packing case will be used. Since small packing cases are usually transported in covered vehicles and stored in closed warehouses, it is not necessary to use adhesives that are particularly resistant to water or dampness; common glues based on albumin, casein or soya are quite sufficient. Large packing cases or reusable cases designed for long use, which may possibly be transported on open vehicles or stored temporarily in the open air, require more resistant glues of the urea-formaldehyde type with a high percentage of flour added. For packing cases that are likely to be subjected to bad weather during transport or storage, urea-formaldehyde type glues with little flour added may be used. Finally, in the rare instances when cases are subjected to protracted transport and above all protracted storage under very unfavourable climatic conditions, very strong glues of the phenolic type must be used.

Ordinary fibreboard can be substituted for plywood when glues of the casein, albumin or soya types, or glue of the urea-formaldehyde type greatly extended with flour, are required. Special weatherproof fibreboard should be used for cases requiring glues of the urea-formaldehyde type with little flour added. Fibreboard should not be substituted for plywood when phenolic-type glues are necessary.

The mechanical strength of plywood and fibreboard for packing cases can be evaluated very usefully by means of a special type of test, which is not much used for the evaluation of ordinary plywood, namely, perforation tests, and especially dynamic perforation tests. The best plywoods for packing cases are produced from relatively high-density woods (0.60–0.70) and the thickness to be used will depend on the resistance of the species in question to perforation, which is on the whole proportional to the density of the wood, although there are exceptions that require preliminary testing.

Short-fibre hardboard panels produced from the wood of broadleaf trees generally have strengths comparable to those of plywood of the same thickness made from wood of a density of 0.40–0.50. Long-fibre hardboard panels produced from coniferous wood generally have strengths comparable to those of plywood of the same thickness made from wood with a density of 0.50–0.60.

It should be noted that the number and the thickness of the plies of which plywood is constructed greatly influence its mechanical strength. The more plies a piece of plywood has, the stronger it will be. For example, a piece of 9-ply plywood 9 mm thick will be 25–30% stronger than a piece of 3-ply plywood of the same thickness. However, since plywood with a small number of plies is cheaper than multi-ply plywood and thus in the final analysis frequently more attractive, it is desirable that such plywoods, especially 3-ply plywood, be so designed that the total thickness of the plies in each of the two grain directions is equal.

The following types of packing cases are made from plywood and fibreboard: tubs, barrels, small boxes, battened cases, cases reinforced with metal corner stays and miscellaneous types.

Tubs

Generally speaking, tubs are not made from plywood proper, but from two plies glued together at right angles, with a total thickness of 1.5–2 mm (see figure 14). These glued, 2-ply plywoods are bent by hand and stapled together along the seam with staples whose ends are clinched into the wood on the inside of the tub, leaving a perfectly smooth surface. The bottom of the tub is also made of 2-ply plywood and is fastened on the inside by a stapled hoop. Tubs may be cylindrical or conical. Conical tubs can be nested when empty to facilitate their transport and to save storage space. They have capacities of 10–30 dm^3, and their 2-ply lids are kept in place, after filling, by hooks.

Figure 14. Tubs

Barrels

Barrels consist of a body made of a sheet of plywood or fibreboard 3–8 mm thick.

One type of barrel is assembled entirely by stapling (see figure 15(*a*)). The sheet of material making up the body is bent by hand until its two edges overlap by about 5 cm, and it is then stapled together with one or two rows of staples. The outside of the body thus obtained is strengthened by hoops of sawnwood 4–6 mm thick stapled to it. The top and bottom of the barrel are generally identical and are made either of a set of shaped pieces of wood fastened together or of a sheet of plywood or fibreboard. Sawnwood bottoms can be kept in place simply by nails or staples, but bottoms made from plywood or fibreboard are either kept in place between two hoops stapled inside the body or else are provided with a polygonal frame made of pieces of sawnwood kept in place by nails or staples.

Another type of barrel is assembled entirely by gluing (see figure 15(*b*)). The panel making up the body of the barrel is bevelled on its two opposite edges, which are glued, then joined together and held for a certain length of time in the heated jaws of a special, custom-made press. The top of the body thus obtained is strengthened only with a glued sawnwood hoop that serves to keep the lid in place. The bottom, which consists of a panel with a polygonal frame of glued sawnwood, is pressed into the body and a metal hoop is fixed at the same time to the outside of the barrel.

The lid consists of a sheet of fairly thick plywood with a rabbet all around its under edge. The lid fits into the top of the barrel and at the same time rests on the top edge of the barrel. It is secured by a metal hoop with two unequal flanges, one of

(a) Stapled barrel *(b) Glued barrel*

Figure 15. Barrels

which fits under the edge of the top glued hoop, while the other fits over the edge of the lid. This metal hoop is tightened by a toggle arrangement (just as a ski boot is fastened in its binding). This type of barrel can be sealed particularly well, and its sealing can be still further improved by placing a rubber joint in the rabbet around the lid.

Plywood barrels can have a capacity of 30–250 dm^3. Stapled barrels are used to transport components and loose goods, while glued barrels are used to transport powdered products or pastes.

Small boxes

Small boxes can be made by stapling 3–6 mm thick plywood or fibreboard panels together at the corners without the use of any strengthening cleats (see figure 16). Five panels make up the body of the box, which may be either oblong or have sloping sides to permit nesting. The lid consists of a sixth panel, which may have other narrow plywood strips stapled to its edges at right angles so as to surround the top edge of the box completely or which may have thin strips of wood fastened to it to form a frame a little way back from the edge of the panel so that the panel can rest on the top edges of the box while the frame fits inside it. For both types of lid, sealing is effected by hoops.

Another type of box consists of panels fastened to each other by thin metal stays located at all the angles of the box and riveted or stapled to the four vertical panels. The lid and bottom of the box rest on battens fastened inside the box; and after the stays have been folded over, the box is sealed by nailing down the stays and nailing the panels to the battens. Boxes of this type are highly resistant to crushing, light in weight, and have a very high ratio (over 90%) of useful interior volume to

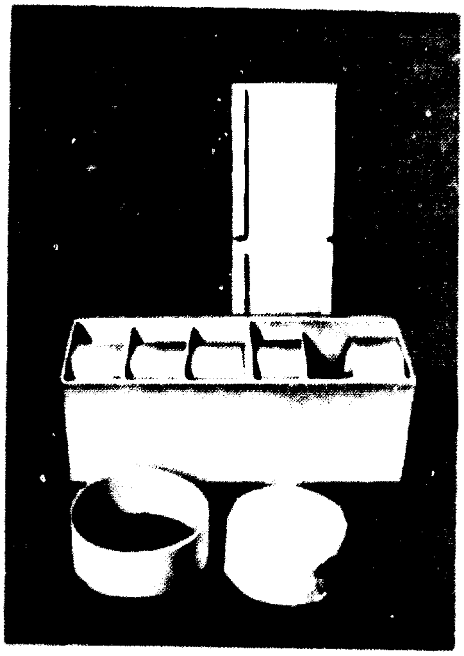


Figure 16. Small boxes

total exterior volume. Their maximum capacity, however, is restricted to about 100 dm^3 in volume and some 50 kg in weight. They are used essentially for transport by air or sea of the "parcel post" type of shipment.

Battened cases

Battened plywood or fibreboard cases consist of six panels strengthened by battens nailed or preferably stapled along their edges (see figure 17). (Technically, it is the panels that are stapled to the battens.) These cases can be assembled by two different techniques.

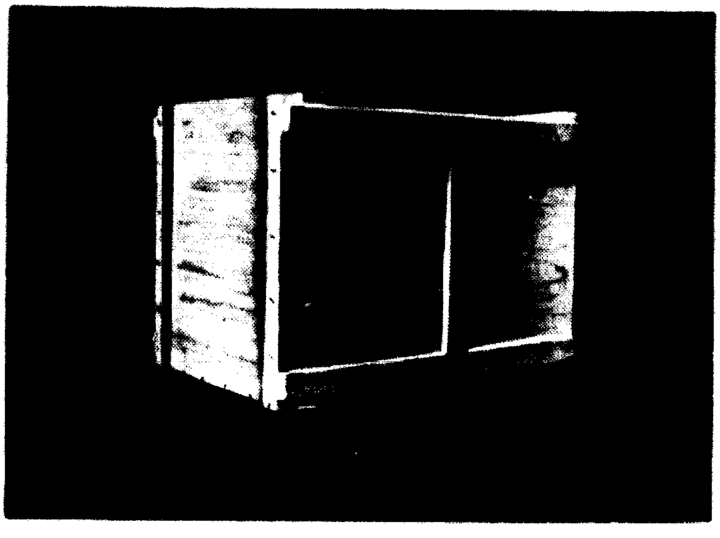


Figure 17. Battened case

The first technique consists of making triangular assemblies. That is, three battens of three panels meet at one corner and overlap and thus enable the panels to be nailed together in three directions. For example, the vertical batten of an end panel is nailed to the edge of the batten of the top of the case, while the latter batten is nailed to the edge of the horizontal batten of the side panel. This side panel batten is itself nailed to the edge of the first batten (i.e. that of the end panel).

The result of this method of assembly is that the width of the end is less than the width of the top, while the height of the side of the case is less than the height of the end. This method makes it possible to produce very strong cases that are almost impossible to open without destroying at least one panel. This type of case is essentially a one-way case and is therefore used almost entirely for export shipments.

The second technique consists of making a frame formed by two end panels and two side panels all of the same height and then nailing to this frame top and bottom panels that cover the edges of the end and side panels. This type of assembly is not so strong as the first type. Cases assembled in this way can be opened easily without damaging any of the panels and are therefore suitable to be reused.

The panels of these cases each have at least two battens, but they may have four battens framing them on all sides. The end panels of cases not assembled by the triangular method must each have four framing battens.

To reduce the exterior volume, two of the panels (the top and bottom) can be made without battens, thus reducing the height of the case by the thickness of two battens, but then plywood made of hardwood with the largest possible number of plys (5 mm thick 5-ply plywood, for example) must be used.

Many different types of battened cases can be made. Cases fastened together by the triangular method may have six panels each with two battens; four panels with two battens and two panels with four battens; two panels with two battens and four panels with four battens; or six panels with four battens.

Cases not assembled by the triangular method may have: two panels with four battens and four panels with two battens; four panels with four battens and two panels with two battens; six panels with four battens; two panels with four battens, two panels with two battens and two panels without battens; four panels with four battens and two panels without battens.

To strengthen the case or make possible the fitting of hoop strips, additional battens may be placed between the framing battens. There is, of course, a definite connexion between the length of the panels, the thickness of panel used, and the distance between successive battens.[1]

The panels are fastened together by nails (preferably spiral-grooved nails) if the battens are nailed to each other. If the panels themselves are nailed to the battens of another panel, broad-headed nails should be used.

Battened plywood or fibreboard cases are used to transport all kinds of industrial, chemical and pharmaceutical goods weighing up to 250 kg.

Cases reinforced with metal corner stays

Battened cases are used extensively in the industrialized countries, but they have the disadvantage of occupying a great deal of space during storage or when being

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[1] See tables 2, 3, 4 and 5 (pp. 13 and 14) in *Caractéristiques et spécifications techniques des caisses barrées en bois contreplaqué destinées aux transports par voies maritimes* (Characteristics and technical specifications of battened plywood cases intended for the transport of goods by sea), published by the Centre Technique du Bois, January 1967.

transported empty. To overcome this disadvantage other types of cases have been developed. The two main types are described below.

The first type of case consists of four vertical panels fastened together in pairs by a stapled or riveted thin metal corner sheet with space left between the two adjacent panels so that they can be bent at the corner. Two of the corners then form an angle of 0° while the other two form an angle of 180°. The top and bottom are made of panels strengthened with two or four battens that are fitted inside the top and bottom edges of the case and kept in place by nails or simply by hoop strips. The second type consists of four panels (sides, top and bottom) fastened together by relatively thick, flat metal strips provided with indentations enabling them to be clipped directly to the panels. The edge strips are corner pieces that have V-shaped notches on their vertical face between the panels to enable the latter to be folded and grooves to permit the insertion and fastening of the end panels. These strips have a slot at one end and a tab at the other (see figure 18). The case is assembled by

Figure 18. Case reinforced with metal stays

bending the strips to an angle of 90° between the panels, inserting the tabs on the ends into the corresponding slots in the corner pieces, and bending the tabs over. It is sealed by inserting the tabs into the slots of the ends of the strips and then bending the tabs over.

There are many other ways of making cases that can be delivered flat, and plywood or fibreboard panels make it possible to develop extremely effective designs.

Miscellaneous types

As has already been seen, panels can be used for the cladding of crates, the upper boarding of pallets and the walls of pallet bins.

It should be noted that although containers themselves do not come within the field of this study, there has been considerable development of the use of plywood for the interior lining of containers, for the manufacture of the walls of containers themselves (out of plywood impregnated with resin and glass fibre) and for manufacturing the floors of containers.

Wirebound cases

Wirebound cases first appeared on the United States market at the beginning of the century in an attempt to compete with corrugated cardboard or solid cardboard cases, which were themselves beginning to provide serious competition for traditional wooden cases.

Wirebound cases are made of four panels (two sides, top and bottom) and two ends. The panels are connected by continuous stapled metal wires, each panel being mounted at its ends on battens with 45° mitred ends that form the frame of the assembled case (see figure 19). The battens are always made of sawnwood, while the panels are almost always made of peeled or sliced wood, and very rarely of sawnwood. The intermediate wires are fixed to the panels by clinched staples, while the frame or end wires are fixed on the boards and battens by splayed-end staples sunk into the wood. The ends are made of peeled wood or panels of plywood or fibreboard and normally have one or two wires.

Figure 19. Wirebound case

To assemble the cases, the side, top and bottom panels are bent to an angle of 90° to each other, and the ends of the case are then fastened on by inserting the end loops of the wires either into notches cut in the battens, if the cases have solid walls, or between the frame wire and the batten in the open space between two boards, if the cases have partially open sides. In both types of case the loops are then bent towards the outside over the frame wires. The ends of the reinforcing wires are used for sealing as described below.

Sealing by twisting. The wires that stick out beyond the wood at each end of the case are twisted together to form a permanent seal, that is, the wire must be cut in order to open the case. This type of sealing therefore rules out the possibility of reusing the case and also raises problems with regard to customs examination when used for export goods. Moreover, as the twisted ends of the wire, which are sharp, stick out beyond the sides of the case, they may injure those handling the cases, and, indeed, they have caused many accidents.

Sealing by twisting loops. The wires are bent over at each end to form a loop, and the end is rolled around the wire itself. This system requires looping before manufacture and complicates the production process. The two loops at the ends of a single wire must be of slightly different shape so that one loop can enter the other, and the cases are sealed by bending the "male" loop over the "female" loop. The twisting of the wire always leaves one end sticking out, and although this end sticks out less than when sealing is effected by twisting the ends of the wires, it is nevertheless a danger to those handling the cases.

Sealing by means of stapled loops. The wire is bent over on itself at each end to form a "hairpin", and the end of the wire is then inserted into the edge board and clinched under it. The shape of the loops thus obtained is designed primarily to ensure that the continuous stapled-down part of the wire receives the tension during use and not the end of the wire that is simply fastened under the board; and second, the shape is so designed that one loop can easily be inserted into the other. Sealing is carried out by inserting the male loops into the female loops and then bending over the male loops. The reinforcement of cases with wires has made it possible greatly to reduce the thickness of the boards used, which permits a saving of approximately 50% on the weight of the case, compared with traditional cases made of sawnwood, and a saving of about 20% on volume. As wirebound cases are delivered flat, they can be stored and transported easily and take up only 20% of the space they occupy when assembled. These cases can be assembled very rapidly without the use of nails by unskilled labour at the rate of 100–150 cases per hour.

The stapled loops make possible rapid sealing with a very simple special tool at the rate of 100–165 cases per hour, depending on the number of loops, but it is also possible to use semi-automatic machines which enable rates of 400–800 cases per hour to be achieved or automatic machines which seal 1,100–1,400 cases per hour. These cases are also very easy to open, since it is necessary only to straighten out the loops. This type of sealing makes it possible to reuse the cases and return them and store them flat. How often such cases can be reused depends on the diameter and the nature of the reinforcing wire used. A thick wire (2.4 mm diameter) made of hard, high-carbon steel can be reused only about 5 times, whereas a thin wire (1.6 mm diameter) made of soft, low-carbon steel can be reused more than 20 times.

This type of wirebound case is used both for agricultural products (particularly citrus fruits) and industrial products, the total weight which can be carried varying from 10–200 kg. The principle behind wirebound cases can be used for the design of other types of packing cases.

Wirebound baseboard-type cases

For packing single items such as motors, household appliances etc., a baseboard is made and the product is fastened to it, generally by bolts. The baseboard is encircled by battens that form a sort of flange, and the wirebound sides of the case are placed around the product in such a way that the battens of the lower frame fit inside the flange of the baseboard. The lid is made on the same principle as the baseboard, but of much lighter construction, and the battens of the top frame are fitted inside the flanges at the top of the sides. Once it is closed, the case is sufficiently rigid to need no interior supports. This principle of construction can also be used for making pallet cases.

Wirebound cases without lids

Since lids are no longer generally used on fruit and vegetable cases, wirebound cases have been designed with a special panel fitted with looped wires only on its frame. This panel is divided into two identical halves which, by folding through 90° during assembly, become the two ends of the case (see figure 20).

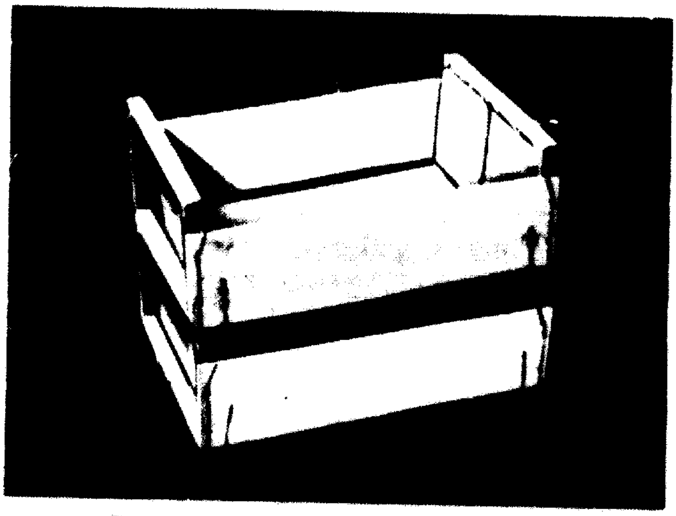

Figure 20. ***Wirebound case without lid***

Wirebound trays

These trays are made of wirebound panels forming the sides, bottom and two ends made either of sawnwood or of composite construction (vertical battens and stapled boards). The panels are stapled to the ends with non-clinched staples. Since wirebound cases are essentially mass-production items, their manufacture requires modern, relatively costly equipment giving a high output with only a minimum of labour. Hence, this type of packing case cannot be produced on a non-mechanized (craft) basis.

Light packing cases

Light packing cases are cases whose panels are made of peeled or split wood or sawnwood of less than 7 mm thickness fastened together with staples. They are the result of the progress made at the beginning of the century in producing peeled veneers for plywood manufacture and of the stapling techniques used in the cardboard box industry. Their development was particularly marked after the Second World War.

The theory behind the construction of light packing cases is that a wooden packing case rarely breaks because the wood breaks, but rather because of failure of the methods of fastening; therefore, by using clinched staples, the strongest method of fastening, it should be possible to reduce the thickness of the wood used.

Although many different types of packing cases have been developed from this concept, their primary use is still for the transport of perishable goods such as fruit and vegetables, fish, poultry, cheese, oysters etc. The main types include oblong cases, nesting cases, cylindrical cases, cases that can be delivered flat (knocked-down cases), cheese boxes and chip baskets (punnets).

Oblong cases

Oblong packing cases have a generally rectangular shape, are constructed of 5 or 6 panels that may be solid or made of strips intersecting each other at right angles with fairly large open spaces between them and fastened together by clinched staples. The ends are usually reinforced with vertical corner strips. The sides of the packing cases are stapled to the ends or to the corner strips, while the top and bottom are attached to the sides and ends by direct corner stapling.

Oblong packing cases can be used with or without lids. Cases without lids may be designed as follows:

(1) With flush ends, that is, ends level with the sides. Horizontal bars are fitted to the ends to support other packing cases placed on top.

(2) With the top area of the case slightly smaller than that of the bottom, so that cases can be stacked one on top of the other.

(3) With raised ends: that is, with ends higher than the sides so as to give better ventilation and more rapid cooling of the products (see figure 21). Such cases can be easily stored one on top of the other. The construction of the ends can be carried out in several ways, the most common of which are:

(a) The "French system". Each end is composed of one or more horizontal boards stapled to two triangular corner strips and a small bar, called a "rest", that is laid flat across the ends of the corner strips and fastened to them by non-clinched staples. The bottom of the case has a number of crosspieces on its underside, and the two outermost crosspieces are set back from the end of the underside by an amount slightly greater than the width of the rest bar. When such cases are stacked, the end of the underside of the case above rests on the case below, and the outermost crosspieces of the underside fit inside the rest bars and, in fact, bear against them. This ensures the wedging and proper positioning of the stacked cases and gives the stack greater stability in storage and transport. This system is effective and well proved, but unfortunately involves fairly complex methods of manufacture.

(b) The "Swiss system". Each end consists of one or more horizontal boards which reach the same height as the sides and are stapled to two triangular corner pieces projecting somewhat above the sides. Each of the corners of the bottom panel is cut off obliquely to leave a space slightly larger than the cross section of the corner strips. When such cases are stacked, the bottoms of the corner strips of the case above rest on the top of the case below, and the underside of the case above fits in between the corner strips of the case below. Thus, the cases are held together in place not just in one direction, as with the French system, but in both directions.

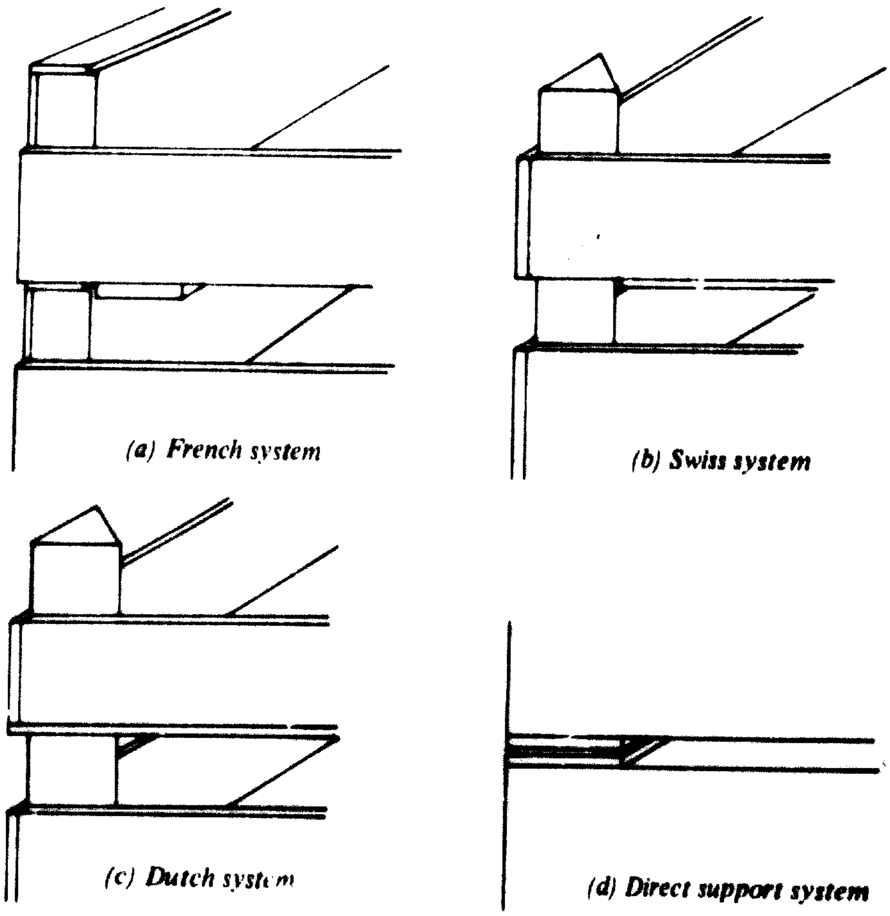

Figure 21. Types of lidless oblong cases with raised ends

(c) *The "Dutch system".* Each end consists of one or more horizontal boards which reach the same height as the sides and are stapled to two triangular corner strips projecting somewhat above the sides. The bottom consists of smooth boards and rests, when the cases are stacked, directly on the top of the corner strips of the case below. There is nothing to keep the cases in place. This type of case is sometimes transported simply by being stacked directly in trucks, but more often than not a certain number of cases (3–10) are stacked one on top of the other, a top made up of four laths is placed on top of the uppermost case, and the complete set of cases is then strapped together to form a unit in which the individual cases are wedged against each other by the pressure of the binding straps. These cases can also be loaded on pallets, covered with a top and similarly strapped together to ensure stability.

(d) *The direct support system.* Each end consists of one or more boards stapled to two vertical corner strips, plus a supporting bar. The bottom is provided with crosspieces at the ends which, when the cases are stacked one on top of the other, rest directly on the supporting bars of the case below. In this system there is nothing to keep the cases in place, but the displacement of cases is limited by the pressure exerted over the entire surface of the supporting bars.

The main types of light oblong packing cases are the following:

(1) Oblong trays with raised ends and sides not higher than 12 cm. The sides and ends are generally made of solid panels consisting of a single board, and the corner strips of the ends are almost always of triangular section. The bottom usually has substantial open spaces between the boards of which it is composed, although its design will depend on the type of inner packing used for the product (see figure 22). The height of the tray depends on the dimensions of the product. These trays are primarily designed for the packing of fragile fruit or vegetables in a single layer.

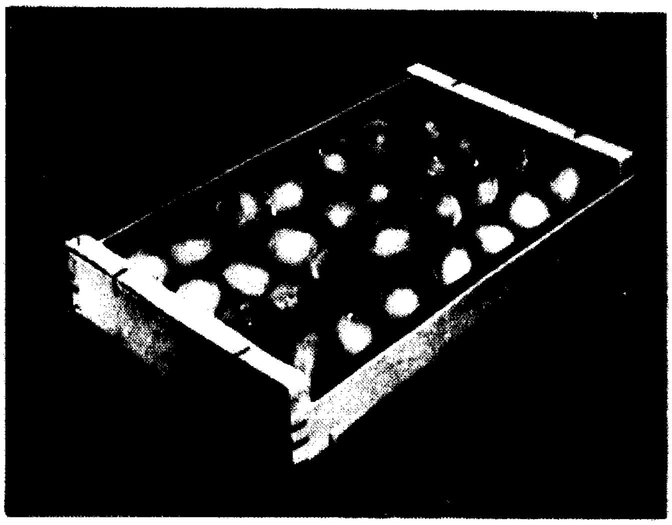

Figure 22. Light oblong tray

(2) Oblong cases consisting of solid panels or panels with only small spaces between the boards, sides less than 12 cm high, and a lid. These cases may or may not be fitted with triangular corner strips (see figure 23). They are used to transport fish, prawns, certain types of cheese and certain fruits.

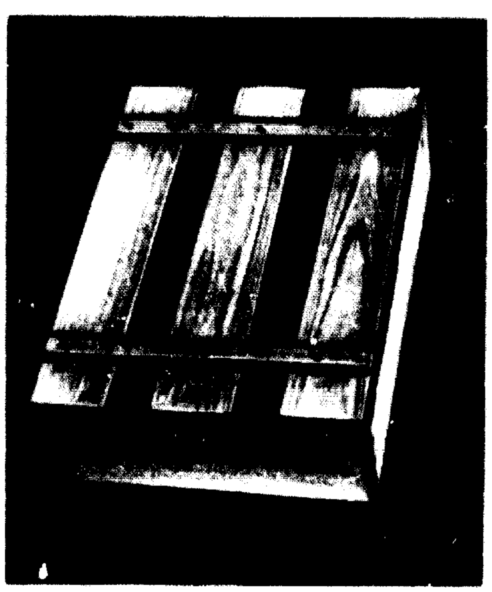

Figure 23. Light, solid-panel case with lid

(3) Light oblong crates consisting of openwork panels with sides 12 to 25 cm high (see figure 24). The size of the open spaces between the side strips depends on the product to be packed: the strips are closer together for products like apples than for lettuce. These crates may be provided with raised ends and are then used for fruits that are not very fragile, such as apples or citrus fruits, or for vegetables, especially lettuce. They may also be provided with tops and used for the transport of vegetables, poultry and cheese.

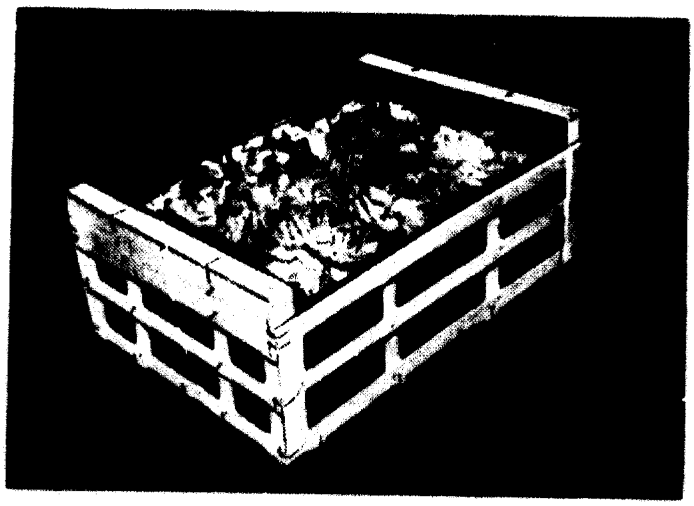

Figure 24. Light oblong crate with open-work panel sides

(4) **Light oblong crates consisting of panels with large open spaces between the slats and side heights of over 20 cm (see figure 25). These crates are used to transport large vegetables.**

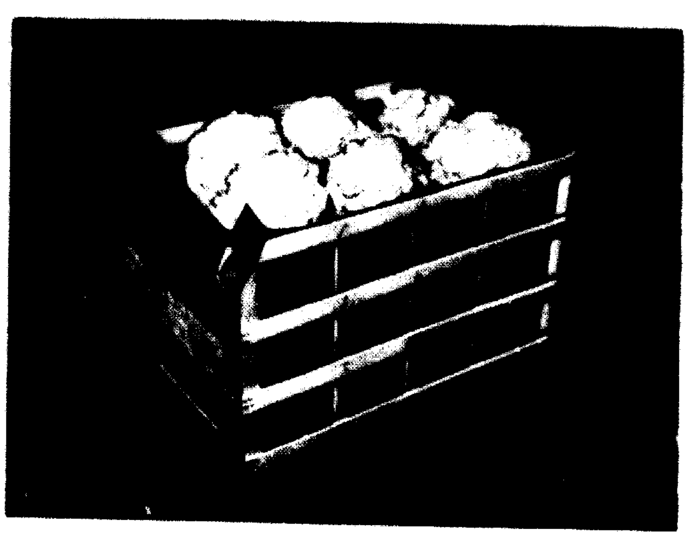

Figure 25. Light oblong crate for large vegetables

Light oblong cases have decided advantages. They are especially strong because of their corner strips, which are usually triangular, to avoid damage to the contents, or rectangular in cases used to transport vegetables. The shape of these cases makes it easy to plan the arrangement of their contents and to determine the number of pieces per case in function of the size of the pieces and in general to define the dimensions and characteristics of the inner packing elements for fruit. Finally, this type of case is also well suited for packing fairly bulky products such as poultry or products such as cheese that are prepacked in rigid containers.

Oblong packing cases are easy to stack on wagons, trucks or pallets, they form homogeneous loads, and they can be designed to fit the pallets exactly. They can be used without lids, which lowers their cost and reduces damage, for cases without lids are handled more carefully than those with lids. On the other hand, oblong packing cases take up a good deal of space in storage and when they are transported empty.

The various advantages of oblong packing cases have led the Inland-Transport Committee of the United Nations Economic Commission for Europe (ECE) to recommend them for the transport of fruit and vegetables for both the domestic and foreign markets.

Nesting cases

After assembly, nesting cases can be stacked empty one inside the other to facilitate storage, transport and handling. They are of trapezoidal vertical section and are classified, according to the shape of their horizontal section, as panniers, hampers or sloping-sided crates.

Panniers are nesting cases whose horizontal section consists of two parallel straight sides and two semicircular ends (see figure 26). Although their construction is complex, strangely enough they were the first light packing cases to be mass-produced on automatic machines.

The body of a pannier consists of slats, some of them rectangular and some of them trapezoidal (to enable the pannier to have a conical construction). To the tops of the slats are stapled an inner hoop of trapezoidal or triangular section, an interior

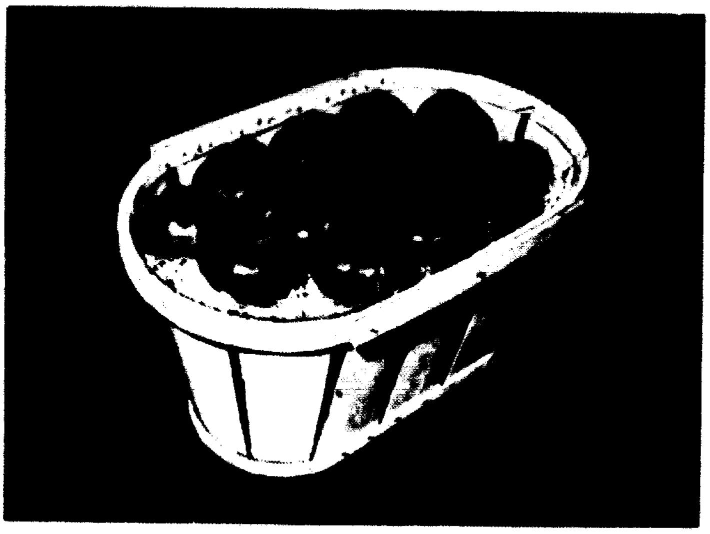

Figure 26. Pannier

lining strip, an outer hoop of trapezoidal or triangular section and two exterior covering strips, while to the bottom of the slats are stapled two hoops (one inside and the other outside) of trapezoidal or triangular section and an outer covering strip.

The bottom of a pannier consists of two lengthwise boards whose ends are cut to quarter circles, stapled to two crosspieces. The lid consists of two broad lengthwise boards with ends cut on the slant and two narrower and shorter boards stapled to two or three crosspieces. The body is strengthened along the top straight edges with two strips or handles.

Hampers are nesting cases whose horizontal section is in the form of a rectangle, with the four corners consisting of four quarter circles. Hampers are made in the same way as panniers.

Sloping-sided crates have a rectangular horizontal section. They consist of four trapezoidal panels made of horizontal slats stapled to vertical slats or sheets with flat staples and a top and bottom consisting of longitudinal slats stapled flat to crosswise slats or sheets. The crates are assembled by simply stapling together the corners without corner strips (see figure 27). Their use is declining, because they are not

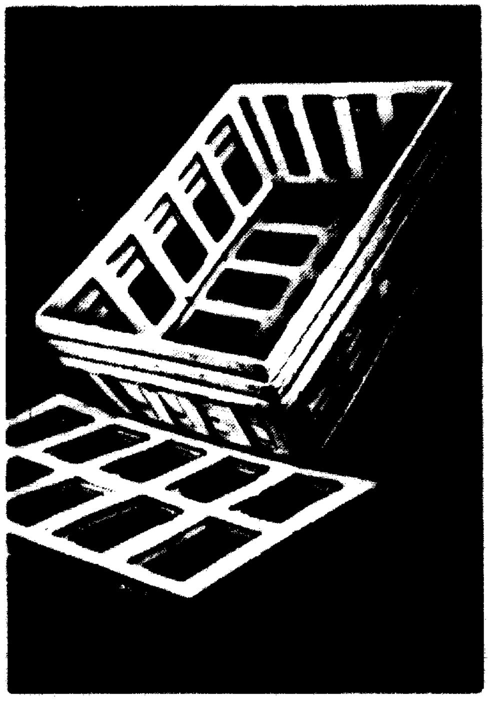

Figure 27. Sloping-sided crate

nearly so strong as panniers and hampers, and thus do not really make suitable reusable packing cases, while the fact that they can be stacked inside one another is of little interest as far as one-way packing cases are concerned.

Nesting cases occupy approximately 70% less space than oblong cases in storage and transport when empty. Because of their construction, panniers and hampers are particularly strong, even when they are very light; and they can be used for many trips. On the other hand, they have a great many disadvantages: they always need a lid; their deep shape is not suitable for the packing of fragile products; and their trapezoidal shape is not well adapted to bulky products or products of rigid dimensions. Their shape makes it impossible to pack goods in a standardized arrangement or to use inner packing elements such as trays with compartments molded in them. Finally, their shape does not permit rational loading on pallets.

Cylindrical cases

Cylindrical or sloping-sided round cases have a circular horizontal section. They are complicated to manufacture and offer very few advantages and a great many disadvantages compared with other cases.

Knocked-down cases

Knocked-down cases, as their name implies, are delivered to the buyer flat so that he can assemble them himself, generally by hand. These cases are almost all based on the general idea of the wirebound cases previously described. Other types have been designed, but most designs are either very complicated or do not provide enough strength.

Cheese boxes

Cheese boxes are designed for packing cheeses for retail sale, such as Camembert. They consist of a bottom part and a lid (generally larger than the bottom) each consisting of a shaped sheet of veneer with a strip stapled round it at right angles to form a flange. The ends of this strip are stapled or glued together.

Wooden cheese boxes are used for soft cheeses (see figure 28). Cardboard boxes or plastic packing cases have not yet proved satisfactory for this purpose. Cheese boxes may be of many different shapes – round, half-round, square, oblong, diamond-shaped, elliptical or triangular.

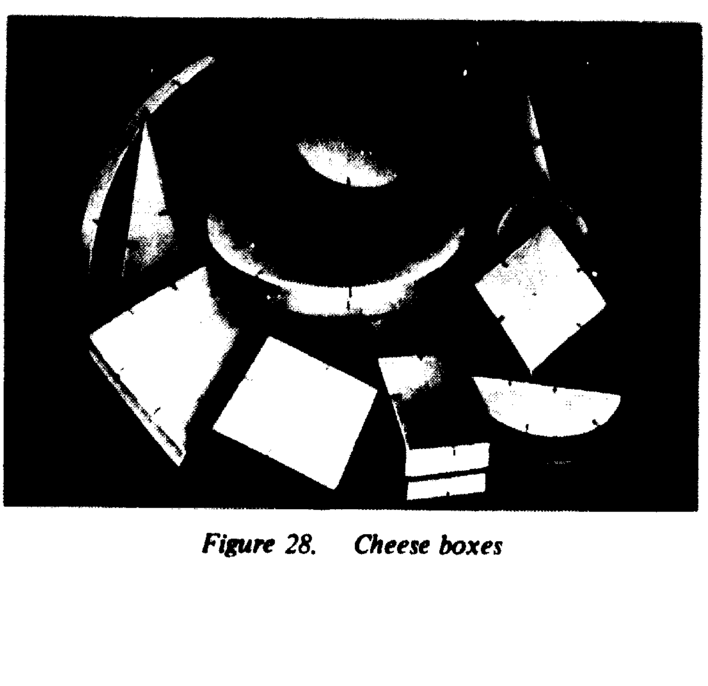

Figure 28. Cheese boxes

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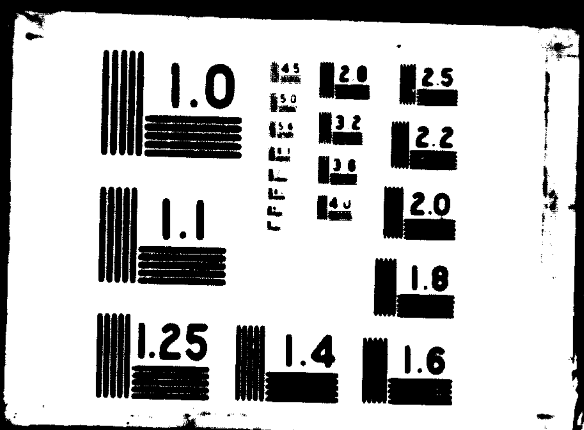

Punnets

Punnets are small, light baskets made of strips of veneer interwoven and/or stapled together and are generally designed to hold small fruits (such as strawberries or raspberries) or mushrooms. They usually have a curved handle joining the top edges of the two sides (see figure 29). For transport, they are generally placed in larger, oblong cases. Punnets for small fruits are almost always one-way containers, but larger punnets or baskets for mushrooms are reusable, although their shape is not well adapted for reuse.

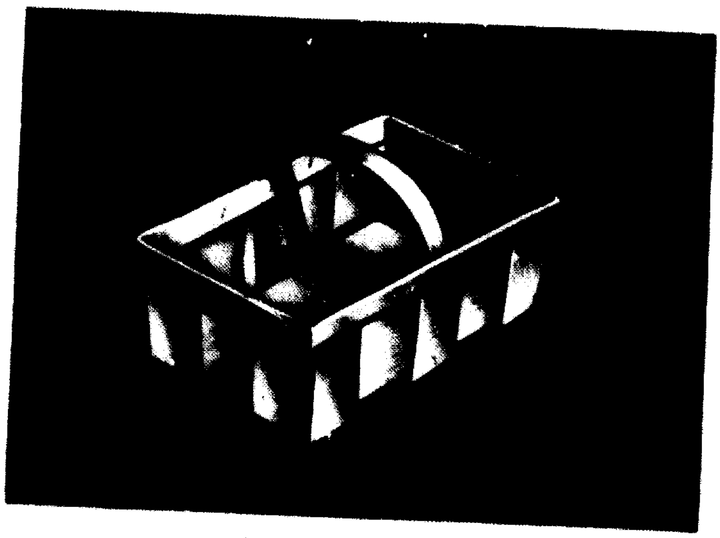

Figure 29. Punnet

Particle board packing cases

Particle board is made from particles (i.e. small fragments of any shape, structure or origin and produced by any process) of wood or other ligno-cellulosic material held together by bonding with various adhesives and the application of pressure. The particle board industry has grown extraordinarily rapidly all over the world during the last decade. Particle board is used primarily in the furniture industry and in building, but possibilities for its use in the packing industry have been investigated along two main lines: the use of particle board sheets and the manufacture of shaped particle board packing cases in moulds in a single operation. These investigations have not yet resulted in definitive conclusions, but the progress that has been made is reviewed below.

Packing cases made from particle board sheets

Conventionally made particle board sheets can be used for packing cases in the same way as plywood or fibreboard (see figure 30). However, because particle board is difficult to bend without special equipment, it is not adaptable to the manufacture

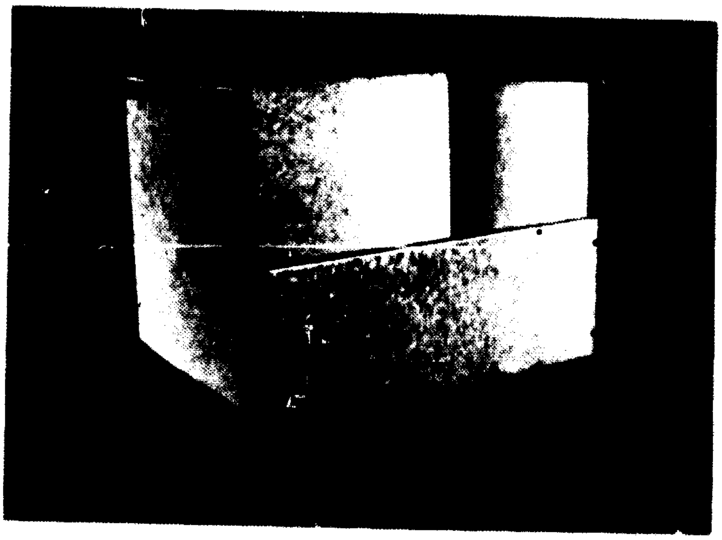

Figure 30. Packing case made of particle board sheet

of the sides of drums or barrels. It is used successfully to make tops and bottoms of cases as a substitute for sawnwood or plywood. It is also used for the tops and bottoms of barrels with sides made of compressed cardboard or spiral-wound cardboard.

Particle board has a resistance to perforation of only about half that of plywood and breaks easily when subjected to blows. Because of this weakness, particle board cannot be used for making stapled boxes, the edge members of wirebound cases, the solid components of light packing cases or the non-battened components that form part or all of a panel that must be fastened directly to adjacent panels. Because its resistance to perforation is so low, a double thickness of particle board must be used to obtain the same strength as a given thickness of plywood. The usefulness of particle board for battened panels or crate linings would therefore appear to be very limited; but when the product to be transported is very evenly distributed within the crate, it may be possible to use panels only 1.5 times as thick as plywood or fibreboard, and then it may be economic to use particle board.

Likewise, where the lining of a crate does not have to bear any strain, consideration could be given to replacing sawnwood boarding with particle board, although the high density of this material would mean that the crate would be heavier, quite apart from the fact that particle board is generally made with glues that are not waterproof. For lining crates or making panels for pallet bins, it would be necessary to use special particle board made with improved moisture-resistant bonding agents, such as phenolic glues, but such particle board would cost some 30% more to make, and it is therefore unlikely that there will be much demand for particle board for such packing cases.

Moulded particle cases

Moulded particle cases are made by direct moulding of the raw material in a single production operation based on the same techniques used in the production of particle board panels. The wood is chipped into particles, dried and mixed with

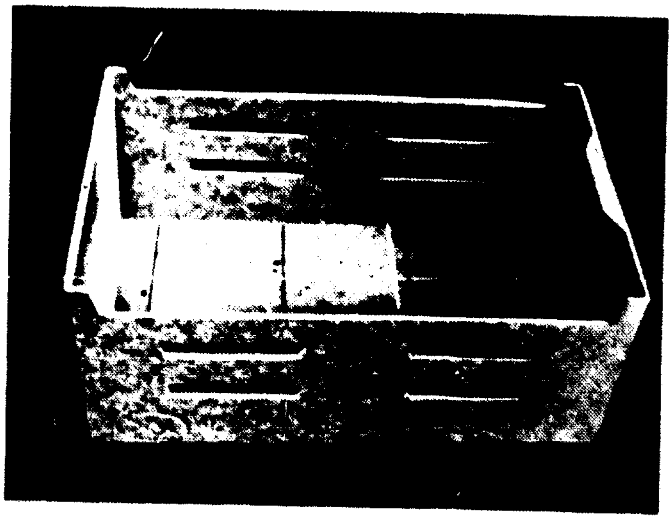

Figure 31. Moulded particle case

binder as in the manufacture of flat, pressed panels. The mixture of wood particles and binder is then injected into a heated mould and subjected to pressure. From this mould emerges the finished product (see figure 31).

In the production of this type of reusable packing case, a large amount of moisture-resistant binder is used (up to 25% of the weight of the particles); such cases must be subjected to heavy pressure in the mould. For one-way cases, only ordinary binders are used representing not more than 5% of the weight of the particles. For such cases relatively low pressure is applied. It is, of course, possible to secure a whole range of weather resistance and strength between these two extremes by using appropriate quantities and types of binder and applying appropriate pressure. Theoretically, the manufacture of moulded particle cases is advantageous: it utilizes wood from small-diameter branches or sawmill waste that can be obtained at low cost; 85% of these raw materials can be used; and the labour required is minimal.

Actually, many problems arise in applying this process. The first stage (the chipping, drying and mixing with binder) is carried out using highly developed techniques commonly employed on a very large scale. The moulding, however, calls for very different techniques from those used in the production of flat panels. Special presses and moulds are required; and while the problems of the injection and distribution of the particle-adhesive mixture in the moulds may have been fully solved in theory, the execution of these operations at the industrial level has given rise to practical problems (with respect to the rates of operation that have to be maintained) to which no satisfactory solution has yet been found. Each model of packing case requires a special mould costing about $10,000. Only the mass production of packing cases can therefore be envisaged.

The moulded case may continue to give off formaldehyde vapour for a long time after manufacture, so it is practically impossible to use this type of case for perishable goods, unless it is set aside for conditioning for a long period between manufacture and use. The rates of manufacture that can be achieved are limited on the one hand by the time needed for the insertion of the particle-adhesive mixture into the mould and the removal of the finished case and on the other hand by the time needed for polymerization of the binder. The total cycle time is about two minutes per mould.

The investment required for production is very high. Over $500,000 is needed for a complete production line operating on a 24-hour schedule and theoretically capable of manufacturing about 1.5 million cases per year. In practice, however, the output of most presses is far below capacity because of frequent stoppages caused by mechanical or electrical difficulties. In the future more highly perfected equipment may be able to give better outputs, but even with good outputs a very large investment is required for the manufacture of a relatively small number of cases. When the production rate and the need to work three eight-hour shifts per day are taken into account, the amount of labour required per case, which seems at first sight to be small, turns out to be quite large. It has been calculated that the direct labour time involved in the manufacture of a moulded particle case for apples is about three minutes, while the direct labour time for an apple crate of the same dimensions made of stapled peeled wood is only four minutes.

The complexity and fragility of the equipment requires highly skilled workers (mechanics and electricians) always to be on call. Finally, it should be noted that the production rate is constant: a production line is not flexible and it cannot adapt itself to market needs.

The technique of producing moulded wood particle cases will probably improve eventually, but at present their production should be approached only with the greatest caution and with the idea of studying the process rather than using it industrially.

Composite packing cases (wood plus another material)

Wood is frequently combined with one or more other materials in the manufacture of packing cases. Generally speaking, composite packing cases are designed in such a way that each of the materials provides part of the required protection; thus, an outside wooden case provides mechanical protection, while an inner envelope of welded plastic film containing small bags of dehydrating materials provides protection against moisture. For some packing cases, however, two or more materials are used to form the case itself. Wirebound cases, where wood and metal (in the form of wire) are used, provide an example. Other types of composite cases include:

(1) *Cases with a wooden baseboard and board body.* This type of case is used only for the domestic transport of household appliances, such as refrigerators, washing machines, and the like. It is a frequent practice to fix the product to a wooden baseboard made of two skids and two crosspieces and to place on top of this a corrugated board case with corrugated board corner packing pieces or expanded polystyrene packing pieces or expanded polystyrene packing pieces between the product and the board case. The case completely covers the appliance and rests on the base, and the entire unit is held together by metal straps.

(2) *Cases with a wooden framework covered with corrugated or compressed board.* This type of case consists of a frame with a wooden base and a superstructure made of panels consisting of wooden uprights and crosspieces on which sheets of cardboard are stapled.

(3) *Cases with wood/paper composite panels.* Wood/paper composite consists of a sheet of veneer 2–5 mm thick on which one or two sheets of kraft paper are glued. To be produced at a reasonable cost, the paper must be glued to the green wood as it emerges from the peeling machine. This technique generally calls for rather complex equipment, and only a few enterprises in the entire world manufacture this material in the form of panels that can be used as the cladding for cases and crates. This material, however, is in common use for the manufacture of matchboxes.

(4) *Cases with metal frames and panel cladding.* This type of case has been mentioned in connexion with packing cases made of plywood or fibreboard. This design can also be adopted for the manufacture of pallet bins, and it has given rise to the production of containers with plywood walls.

Apart from those described above, there are few types of packing cases in which wood is associated with other materials. It is quite possible that this represents a gap in research and that very interesting developments may be achieved in this field in future.

Barrels

This study of types of wooden packing cases would not be complete without some mention of barrels used as containers for liquids and drums and barrels for solid goods.

Casks for containing liquids are designed essentially for the storage of wine and spirits. These casks and the vats used for wine making can scarcely be considered to be packing cases. Use of this type of cask is declining because it is too expensive and fragile. Casks are being replaced by tank wagons and road tankers for transport purposes.

Drums and barrels for packing solid goods are one of the most ancient methods of protecting and transporting merchandise. Because of their cylindrical or elliptical shape they can be rolled and thus are easy to handle, but they are difficult to stack or to use with pallets.

Unlike the staves of casks, which are made of split wood, the staves of packing barrels are made of sawnwood. After the barrel heads have been inserted into the crozes, the assembly of the barrel is completed by means of hooping with strips of nailed split wood or with metal hoops. Packing barrels are still in common use in many countries, but their further development cannot be recommended, since they are no longer appropriate for present-day transport conditions.

This study has attempted to describe the major types of packing cases in current use. Composite packing cases, which combine two designs, may be adopted to suit the special requirements of a particular country or area.

No mention has been made of small sawnwood packing containers such as very small boxes or cigar boxes that may be considered nearer to the carpentry or even the joinery trade than to the wooden packing industry. Likewise, products have been omitted that cannot be considered packing cases, such as cotton reels or the reels designed for the reception, transport and laying of wires and insulated cables.

Chapter 4

STANDARDIZATION, LABORATORY TESTS AND QUALITY CONTROL

Standardization

The object of standardization is to make possible:

(a) Rational organization of manufacture, from the raw material stage to the finished product;

(b) Technical documentation kept up to date by a specialized body;

(c) The elimination of waste;

(d) Increased production;

(e) Steady functioning of manufacturing activities over a period of time;

(f) Reduction of manufacturing costs;

(g) Specific guarantees of quality, consistency and safety;

(h) Products of improved quality, quantity and consistency;

(i) An increase in national productivity.

Standardization requires that a series of choices be made. For wooden packing cases, these choices concern shape, basic dimensions and quality.

Choice of shape

The shape of a packing case is of great importance, as it influences the performance of the product required, the choice of inner packings, or wrappings, the strength of the case and the cost of storage and empty return of reusable cases.

The current preference for simple shapes, generally cubic or oblong, has been influenced by modern transport conditions, and the trend towards using this type of shape should be encouraged. However, the level of development of a country may make it necessary for a given period to use nesting shapes for certain sectors of production to reduce the cost of returning empty cases over long distances.

At the international level, the Inland Transport Committee of the United Nations Economic Commission for Europe (ECE) in its "International Protocol" (drafted in 1954 and adopted in its present form as "Resolution No. 203" in January 1967) decided that wooden cases for fruits and vegetables used in international transport and trade should be oblong and that nesting cases such as panniers or hampers should not be used unless contained in larger oblong packing cases.

Choice of dimensions

With few exceptions, the determination of the dimensions of packing cases presents many problems and is an inexhaustible source of controversy. In practice, the standardization of dimensions is subject to several determining factors: the dimensions of the product to be packed; the dimensions of the wood used; and the dimensions of the pallet and the transport equipment used.

Dimensions of products

Products to be packed are of all types, shapes and sizes, from strawberries to the largest machine tools. It is difficult to imagine how one method of standardization could be found that would be well adapted to all products.

Large products generally require special packing cases, the dimensions of which will be determined by the dimensions of the product. Limitations may be imposed by the requirements of the means of transport, for example, limitations on volume and weight prescribed by the road or rail network, and by the handling facilities (maximum permissible gross weight).

The standardization of the size of packing cases for medium-sized and small products, however, should be studied, and the question arises whether exterior or interior dimensions should be standardized. Interior dimensions should be standardized, particularly for medium-sized industrial products such as household appliances. For small products, however, and in particular for perishable goods such as fruits and vegetables, the wide range of sizes of packing cases used throughout the world shows that not too much attention need be paid to the requirements of the product.

The TNO Laboratory at Delft, the Netherlands, demonstrated, in a report prepared for the Organisation for Economic Co-operation and Development (OECD) (Project No. 372/2 1960),[2] that the dimensions of products such as apples are of little importance as far as the choice of the size of packing case is concerned, whereas products such as lettuce or cauliflower have quite rigid dimensional requirements. The report is quick to add that, "it is striking to note that these requirements depend to a great extent on the method of sizing adopted".

In France fruits and vegetables of all sizes are packed in cases of only two basic dimensions: 57 X 34 cm and 50 X 30 cm. In other European countries the same products are packed in cases of many different dimensions such as 54 X 39 cm, 65 X 40 cm, 54 X 42 cm, 56 X 37 cm, 51 X 31 cm, and 55 X 38 cm, to mention only a few. More than 20 basic dimensions varying from 43 X 30 cm to 60 X 46 cm are used to make packing cases for lettuce and other green salads; for cauliflower there are at least 12 different dimensions varying from 44 X 31 cm to 78 X 56 cm.

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[2] "Normalisation des emballages en bois pour fruits et légumes" ("Standardization of wooden packing cases for fruits and vegetables")–study of the possibilities for standardizing one-way wooden packing cases for fruits and vegetables in the light of palletization requirements.

In 1958 and 1960, OECD drew up three catalogues of "dimensional types of wooden packing cases for fruits and vegetables used in Europe". These catalogues, which cover 23 countries, include more than 600 types of packing cases with over 250 basic sizes.[3]

The difficulty encountered in trying to standardize dimensions of packing cases is not so much a mathematical problem as it is one of changing established traditions. Although everyone agrees on the need for standardization, each manufacturer thinks that his type of packing case is the best and should be adopted as the standard.

If it is assumed that, either by persuasion or by compulsion, it is possible to arrive at a method of standardization that will take relatively little account of the products themselves, the only real problem will be to pack into the standardized range of cases a given number of units or a round number of kilograms of goods in order to facilitate commercial transactions. Subsequently this procedure may greatly influence the standardization of the products themselves.

Dimensions of wood used

It might be thought that the dimensions of packing cases should be based on the most common commercial sizes of sawnwood in a given country in order to reduce waste of raw material during manufacture. For countries that import all or part of their timber in the form of sawnwood, this reasoning may be justified. For countries producing wood themselves, however, the amount of wood used for packing cases is sufficient to justify the cutting of special sizes of wood, if necessary, particularly as the production of packing cases in such countries is usually carried out by the same enterprise that saws the logs in the first place. It would therefore appear that, with few exceptions, the dimensions of readily available sawnwood should be disregarded when studying the standardization of packing sizes.

Dimensions of pallets and means of transport

The dimensions of the vehicles or pallets used for transport are the third factor that must be taken into account in deciding on the sizes of packing cases. Many types of vehicles are used: airplanes, ships, containers, trains, trucks and light vans. Each of these categories contains many different models, so that it would be futile to list all of them with their dimensions. The only carriers that at present have been standardized by ISO are ISO series 1 containers, whose minimum interior dimensions are: height, 2,197 mm; width, 2,299 mm; length, 11,998, 8,931 or 5,867 mm. No agreement has been reached so far on the interior dimensions of insulated or refrigerated containers.

The dimensions of pallets have been studied at the international level in terms of dimensions of the vehicles used most frequently and of the over-all range of products

[3]These three catalogues are as follows:

(a) Catalogue of types and sizes of wooden packing cases for fruits and vegetables used in Europe (OECD project No. 372, September 1958);

(b) Catalogue of types and sizes of wooden packing cases for fruits and vegetables used in Europe—supplement to catalogue published in 1958 (OECD book 33);

(c) Draft catalogue of types and sizes of wooden packing cases for fruits and vegetables used in several Eastern European countries and in Israel (document W/TRANS/WP.11/107 of the Inland Transport Committee of ECE, Geneva).

to be transported rather than of specific products. ISO has issued two recommendations concerning the dimensions of pallets:

(a) ISO R 198.[4] which lays down nominal dimensions of 800 X 1,200 mm, 1,000 X 1,200 mm and 800 X 1,000 mm.

(b) ISO R 329.[5] which lays down nominal dimensions of 1,200 X 1,600 mm and 1,200 X 1,800 mm.

Although the International Union of Railways has established a pool of pallets in Western Europe based on the dimension 800 X 1,200 mm, the pallet most commonly used internationally has the dimensions 1,000 X 1,200 mm. Table 1 gives the dimensions ECE Resolution No. 203 prescribes for packing cases for fruits and vegetables and gives the corresponding percentages of utilization of pallets of various dimensions.

TABLE 1. BASIC DIMENSIONS ESTABLISHED BY ECE FOR FRUIT AND VEGETABLE PACKING CASES AND PERCENTAGE OF UTILIZATION OF PALLETS OF VARIOUS DIMENSIONS

Outside dimensions of packing cases for fruits and vegetables (cm)	*Dimensions of pallets in mm*				
	800 X 1,200	*1,000 X 1,200*	*800 X 1,000*	*1,200 X 1,600*	*1,200 X 1,800*
60 X 40	100	100	90	100	100
50 X 30	94	100	94	94	97
40 X 30	100	100	90	100	100
50 X 40	83	100	100	94	92

Thus, it can be seen that 1,000 X 1,200 mm pallets are the most advantageous to use in the transport of fruits and vegetables.

As has already been stated, palletization should be adopted for its own merits and subsequently everything else should be designed to suit the palletization. It is recommended that pallet standardization policy be based on the dimensions laid down by ISO. This does not mean that other, temporary solutions may not be envisaged, but the adoption of such temporary solutions may subsequently hinder the rational standardization of pallets and packing cases.

The standardization of containers, carried out on the basis of containers already used in the United States, took place much later than, and quite independently of, the standardization of pallets. As a result, the interior dimensions of containers are not adapted to the dimensions of the specified pallets of 1,100 mm width. Although the use of 1,100 mm wide pallets does enable two pallets to be loaded side by side in a container, the same container will accommodate two 1,000 X 1,200 mm pallets,

[4] ISO recommendation R 198 "Double-deck flat pallets for through transit of goods".

[5] ISO recommendation R 329 "Large pallets for through transit of goods".

one in one direction and the other at right angles to it. There is no evidence that the coefficient of filling ISO series I containers is better with pallets 1,100 mm wide than with 1,000 X 1,200 mm pallets. The only real difference is that the pallets 1,100 mm wide can have only two entries, while 1,000 X 1,200 mm pallets must have four. It seems obvious that for transport palletization there is every advantage in having mainly four-entry pallets.

Standardization of packing case dimensions is possible, but it must be based on the standardization of pallets; the basic dimensions of the cases should be sub-multiples of the dimensions of the pallets, especially the 1,000 X 1,200 mm pallets.

In 1968, ISO established a technical committee (TC 122) responsible for studying all problems relating to packing cases; subcommittee 1 of this committee is responsible for dealing with the question of dimensions. Although this work is only in its initial stage, it already faces the difficult problems brought on by the existence of two different systems of measurement: the metric system and the system used for many years in the United Kingdom and the United States.

In addition to the two ISO recommendations previously referred to (R 198 and R 329), Technical Committee 51 has issued recommendation R 445 (vocabulary of terms relating to pallets).

Choice of quality

While the standardization of dimensions is an important consideration, the standardization of the quality of packing cases is probably even more important. Transport conditions can vary tremendously depending on the method of transport used, the distance covered and the number and magnitude of the handling operations. Ideally, packing cases should be designed for the specific conditions under which they are to be used. This, however, is completely impossible. A distinction has been made in chapter I between one-way cases and reusable ones from a purely economic point of view. While this distinction is completely valid, the technical definition of packing cases from the production point of view is impossible without taking transport conditions into account. A one-way packing case that is designed to provide for the transport of a product on a smooth road has nothing in common with a one-way packing case designed for the transport of the same product to a destination 2,000 km away be a succession of different means of transport. This observation leads to the idea of cases built on minimum levels of strength leading to packing cases divided up into categories of different quality. From the point of view of the manufacturer, the number of categories would have to be kept as low as possible in an ascending order of strength, users being free to select one of these categories in the light of their own needs.

Three minimum levels of strength could be established as follows:

Level 1 – packing cases made at just sufficient strength to be compatible with the demands of a single overland journey not involving special risks;

Level 2 – packing cases sturdy enough to make several trips by land, but not expected in principle to make more than one trip under difficult conditions;

Level 3 – very sturdy packing cases capable of being used for a long period even under the most difficult conditions.

The standards of these levels of strength may vary from one country to another and may also vary in time as transport conditions improve. Compliance with these levels could be effected by one of two methods, either by establishing a detailed definition of the characteristics of packing cases according to their function and expected application or a definition of minimum strength requirements based on laboratory tests.

The first method has the advantage of establishing a detailed definition for standardized packing cases according to their function, but it has the disadvantage of possibly limiting innovations by preventing cases from being made in any way other than that prescribed. The second method permits the imaginative development of new manufacturing methods and applications. Its disadvantages are that it requires the use of a laboratory and it does not specify the practical steps that must be taken to manufacture cases capable of meeting test requirements. To comply with changing conditions, laboratories would have to review their methods of testing frequently to ensure that the methods corresponded to actual conditions of transport.

Consideration of these advantages and disadvantages leads to the conclusion that qualitative standardization should be based on a combination of the two methods. The basis of such standardization would be an examination of the "performance" of the cases through tests of their strength in laboratories. Based on the results of these tests, detailed specifications would be established, not in the form of obligatory regulations, but in the form of recommendations that would be reviewed periodically. These specifications would fall into two categories: general specifications covering either all types of packing cases or individual categories of cases and including instructions regarding the application under consideration, the quality of the wood, its moisture content and general manufacturing conditions; and then, individual specifications indicating the exact details of the packing case in question and giving its pattern of construction, the dimensions of its various components, and the methods of attachment of the components.

Such specifications would serve as a guide for manufacturers, who, at the same time, would be free to adopt any other specifications that would enable them to improve productivity or secure equivalent strength using less wood, provided, of course, that the case thus manufactured complied with the laboratory test requirements.

This qualitative standardization is so important that it seems strange that it could have been forgotten. The fact that packing cases can be relied on to comply with certain strength requirements enables users to select those types of packing cases whose strength is best adapted to the conditions in which they are to be used.

For those engaged in transport operations, this procedure would give the advantage of reducing the amount of damage to cases, provided that the minimum quality requirements in the different categories were adhered to and enforced by regular checks on production. For the manufacturer, qualitative standardization would help to eliminate unfair competition consisting of supplying packing cases of inferior products offered at low prices in order to secure sales. Buyers would be guaranteed a minimum strength level for all products, and competition could then take place without any lowering of quality. Unfortunately, the problems of the quantitative standardization of packing cases have not been studied to any great extent at the international level. ECE Resolution No. 203 referred to above gives testing methods and details of the test results that should be obtained for fruit and vegetable packing cases. Subcommittee 3 of ISO Technical Committee 122 is in the process of formulating test programmes. It is hoped that this subcommittee will eventually devise methods and programmes that can be applied by all laboratories.

Laboratory tests

There are certainly many ways of making a packing case for a specific purpose (although not all these methods are rational). Of the methods that are best from the technical point of view, those that give the greatest economy of raw materials and labour and give the best utilization factor should be chosen.

Until recently, the decision on how to make a packing case was based on the practical experience and ingenuity of manufacturers, users, and transport enterprises. Representatives of these groups, however, are not in complete accord and offer a variety of opinions regarding the ideal packing case. Evidence points to the need for checking and investigating different opinions and proposals by means of systematic laboratory tests before series production is embarked upon.

Although they are naturally somewhat theoretical, laboratory tests are of great value because they can, for example, subject two similar packing cases to a particular stress, repeat the stress, modify it, subject a part of each case to it, and then compare the exact behaviour of the two cases tested or the two parts. Such tests, which can be carried out in a very short time, can give more valuable information than months or years of practical experience. It is also possible to reproduce in laboratories all the climatic conditions to which packing cases may be subjected.

The choice of the tests to be carried out and the methods of testing to be used have always been a vital issue. Many studies are being carried out at the national and international level (particularly by Subcommittee 3 of ISO Technical Committee 122) to define and standardize tests, testing methods and the results that should be obtained.

The following requirements are essential for tests or testing methods:

(a) Tests must reproduce as faithfully as possible the stresses to which the packing case is normally subjected and which could bring about partial or total destruction of the case or its contents. The method of testing must as far as possible reproduce the cause of actual damage exactly or reproduce damage identical to that under consideration, although caused by a different stress.

(b) Tests must evaluate the strength of packing cases of different constructions so that they may be easily compared.

(c) Testing methods must produce clear damage during the tests or, even better, damage that can be measured objectively in order to eliminate any need for subjective interpretation of the results.

(d) Tests must be reproducible in every detail.

(e) Tests must be simple to perform and require little time.

Tests should be chosen, therefore, according to their capacity to simulate the stresses to which packing cases are subjected in handling and transport. The most common stresses are described below.

Climatic conditions

Depending on their place of origin and their destination, packing cases and their contents may be subjected to different climatic influences, such as change of temperature or humidity, salt air or sandstorms. The laboratory should be able to reproduce the climatic conditions prevailing at each stage of a journey during every season of the year. Because it is impossible to carry out individual climatic tests on each packing case, Subcommittee 3 of ISO Technical Committee 122 has established the following scale of climatic conditions comprising eight different temperature and humidity levels: very cold (−55°C), cold (−18°C), humid temperature (15°C and 85% relative humidity), temperate (20°C and 65% relative humidity), dry temperate (23°C and 50% relative humidity), hot and humid (38°C and 85% relative humidity) and hot and dry (60°C and 30% relative humidity). Only conditions that can have a marked influence on the strength of the packing cases have been considered.

Stacking

Packing cases are invariably stacked at some time during transport. When full cases are stacked, the bottom case must support the weight of the whole pile. The lower cases are thus subjected to a vertical force whose magnitude depends on the weight and number of the cases in the stack. Cases are usually stacked to heights of 4–5 metres, but in cold storage, for example, they may be stacked as high as 10 metres.

The weight bearing on the upper surface of a case may be spread uniformly or non-uniformly over this surface, depending on whether the stack consists of homogeneous or heterogeneous cases and on the size and shape of their contacting surfaces. The weight on a case tends not only to compress it but also to deform it. When cases are tested, the methods used should allow for deformation similar to that which occurs in a stack.

Presses with rigid plates fail to allow deformation; consequently, they are unsuitable for such tests, although they may be acceptable for comparative tests of materials. More suitable are presses whose plates are movable in the horizontal and the vertical plane. Stacking tests can be carried out most easily by placing a weight on the case. Subcommittee 3 of ISO Technical Committee 122 has defined a stacking test method that is in keeping with the conditions described above.

Vibration during transport

The vibration caused by the vehicles themselves is an inherent feature of transport and creates to-and-fro movements that tend to distort the packing cases. The type of vibration differs basically depending on the type of transport used: airplane, ship, train, wagon or truck.

This type of stress may be reproduced either by a vibrating table operating at a frequency and amplitude selected according to the means of transport, or by a jolting table that reproduces the successive vertical shocks caused by transport in trucks. As cases are normally stacked when transported, tests should be carried out with a weight placed on top of the cases that corresponds to the weight of a pile whose height is in keeping with the method of transport under consideration. Subcommittee 3 of ISO Technical Committee 122 has defined a test method using a vibrating table.

Shocks during transport

Shocks occur frequently during transport. In air transport they come, for example, from air pockets, which are unavoidable. In rail transport shocks occur in railway shunting yards, but their frequency can be reduced by improving handling operations and shunting facilities. Shocks bring about displacement of the goods within the packing cases and are defined by the maximum deceleration value attained and by their duration.

In the past shocks have been reproduced inaccurately in the laboratory by tests on an inclined plane. Shocks obtained with such apparatus give a "deceleration time" curve that is completely different from those recorded for shocks during transport: the maximum deceleration is about five times greater, and the time ten times shorter. For this reason, this test should not be used, but should be replaced by one that is capable of more faithful reproduction of the shocks suffered during transport.

Falls

During handling, cases are accidentally dropped, or deliberately thrown or dropped, by handlers in order to put them in place, instead of laying them down carefully. Packing cases may also be dropped because of defective mechanical handling equipment, especially in ports, or because of defective stowing.

The number and magnitude of the falls depend on the gross weight of the packing case and to a lesser extent on its size: the heavier or bulkier a case is, the less brutally it is handled. Falls are very common accidents but should not be considered an inherent feature of transport. They are not normal stresses, and responsibility for them lies with the handler. Falls can be eliminated by improving transport facilities and educating handlers to be more careful. Nevertheless, some dropping tests are still necessary, but they should be put in their proper perspective and should not be used, as they often are, as the basis for testing the strength of packing cases.

Falls are reproduced in the laboratory by free fall tests, which consist of dropping a packing case, either flat, on edge, or on one of its corners, onto a rigid surface from a certain height. Subcommittee 3 of ISO Technical Committee 122 has defined free fall testing methods. Falls can also be reproduced by means of a tumbling drum constructed with baffles inside that rotate around a horizontal axis causing the packing case to fall in all possible positions. Although this apparatus facilitates testing and takes more account of the shape of the packing case than free fall testing, cases never fall exactly the same way from one test to another and therefore this method cannot be considered reproducible. For this reason it was not adopted by Subcommittee 3 of ISO Technical Committee 122. All tumbling drums used in laboratories throughout the world, however, conform with the standard of the American Society for Testing Materials (ASTM). Another test that can be used for fairly large packing cases is the rolling test, which consists of tumbling a case over, pivoting it on one of its edges, and then dropping it successively on each of its faces.

Besides testing packing cases, laboratories are called upon to test materials to ensure that they comply with established standards.

The testing of packing cases in laboratories can be carried out from two different points of view corresponding to two different needs. First, when an examination is conducted to determine whether a packing case meets one of the minimum strength levels, the tests are performed in an established order, each test being carried out in accordance with intensity criteria laid down in advance as a function of the strength that must be achieved for the various strength levels. This series reproduces as faithfully as possible the succession of stresses to which the full packing case (or empty case if it is reusable) will be subjected during its lifetime. The results of the test will prove whether a case is still capable of protecting its contents and consequently corresponds to the minimum level.

Subcommittee 3 of ISO Technical Committee 122 has established the following sequence for carrying out the tests: inner wrappings, stacking, shocks, climatic conditions, vibration, and again stacking and shocks. The subcommittee is in the process of defining the intensity levels for each of these tests.

The second aim is to compare the strength of two different packing cases to determine which is stronger, or to determine the weak points of a packing case in order to eliminate them. Appropriate tests should be chosen from among those mentioned above or from other tests. The case should be tested to destruction. It is not certain, of course, that the most appropriate test will always be performed first. In this instance, the investigation should be repeated with another test. These investigations represent fundamental research, and even though wooden packing cases are often considered to be very well known, systematic testing has made it possible and will continue to make it possible in the future to improve their design.

Although dropping tests should not be considered the only kind of test to determine the quality of a packing case, they can be used as a basis for future research. For example, in attempting to improve the attachment of the elements of nailed sawnwood cases, tests of stacking or vibration are of little value, since the cases cannot be tested to destruction. Tumbler drum tests may be used, varying the sizes, loading and jointing methods. It has been possible to discover how the shape of a case influences its strength; to compare the relative merits of assembly by smooth nails, spiral-grooved nails, thin nails or staples (the smooth nails commonly used have been found to be too short generally); to note and obtain precise figures on the improvement achieved by using spiral-grooved nails; and to work out specifications for "homogeneous" packing cases, that is, cases that do not break consistently at the same place.

To determine the strength of light packing cases, vibration tests should be used until the cases break. The frequency and amplitude of the vibration may be increased above the values usually used in evaluation tests if necessary.

For testing pallets, a free fall test from a given height, whereby the pallet lands on one of its corners, measures the amount of deformation produced by the number and kind of falls.

Quality control

Although tests and specifications are important, the task remains of ensuring in practice the manufacture of packing cases that are of uniformly good quality and in accordance either with specifications or minimum strength requirements. Users must be given some guarantee of quality and should be able to distinguish well-made cases from those of mediocre design or construction. Unfortunately, the former usually cost more than the latter, and it can be difficult to provide obvious proof of the quality of packing cases at the time of purchase.

To distinguish good packing cases from inferior ones, seals of quality (or of conformity to set standards) and quality control procedures have been established. Reliable manufacturers or groups of manufacturers who are proud of the quality of their products do not hesitate to put their names on their products. It is only after considerable effort and extensive publicity campaigns that some of these brands become symbols of quality for the public. These brand names are based only on the quality of the work and the professional conscience of those who manufacture the products to which they are attached. Widespread familiarity with a particular brand name, however, often depends on the financial strength of a manufacturer and the extent and effectiveness of his publicity.

Seals of quality administered by trade associations indicate that manufacturers are willing to conform to exact and well-known regulations. These seals of quality could be questioned, however, as it is the trade association that both sets the standards and awards the seals of quality.

The best solution to quality control may be the system of national seals of quality administered by independent bodies offering all necessary guarantees of impartiality. Manufacturers awarded such seals of quality should be free to manufacture other products of lesser quality provided that they do not affix the seal to them.

Seals of quality should gain recognition preferably because of the advantages that their guarantee represents to users of the product rather than because of financial advantages the manufacturer may derive, although such advantages can help the establishment and development of a seal of quality considerably. Care should be taken to avoid a system in which seals of quality are systematically imposed by some controlling authority, as this procedure amounts to compulsory standardization.

Sometimes, of course, it may be useful and even necessary to make the standardization of a particular type of packing case compulsory, especially when the packaging industry is in the early stages or a new type of case is being developed, in order to avoid proliferation of types of packing cases or to help on to the market only packing cases really corresponding to the needs of the moment. Compulsory standardization may also be necessary to defend consumers against fraudulent or dubious business practices. In such circumstances, however, seals of quality are no longer of any interest, since all packing cases would then legally have to conform to the same regulations. If a seal of quality is to have any value, and this will depend on the reputation of the body issuing it and the documents on which it is based, this value will be determined above all through independent and impartial testing.

Packing cases are checked at three stages:

(a) The laboratory stage, where, in both the initial evaluation tests and subsequent routine quality checks, the level of strength and the weak points are established and the possibilities of improving the construction or method of manufacture are analysed.

(b) During actual use, both at the place of dispatch and at the destination. Regular checks at the destination enable a large number of packing cases from different points of dispatch to be examined, and it is possible to check the way the packing cases have withstood wear and tear during actual use.

This check makes it possible to provide the laboratories with valuable information on the correctness of the test methods and levels of test intensity selected. This information in turn enables the laboratories continuously to modify and improve test methods and facilities. Such checks also provide manufacturers with valuable information on the extent to which their packing cases meet the needs of users.

(c) At the manufacturing stage. Periodic checking makes it possible to verify that packing cases conform to specifications, and samples can be taken for laboratory testing.

For several reasons it is impractical for representatives of a body issuing a seal of quality to be responsible for checking all products bearing its seal. Such a system might invite abuse and would be costly because it would require an inspector to be stationed in almost every factory. Furthermore, it would in fact make the inspector rather than the manufacturer responsible. Such inspection would be repressive in nature rather than educative. The role of inspection should be to guide manufacturers and to inform them of weak points and defects in their products.

Checking of the seal of quality should not be based on the checking of output, but rather on the checking of the quality control carried out by the manufacturer himself, for it is impossible for any enterprise to produce goods of consistently high quality without having itself established a good system for inspecting production. Such self-checking not only ensures the maintenance of the required quality but also enables manufacturers constantly to improve their products and productivity.

Checking of the seal of quality will thus ensure that the products bearing the seal are in accordance with the specifications laid down for them.

Factory checking verifies compliance with a given specification for the packing case in question. In practice, it is purely visual or requires only simple measuring instruments and must cover the following points in particular:

(a) *The quality of the wood.* Checking of the quality of the wood is necessary to ensure rejection of components with faults, such as knots, cracks and mould, that exceed permissible limits, and also to ensure that components are not used whose quality is too markedly superior to that required, as this would increase manufacturing costs needlessly.

(b) *The accuracy of cutting of the sawnwood.* The accuracy of the dimensions of the sawnwood used (length, breadth, thickness) must be checked to ensure that there are no errors in the dimensions and that they are within the tolerances established. For peeled and sliced wood, the thickness generally falls well within the permissible limits if the machines are in good condition, but for sawnwood there can be considerable variation in thickness owing to errors by mill workers, such as faulty setting of a saw or machine. To improve the standard of sawing, it is necessary to know what these variations are. This can be done by applying extremely simple statistical methods and calculating the standard deviation using Henry's straight line. Thus, with old band saws it is necessary to set the thickness of sawing to 5.6 mm to ensure that 95% of the sawn boards have a minimum thickness of 4.5 mm, whereas with a more suitable machine in good condition the sawing thickness can be set to only 5 mm. The check in question thus shows the improvement in the utilization of raw material that can be achieved (over 10% in this illustration).

(c) *The quality of cutting.* Sawing of wood does not usually present problems, but slicing and peeling often produce material that is of inferior quality because it contains cracks. These cracks are due to the actual techniques of peeling or slicing, but they can be avoided if the machines used are in good condition, and if their most important operating parts (knife and pressure bar) have been adjusted properly.

(d) *The quality of stapling and nailing of the plane elements.* Checking of this feature determines whether nails or staples have been driven in at the right place and are properly clinched, and whether the squareness of the panels thus made is within the set limits.

(e) *The quality of the assembly.* As the accuracy of the positioning of the nails or staples as well as that of the panels must fall within established limits, this feature must be checked carefully. Such checking must not be limited to the end of the production line when the packing case is finished, but must be done at each stage of manufacture because its object is to prevent defective packing cases from being manufactured rather than to eliminate them later. As soon as a defect is observed, action must be taken at the work station or machine where the defect has been produced to find out the cause and to remedy the defect as quickly as possible. It will readily be appreciated that the causes of defects can be reduced by using suitable equipment and keeping it in good condition.

In large enterprises it may perhaps be possible to appoint one employee as an inspector, but this method may not convince the workers of the importance of doing their work well. Another method of checking—more difficult to organize but undoubtedly more effective from the point of view of productivity—is the following: Each enterprise is divided up into a certain number of departments, such as sawing or peeling, panel manufacture, assembly and storage. Each department "sells" its products to the following department and must check its own work; the "buyer" department checks the quality of these products when it takes delivery of them by sampling in accordance with simple statistical methods, on the basis of previously established criteria. It then either accepts or refuses the batches offered to it. When a refusal is acknowledged to be justified by the foreman, the batch is checked item by item by the "seller" department, and the defective items are eliminated. A system of quality bonuses is established to ensure that such refusals of batches do not occur, for faulty products adversely affect the whole enterprise, including the morale of workers. This system of checking should begin with the sawing or peeling department and then be extended to other departments on the understanding that at the beginning the batches will not be refused; instead, the results of the checks made will be studied to determine the reasons why some items are defective with a view to eliminating the causes and not merely the defective items.

An effective system of factory checking, such as the one described above, can save a great deal of money for a manufacturer of wooden packing cases. Frequently in the manufacture of packing cases, any quality of wood—good or bad—is considered adequate; elements of roughly correct dimensions are deemed satisfactory; and haphazard assembly is permitted. To compensate for defects, which are almost always defects of manufacture rather than defects in the wood, a manufacturer uses elements that are thicker or of larger cross section than those specified, and this increases his production costs. With a proper design for a packing case, materials of good quality, and an effective system of inspection, the volume of wood needed to make a packing case of a specified strength can be greatly reduced. A saving of approximately 30% on raw materials can often be obtained, and such savings will soon make up for the cost of establishing the system of inspection.

For a checking system to be effective—that is, a system that brings about an improvement in quality without an increase in the manufacturing cost, substantial savings in raw materials and increased productivity—a number of conditions must be met. Workers must understand what they are supposed to do and why. They should be paid well only if they work well, and they should know what items to check and that their work will be checked later. Machines should be capable of producing specified work within required tolerances, for workers cannot be expected to do something that their machines do not permit them to do. The tolerances established should be known to all concerned. All the necessary checking equipment should be available, such as micrometers, sliding calipers, measuring rods and thickness gauges. (For example, thicknesses should be checked with a micrometer or a sliding caliper rather than with an ordinary rule.) The factory should be suitably organized to permit methodical checking of work, and the management should adopt a positive approach to inspection. The foremen should also understand the importance and value of thorough checking.

Chapter 5

MANUFACTURING

Technical processes and choice of machinery

Many technical processes are employed to manufacture the numerous types of wooden packing cases now in use. This study concentrates on the manufacturing processes for nailed cases and pallets, light oblong packing cases, and wirebound cases. A flow sheet has been made for each process indicating the progressive steps involved from the stage of sawing logs in the timber yard to placing the finished product in storage. These processes can be carried out either as a complete chain (vertical integration) or link by link (horizontal integration). Depending on certain economic criteria, the manufacturing process can be divided into different sectors, which may or may not be located in the same place and may or may not be integrated into a larger timber complex.

It should be noted that all the figures given in this chapter are simply orders of magnitude designed to facilitate comparison and cannot be used as the basis for studies of particular cases. The figures on investments cover only the main manufacturing machinery and do not include costs for buildings and auxiliary or secondary equipment. Figures on the number of workers are based on the assumption that a factory is well organized and its personnel competent.

Nailed sawnwood cases and pallets

As the manufacturing process for nailed sawnwood cases is very similar to that used to produce pallets, the general process that produces both is discussed below. This will make it easier to define the general problems that will later be used in the study of economies of scale.

A considerable part of the procedure shown in figure 32 is very similar to that followed in a conventional sawmill, both in respect of the quantities of sawnwood produced and the methods used to produce it.

Logs at the sawmill–bucking

Logs are generally brought to the sawmill by special trucks equipped with devices for loading and unloading the logs. Bucking is carried out either with mobile

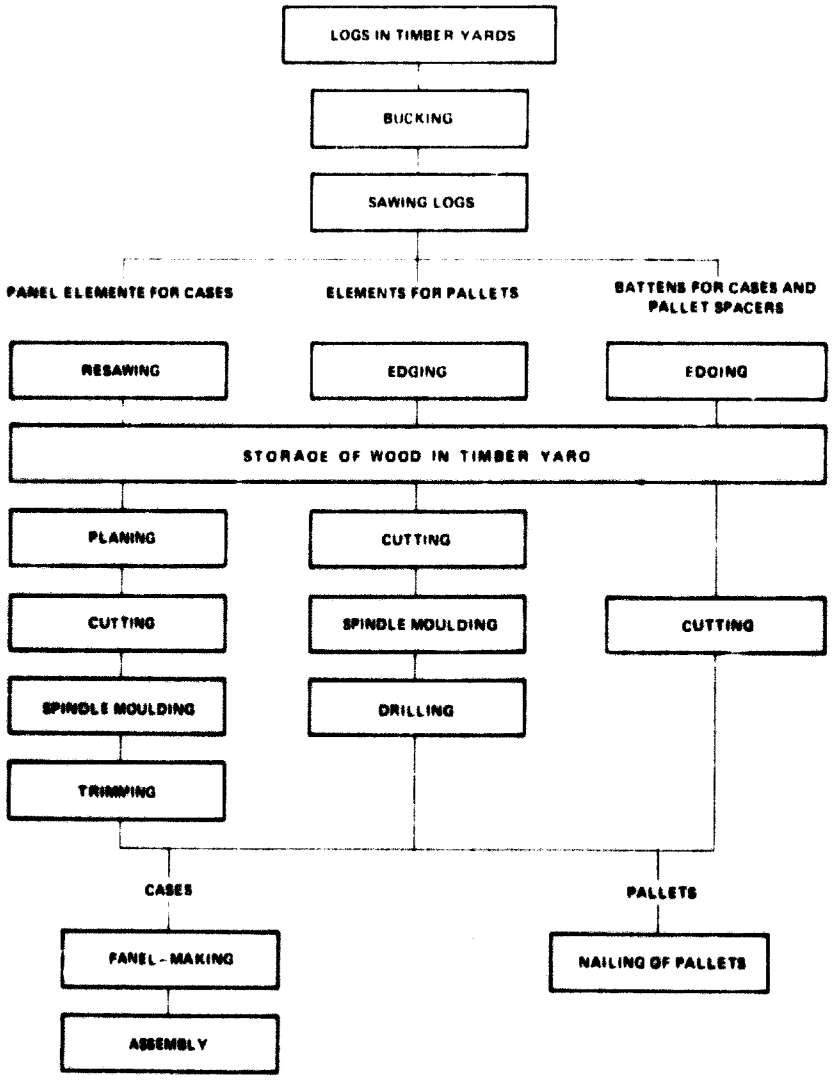

Figure 32. Manufacturing process for nailed cases and pallets

equipment (chain saws operated by one or two men, depending on the diameter of the logs) or fixed equipment (logs transported by chain conveyors and cut up either by chain saws or large-diameter circular saws).

Depending on the amount of timber to be processed each day, logs are handled by one of the following means: manual rolling by peaveys, transporting by bogeys on rails, transporting by lift trucks, transporting by chain conveyors, or transporting by a travelling gantry crane.

Sawing

A log band saw is indispensable as head saw, for a saw with a hand-fed carriage (push bench) would not be capable of performing all the required operations and sawing logs of large diameter. For a small turnover, a conventional log band saw is sufficient. A modern log band saw with a remote control automatic turnover carriage, centralized dogging and taper setting, automatic division and rapid feed should be able to cut approximately 40 m^3 of logs per day in parallel (through and through) sawing, and 20–30 m^3 of logs with one or more turnover operations per log. This latter method is preferable to the parallel sawing method, as the wood produced requires less handling on the machines that process it subsequently.

Primary sawing can be done in three ways:

(a) *Parallel sawing.* Each log, after being dogged on the carriage, is sawn entirely by successive parallel cuts; the boards thus obtained are later finished either on the head saw itself or, more usually, on resaws.

(b) *Sawing with one turn.* The log is dogged on the carriage and a few parallel cuts are made until a sufficiently wide base is formed. The log is then turned so that it rests on the base formed and is sawn with parallel cuts. The boards thus obtained have one sawn edge, which facilitates subsequent resawing operations.

(c) *Sawing with three turns.* The process begins in the same way as in the preceding method, but after the first turn a second base is formed by parallel sawing, the log is turned a second time, and a cant with three sawn faces is obtained by parallel sawing. This cant is then sawn up by parallel sawing and a third turning operation into boards that are sawn on all four surfaces. Boards and other sections of the desired final width and thickness are thus obtained on the head saw from a considerable proportion of the log.

The speed of execution of these three methods depends on the loading and turning mechanism with which the machine is equipped. Depending on the turning operations and the type of machine employed, maximum production may vary as shown in table 2.

TABLE 2. METHODS OF PRIMARY SAWING

(m^3 of logs per day)

	Log band saw	
Sawing method	*Non-mechanized*	*Mechanized*
Parallel sawing	20	45
1 turn	15	35
3 turns	10	25

The decision as to which of the above methods to adopt depends on the volume of logs to be sawn.

Resawing

For resawing, several machines are needed:

(a) *A resaw on which the cants and deals are sawn.* The planks obtained from sawing the cants will be subjected to further edging, whereas the planks obtained from the deals already have their final width and thickness.

Battens can also be sawn on the resaw. This operation calls for either an assistant to the sawyer or a saw equipped with an automatic returning mechanism, since it is essential to provide for the returning at the front of the saw of one of the parts of the piece being sawn. Such machines can be kept in operation between 30 and 95% of the time, depending on the extent to which a mill is mechanized.

(b) A gang saw or multi-blade vertical frame saw. If a mill processes more than 30 m³ of logs daily, producing wood of standard dimensions, particularly for pallets, it is economically justifiable to use a gang saw after the head saw. The gang saw cuts up deals into specified widths, thus producing finished boards in a single operation. A gang saw can be kept in operation approximately 95% of the time.

(c) An edging saw with one, two or more blades to handle relatively thin deals. The type of edging saw to be chosen will depend on the volume of wood to be sawn.

The mechanization of sawmills reduces considerably the amount of labour required, but it requires a large investment. Table 3 provides an approximation of the saving of labour that may be expected from mechanization.

TABLE 3. SAVING OF LABOUR RESULTING FROM MECHANIZATION

Amount of timber sawn (m^3 of logs per day)	*Labour time per m^3 of wood sawn* — *Conventional sawmill*	*Mechanized sawmill*	*Time saved*
15	4 h 50 min	3 h 45 min	1 h 05 min
20	4 h 25 min	3 h 12 min	1 h 13 min
25	3 h 50 min	2 h 35 min	1 h 15 min
30	3 h 30 min	2 h 10 min	1 h 20 min
40	3 h 00 min	1 h 48 min	1 h 12 min
50	2 h 50 min	1 h 30 min	1 h 20 min

Before a decision is made to mechanize a sawmill, many factors must be evaluated to determine whether the saving on wages resulting from mechanization will be sufficient to amortize the expenditure for machinery. Mechanization should not be envisaged unless it definitely makes operations more profitable.

Storing wood in the yard

Wood used for packing cases and pallets must be dried before it is used, as it should have a low relative humidity, generally about 15–20%, or up to 30% for the spacers of pallets. Air drying is normally carried out rather than artificial drying in a kiln, since it is not likely that the investment needed for kiln drying could be justified in view of the fairly high relative humidity level that must be obtained.

When the manufacture of packing cases is carried out entirely in one factory, the wood is dried after it has been sawn into pieces of specified thicknesses and widths, particularly if the sawmill is mechanized. The wood to be dried is therefore relatively thin, and drying is rapid. When the wood is sawn at a place other than the factory where the cases are manufactured, it is better to saw the wood into several standard thicknesses, dry the wood thus sawn, then ship it to the factory that will carry out the necessary resawing and manufacture the cases.

Machining of packing case elements

Certain machining operations are necessary for producing the components for packing cases. Planing is needed only rarely in case-making; and if it is required in order to improve the appearance of the case, a simple, conventional planing machine may be used.

Crosscutting the wood into the desired lengths is usually carried out with pendulum-type crosscutting saws with a single circular saw blade or, for mass-produced products where a large quantity of pieces of the same length is required, with saws with two or more blades. The profitability of the crosscutting operation depends more on the proper organization of the workplace than on the type of machine used.

Shaping processes are used to make the handles of cases or for rounding or bevelling the edges of components. Such work is done with routing machines operating with templates or spindle moulding machines working against a stop. Generally, this work is done in small series and requires only very simple machinery. For the large-scale production of pallets, however, it may be economic to make the chamfers with an automatic, continuous chamfering machine. Such a machine can chamfer 10,000 boards per day, a sufficient number for the daily production of 2,000–3,000 pallets.

Drilling may be required to permit the nailing of very hard wood, or for bolting parts together. This operation is usually carried out in small series and requires only a very simple machine such as a portable electric drill.

Trimming consists of making box panels of specified width from elements of varying widths. Such work is done on an ordinary circular saw with a moving table and requires no specialized or automatic machinery.

Panel-making and assembly of cases and pallets

Cases and pallets are assembled by nailing or sometimes by stapling. The major methods of assembly in increasing order of potential production capacity are described below.

Nailing by hand should not be ruled out automatically, since it requires no machinery and provides great flexibility in manufacturing. Portable pneumatic stapling machines are used for assembling thin elements. Such machines are loaded with strips of 100–200 staples, usually of 55 mm leg length, but they will drive staples of a maximum leg length of 63 mm if necessary. These machines cost approximately $200 each and require a supply of compressed air, but compared with the production rate of hand nailing, twice the amount of work can be accomplished.

Magazine-type portable pneumatic nailing machines also enable assemblers to work at twice the rate of those nailing by hand. The nails used are generally the special "T" type, which are delivered in strips and placed in a magazine just like staples. The maximum length of the nails used is usually 60 mm, but certain models can drive in nails up to 90 mm long. These machines cost approximately $200–$300.

Hopper-type portable pneumatic nailing machines can drive in ordinary or spiral-grooved nails up to 110 mm long. Nails are driven in at the rate of 100 per minute; since they are loaded loose into a hopper, the machines do not require frequent reloading. This type of pneumatic nailing machine costs between $400 and $1,500.

Stationary nailing machines can drive in up to 24 nails at a time, depending upon the number of nailing heads with which the machine is provided. They can drive in up to 100 sets of nails per minute. It should be borne in mind that these machines always drive in the nails in the same pattern; to change the pattern, the machine must be reset. The use of these machines can be envisaged only for quite large production runs. Their price varies from $4,000–$20,000.

Stationary nailing machines capable of producing various nailing patterns are identical with the foregoing machines, but operate with an electric selector board using cards that permit selection of the particular nailing heads needed to form a pattern. With these machines it is possible to vary the nailing pattern automatically for as many as 12 different cycles and to change the article being manufactured, within certain limits, without resetting the machine. The cost of the selector board is approximately $1,000–$2,000.

Automatic nailing lines are composed of a number of the nailing machines described above plus more or less automatic feeding and handling systems. Such production lines require a large investment and are justified only for very large outputs. An automatic production line makes it possible to manufacture 1,500 pallets per eight-hour day, but it costs about $100,000.

The production process and the machinery to be used will thus be chosen from the above on the basis of the size of output envisaged, the degree of standardization necessary, the amount of investment required and the cost of labour.

Light oblong packing cases

The manufacturing process for light oblong packing cases is a little more complicated than that for nailed wooden cases. A flow sheet of the process is shown in figure 33.

Logs at sawmill and bucking of logs

The problems and their solutions are the same for light oblong cases as for sawnwood cases.

Barking

Barking is necessary before peeling to avoid excessive wear of tools, and above all to avoid breakages that may be caused by stones embedded in the bark as a result of logging operations. Some types of wood with a very thin bark and delivered in a

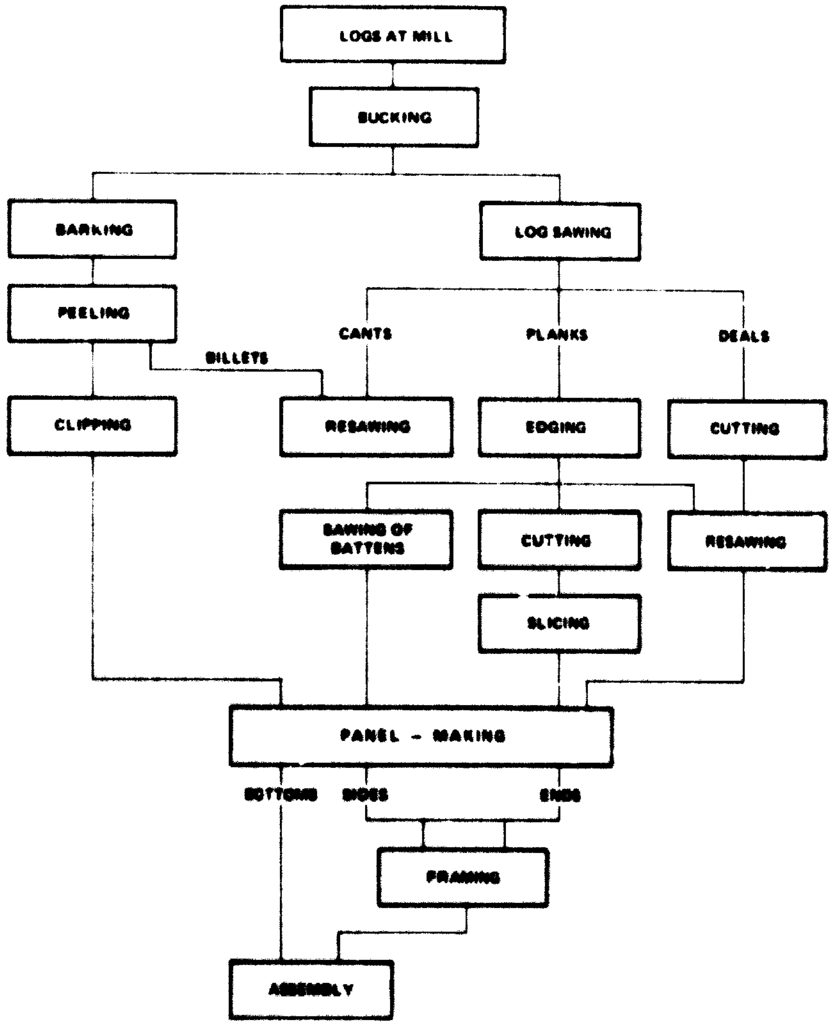

Figure 33. Manufacturing process for light packing cases

clean condition, however, can be peeled without barking. The method of barking will depend on the quantity of logs to be peeled. For up to 10 m^3 per day, barking can be done with an axe or with special hand tools called bark strippers. For 5–25 m^3 per day, portable barking machines with travelling, percussive or vibrating blades should be used. For 10–50 m^3 per day, it is practicable to use bark-stripping machines with an underslung bark-stripping shaft and manual adjustment of the log position, operating discontinuously. For over 50 m^3 per day a continuously operating automatic bark-stripping machine with a cutting head or rotating ring should be used. With this type of machine, barking is often done before the logs are bucked. The type of barking machine chosen will depend also on the length and diameter of the logs that the machine can take.

Peeling and clipping

Peeling and clipping are frequently combined. Peeling consists of transforming a log into a continuous sheet of veneer; the log is peeled tangentially to the growth rings by a knife mounted parallel to the axis of the log, which is fixed between centres and then rotated. Many species of wood can be peeled without any special preparation, but others, especially hard woods, must first be steamed or immersed in hot water.

The thickness of the veneer obtained is determined by the amount that the knife moves forward for each revolution of the log. The width of the veneer is determined on the peeling lathe by setting knives or blades that cut crosswise into the wood to a depth slightly greater than the thickness of the peeled veneer.

These knives separate the sheet of veneer, and the distance between them therefore determines the width of the band and hence the length of the peeled elements. At least two knives are set to trim the edges of the billets, as it is not possible to achieve sufficient accuracy when the logs are crosscut. Between these two edge knives, other knives can be installed so as to give two, three, four or five bands of veneer. For reasons connected with keeping the veneer-peeling lathe clear, it is preferable to restrict the number of bands to three.

The veneer-peeling lathes used are based on the same principle as those used for the manufacture of plywood, but they are of completely different dimensions. As the dimensions of light packing cases are almost always less than 60 cm, it is not necessary, as it is in plywood manufacture, to use peeling lathes with a working width of 4 m or more, which require logs of large diameter and leave very large cores. The peeling lathes used for making veneer for light packing cases have a maximum working width of 1.40 m. In practice, there are two categories of peeling lathes that produce veneer for packing cases:

(a) Large peeling lathes with a working width of 1.20 m–1.40 m, which can take wood 0.80 m or even sometimes 1.00 m in diameter and can process 15–30 m^3 per day with a yield of approximately 60%. The cores have a diameter of 14 cm. The cost of such a machine varies between $15,000 and $24,000.

(b) Small peeling lathes with a working width of 0.60 m–0.80 m that can take wood 0.50 m in diameter and process 7–15 m^3 of logs per day with a yield of approximately 70%. The cores have a diameter of 8 cm. The cost of such machines varies between $10,000 and $15,000.

To alter the thickness of the veneer produced, certain gears must be changed in the driving mechanism of the carriage and the knife and the pressure bar must be adjusted. On some up-to-date veneer-peeling lathes these changes can be made automatically by simply setting a lever at the desired thickness.

Clipping consists of obtaining strips of a given width from peeled veneers of a specified thickness and length. Clipping can be carried out by means of:

(a) *Knife clippers with intermittent vertical movement.* The veneer sheets are seized by hand as they come from the peeling lathe and laid in layers on a table equipped with an intermittent drive system. The layers of veneer are gripped between two devices that move the set of sheets forward a distance equal to the desired width of the strip while the knife is rising and then hold the set of sheets still while the knife is descending and cutting. This type of clipper requires labour for transferring the veneer sheets from the veneer-peeling lathe to the clipper, but it does ensure a certain degree of synchronization. Such cutting is not highly precise but the width of the strips can be changed very quickly.

(b) *Clippers with rotating knives.* Two knives turn on an axis and pass in front of a stop-controlled opening. The veneer is moved into the opening by a drive system, and at each revolution of the knife a piece is cut from the sheet of veneer. The width of the strip is determined by the ratio between the speed of rotation of the knives and the speed of advance of the veneer. This type of clipper is much more accurate than the type described above, but it does not permit synchronization between peeling and clipping.

(c) *Rotating clippers on the "back-roll".* The special feature of this method is that the clipping operation is done on the peeling lathe before the peeling proper is effected.

A roller with longitudinal knives is installed on the peeling lathe and pressed either mechanically or hydraulically against the billet along a line diametrically opposite to the line of the peeling knife. The roller is rotated by friction with the billet. When one of its knives passes over the billet it cuts a slit which, when the veneer is peeled off, in effect turns the continuous sheet of veneer into a succession of strips. This method has the advantage that it eliminates the need to handle the sheets of veneer between the peeling and clipping operations and produces widths of accurate dimensions. However, it calls for great precision in the manufacture of the rollers, and a different roller is required for each thickness and each width of veneer manufactured. As the width of the strip is determined by the spacing of the knives around the circumference of the roller, the knives must project by an amount exactly equal to the thickness of the veneer being peeled. If the knife does not project far enough, the cut will not penetrate the thickness of the veneer, and the strips will not separate from each other after peeling; but if the knife projects too far, it will cut into the wood that is to be peeled off on the next rotation of the billet and will thus weaken it. A different roller is therefore needed for each thickness of veneer and for each width. As a roller costs approximately $500 and has to be changed every time the dimensions of the strips to be produced are changed, it is necessary to achieve a good degree of standardization of the sizes in order to keep down the number of rollers required and avoid changes of dimensions.

The "back-roll" method, although operating simply by pressure, requires very powerful machinery–it requires about 75% of the power needed for the peeling process itself. This power varies as a function of the thickness of the veneer being peeled, the hardness of the wood, and the specified width of the strips. The use of the back-roll method is therefore limited by these three parameters.

The cores are either sawn into sections, especially corner strips, or are sold for the manufacture of paper or particle board.

Veneers to be used for light packing cases need not be made from billets of large diameter. Veneer peeling lathes with a working width of 1.20–1.40 m can peel wood with a diameter as small as 30 cm, while lathes with a working width of 0.60–0.80 m can peel wood of a diameter as small as 20 cm.

Sawing

There are very few light packing cases that are not made with some elements of sawnwood, as almost all light cases have corner strips, and some have laths especially the top laths of the sides made of sawnwood. Moreover, certain billets that cannot be peeled because of their quality or dimensions are sawn. Sawing wood for light packing cases should be limited as far as possible to essential elements and only wood of small or medium diameter should be sawn. Two types of saws can be used for sawing billets: a log band saw equipped with a light carriage; or an automatic or non-automatic saw with a hand-fed carriage.

A log band saw is used when more than 10 m^3 of logs per day are sawn; when the billets are large; and when, in addition to supplying sawnwood for light packing cases, sawing operations are required to provide wood for other purposes. The saw with a hand-fed carriage is used when conditions are the reverse and requires a much smaller investment than a log band saw. The billets are sawn without being dogged, the to-and-fro movement of the carriage requires less power, the selection of thicknesses is rapid, and the turning by hand is easier. Furthermore, these machines can be equipped with various feed devices that facilitate the rapid recovery of all products.

In both instances the method of sawing is the same: sawing with one turn to produce boards 25–30 mm thick and planks 60–120 mm thick. The boards are used for manufacturing strips or laths for slicing. To make strips, the boards are cut into square sections on a multi-blade resaw. These square sections are then resawn on special machines that can produce about 4,000–5,000 strips per hour. It is even advantageous to use such a machine for considerably smaller quantities that require the machine to operate for only a few hours a day.

For making laths, the boards are cut to the required length and then sawn by band saws, which may be: smooth-table saws; saws equipped with a very small hand-fed carriage that can produce 1,000 laths per hour; saws equipped with an automated carriage that has a reciprocal motion on which the wood is dogged and which can produce some 2,000 laths per hour; and horizontal saws that are fed wood from a turntable and that can produce 3,000–5,000 laths per hour.

The 60–120 mm thick planks are cut to the required length, then cut into shooks on one of the machines used for the laths. To produce larger quantities of shooks, it is possible to use a machine with multiple biconical circular saw blades mounted on upper and lower shafts and capable of producing 10,000–15,000 shooks per hour.

Slicing

In packaging terminology, slicing is defined as cutting a piece of sawnwood by means of a knife operating like a plane knife parallel to the axis of the wood. Boards with one sawn edge are sawn to the specified length and placed on a slicing machine of one or two types:

(a) A vertical slicing machine on which the knife reciprocates vertically but cuts only on the downstroke. The wood is kept in place by vertical clamps and is advanced each time the knife rises. The cutting width of such a machine is from 0.60–0.80 m and its output is approximately 0.5 m^3 of finished product per hour. The machine costs approximately $2,000–$4,000.

(*b*) A rotary slicer, which consists of a large-diameter flywheel (3–5 m in diameter) in which there are openings in which knives are placed. The thickness of the product depends on the distance between the flat face of flywheel and the amount that the knife projects. The wood is pressed against the face of the flywheel, which, when it turns, causes the knife to pass over the wood and thus slices off thin pieces. Production is between 7,000 and 12,000 pieces of sliced wood per hour (i.e. about 2–3 m^3 of finished product); a rotary slicer costs approximately $20,000–$30,000.

Panel-making

Panels are made from elements obtained by one of the three methods described above. These elements are laid out in jigs and fastened together by stapling. Stationary machines that use reels of wire and not pre-formed staples are always used for this operation. For a very long time rotating coils of wire weighing 7–10 kg were used, but these have been replaced by stationary reels carrying 100–500 kg of wire. Considerable time is saved by using stationary coils, as stopping for reloading is less frequent.

Several systems can be used for making panels. Small-series production can be carried out with a single-head, table stapling machine, which inserts only one staple at a time and requires only one or two jigs. The operator (or an assistant) places the panel elements in the jigs, then inserts the staples one by one. As it is not possible to provide any guides, the work must be carried out by visual judgement and requires great dexterity; and the quality of the output is not the best. The daily output is low, but the investment required is only about $1,200.

The manufacture of larger series of panels can be accomplished with a multiple-head, table stapling machine. This type of machine has several working heads and thus inserts several staples at once. The work is carried out in the same way as with the single-head machine, but a side guide is used to position the staples accurately in one of the two directions while visual judgement is used for the other direction. This machine has the same disadvantages as the preceding type, but is capable of greater output and requires an investment of approximately $1,500.

Panels for light packing cases should normally be manufactured on multiple-head stapling machines equipped with automatic feeding and positioning of the jigs under the stapling heads. Such machines are equipped with a long table along which the jigs pass. Workers place the laths in the jigs as they pass, and the stapling is carried out automatically. These machines can be used to make all types of panels, or they can be specialized to make only one product such as the ends of packing cases. Depending on the nature and magnitude of the output required, one of the systems described below should be adopted.

(*a*) *Multiple-head stapling machines with intermittent advance*

In these machines the jigs are fed to the table by the rotary motion of endless belts. While the stapling heads move up and down continuously, the jigs are brought under the heads by pushers which engage with serrations on each side of the jigs. While stapling takes place, the jigs are held stationary by a braking system. The jigs are returned under the machine by endless belts. The intermittent passage of the jigs under the heads limits the production rate to about 100 strokes per minute. Such machines are capable of producing between 6,000 and 10,000 panels with four rows of staples per day and cost approximately $3,000–$4,000. It is very easy to change over from one type of product to another, however, since all that is needed is to remove one set of jigs and replace them with another set, as well as possibly adjusting the spacing of the heads.

(b) Multiple-head stapling machines with continuous advance of the jigs and a constant pitch

The jigs of this machine are fastened to a continuously moving endless chain and pass in front of the workers and under the stapling heads at a constant speed. The stapling heads move in a vertical direction in the stapling operation and in a horizontal direction to follow the movement of the jigs during stapling. The result of these two movements is a continuous circular or elliptical movement. The stapling is therefore always carried out at a constant pitch, that is, the spaces between two successive rows of staples are always identical at a given setting. The pitch may vary from one product to another, but it is constant for a given product. The length of the chain is determined by the ratio between the pitch required and the dimensions of the panels; the chain will therefore be of a different length for each product. The continuous movement of the stapling heads and the chain permit very high operating speeds up to 500 strokes per minute, but in practice the rate of stapling is limited by the capacity of the workers to feed the machine with panel components, which is generally between 130 and 200 strokes per minute.

Such machines have a daily output of 10,000–20,000 panels with four rows of staples and cost approximately $5,000–$6,000. Any change in the product being manufactured, however, necessitates the complete replacement of the chain and the jigs, which takes several hours.

(c) Multiple-head stapling machines with continuous advance of the work pieces and variable pitch

The jigs for this machine are attached to an endless chain driven at a constant speed. The stapling heads go through the same movements as on the preceding type of machine, but are actuated by an automatic mechanism in accordance with a predetermined programme. This control mechanism may be mechanical or may consist of a system of photoelectric cells, which is more flexible. These machines give the same output as those of the preceding type and require approximately the same investment. Their chains can be set at a constant length, however, and if the product is changed, all that is necessary is to remove the jigs and replace them with other jigs. Perhaps the most important feature of these machines is that the stapling pattern can be adapted to the design of the panel to be manufactured, and thus it is not necessary to design the panels in the light of a constant stapling pitch.

Framing

Framing consists of assembling the side to be completed and end panels. This operation is the weak point in the manufacture of light packing cases, as no really practical automatic machine has yet been placed on the market to perform it. The framing operation is carried out by single-head staplers operating staple by staple. The operator places two panels in position under the stapling head and inserts each of the staples individually by depressing the pedal of the machine, after which he turns around the half-frame thus obtained, places a third panel in position, staples it, and so forth. As the positioning of the panels relative to each other and the positioning of the staples is determined visually, it is not very accurate. The speed of operation depends on the dexterity of the operator, who acquires such dexterity only through long practice. The rate of operation varies considerably depending on the worker and the type of packing case being produced, for example, from 150 units per hour for vegetable crates to 350 units per hour for trays. The investment required for the framing operation is approximately $1,200.

Assembly of bottoms

Assembly consists of stapling the bottoms of light packing cases to previously manufactured frames. As this operation is usually carried out on a single-head stapling machine inserting only one staple at a time, the same problems arise as in the framing operation. As the operating speeds in framing and assembly are the same, the machines for them usually work as a team. Assembly of bottoms, however, has been mechanized, and a production rate of 2,000 cases per hour can be achieved with an automatic machine, which costs approximately $25,000.

Wirebound cases

Wirebound cases are manufactured by the process shown in figure 34.

Wood requirements

The problems of barking, bucking, peeling and sawing are exactly the same for wirebound cases as they are for light packing cases. Because the output of a single manufacturing line of wirebound packing cases is usually large, barking is generally carried out before bucking. The use of the back-roll process of clipping is particularly advantageous for wirebound cases. Rectangular cleats rather than triangular corner strips are used. The square stock is crosscut after drying into cleats, then mitre cut on a machine with two circular sawblades inclined at 45°.

Drying

Unlike light oblong packing cases, whose elements do not need to be dried during manufacture, the elements for wirebound cases must be dried. All attempts to make wirebound cases with green wood have been unsuccessful, especially because of the considerable risk of attack by destructive fungi when wirebound cases made from green wood are stored flat.

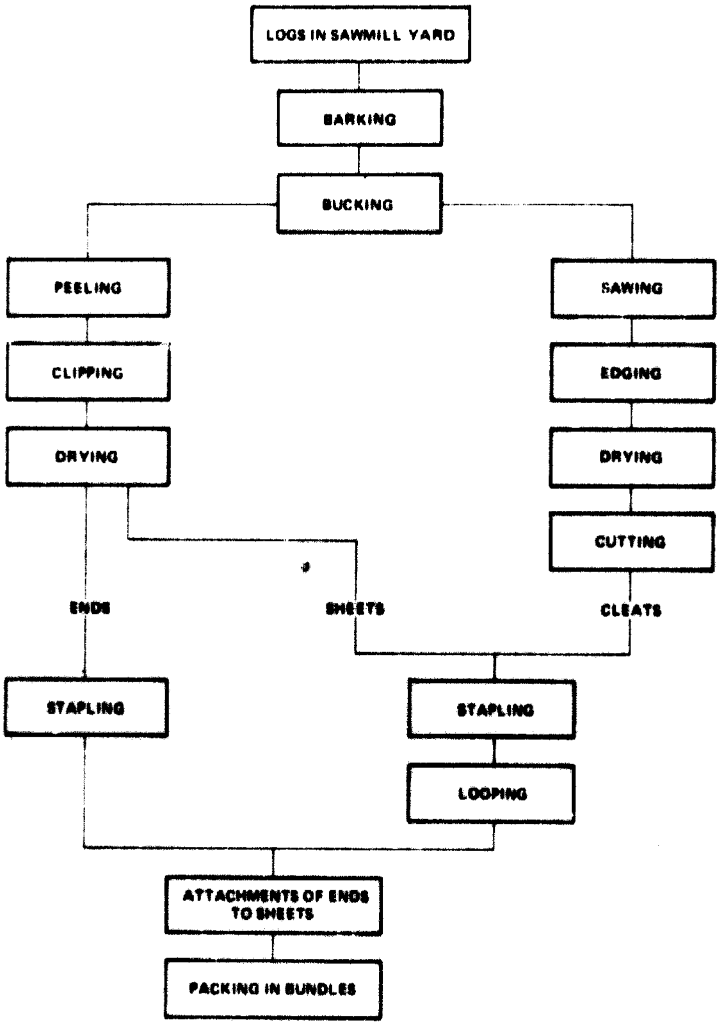

Figure 34. Manufacturing process for wirebound cases

The peeled elements, either in their final dimensions or in dimensions that are multiples of the final dimensions, are dried in roller dryers. Such dryers, which can operate 24 hours a day, cost approximately $30,000 each. The square stock for the cleats is either air-dried or dried in progressive or compartment kilns.

Manufacture

The "sheets", which consist of sides, top and bottom panels connected together by wires, are made on two successive, synchronized machines. The first machine is a multiple-head, variable-pitch stapling machine that operates with continuous advance of the wooden elements. The cleats and shooks are placed in the jigs either by hand or automatically from magazines. The reinforcing wires are fed continuously from reels holding 500–1,000 kg of wire. The wooden shooks and the wires pass together under stapling heads, which simultaneously staple the frame wires and the shooks to the cleats; intermediate wires are stapled to the boards. Successive cases are joined together by the reinforcing wires, with a section of wire left between each case just long enough to make the loops at the ends of the two cases. The stapling machine is capable of inserting staples at predetermined positions, regardless of the pitch of the successive movements and can operate at a speed of 500 strokes per minute.

From the stapling machine the sheet passes into the second machine, which operates intermittently. To synchronize the operation of the two machines, one of which is continuous and the other intermittent, a device called a "monkey's tail" is installed between the two machines. When the space containing only the wires for the loops arrives in the second machine, the sheet stops and is locked in position. Here the wires are cut by shears, mandrels shape the loops and clinch the ends of the wires into the boards, and the sheet then moves forward. This machine has two sets of mandrels whose number corresponds to the number of wires. The two sets of mandrels are different from one row to the other because they must form different loops.

The ends of the cases are manufactured on identical machines. The ends and the sheet can be manufactured in double or even triple widths by using boards that are twice or three times as long as a case. Such sheets are then cut into two or three strips by longitudinal circular saws placed after the stapling machine.

On leaving the second machine, the ends are placed by hand on the sheet and fixed down on one side only by bending over one of the end loops. The flat cases are then placed in bundles and are strapped together.

When manufacturing a single-width sheet, a wirebound case machine can produce between 4,000 and 6,000 cases, such as citrus fruit cases, per day, or twice as many when producing a double-width sheet. Such a machine costs approximately $50,000.

Efficient utilization of raw materials

As indicated earlier in this study, it is possible to select from the available species of wood those that are most suitable for the use to which they will be put. Even in countries rich in timber resources, however, wood should be used efficiently, and the highest possible yield should be sought.

While species of wood can be selected in the light of their inherent qualities, the fact remains that the trees in the forest are of various sizes and qualities. It is therefore usually necessary to take account of all the possible uses for a given tree and its various parts, such as the butt log, the upper logs, sawing billets and industrial-grade billets. High-quality wood and wood in large sizes and industrial-grade billets can be used more advantageously in industries other than the packaging industry.

Proper utilization of raw materials entails sorting of logs before they are sent to the sawmill. Logs should be sorted carefully to remove those that are of superior grade or too large for packing-case wood as well as those that are of poor quality or too small in diameter. As the packaging industry requires logs only 0.20–0.80 m in diameter, of medium quality, and in fairly short lengths, it is wasteful to use wood 5 m long to make pallet parts only 1.20 m long.

The utilization of the raw materials can be improved by recovering the maximum amount of sawmill waste (scabs, edgings and offcuts), but the point comes where the cost of the labour engaged in the recovery operations amounts to more than the value of the wood recovered. The utilization of raw materials can also be improved by more accurate sawing, for, as pointed out earlier, it is possible to save over 10% of the volume of wood by using accurate and well-maintained machines.

Efficient utilization of raw materials depends on the cutting process used. The yields per cubic metre of log vary considerably depending on whether the wood is cut by sawing, slicing or peeling. Comparative studies indicate the importance of selecting the appropriate method of cutting.

Table 4 gives comparative yield indices with sawing taken as index 100. The calculations take into account the usually slightly higher cost of wood used for peeling rather than for sawing, the yield of final product, the labour and the depreciation.

TABLE 4. COMPARATIVE YIELDS FOR VARIOUS METHODS OF CUTTING

Method of cutting	*Index of cost of 1 m³ of logs*	*Yield = m³ of final product / m³ of logs*	*Index of cost of 1 m³ of final product*
Sawing	100	42%	100
Slicing	100	52%	68
Peeling on 1.20/1.40 m machine	133	60%	65
Peeling on 0.60/0.80 m machine	100	72%	55

Although this comparison is valid only for cutting wood thinner than 6 mm or possibly 8 mm by sawing, slicing or peeling on 1.20/1.40 m machines, it shows, nevertheless, the advantages of slicing and peeling. In many instances it would be profitable to design packing cases that cannot be made of wood thinner than 6 mm.

It should be noted that, according to the yields shown in the table above, to obtain 1 m^3 of final product it is necessary to use 2.4 m^3 of logs when the sawing process is used; 1.9 m^3 of logs when they are to be sliced; 1.67 m^3 of logs when the logs are peeled on a machine with a working width of 1.20–1.40 m; and 1.4 m^3 of logs when the wood is peeled on a machine with a working width of 0.60–0.80 m.

It is not possible, however, to make packing cases solely from peeled wood, and whatever the method of cutting, there will always be considerable waste. The yield of a mill that cuts wood only by sawing is approximately 40%, leaving as waste 60% of the total volume of logs processed. The yield of a light packing-case factory using a peeling lathe with a working width of 0.60–0.80 m is approximately 65%, leaving 35% waste. A medium-sized factory cutting 20 m^3 of logs per day produces

7–12 m^3 of waste, or 1,750–3,000 m^3 of wood waste per year. For a larger factory using 100 m^3 of logs per day, the volume of waste is 9,000–15,000 m^3 per year, which is almost equivalent to the output of a small particle board production line. It should be noted, however, that not all wood waste can as yet be used to manufacture particle board.

Vertical and horizontal integration

The vertical or horizontal integration of production raises many problems that can be solved only after studies in great depth have been made that take account of numerous parameters, such as the quantity and quality of the wood available in a given area, the labour situation, the facilities for setting up a plant, the location and needs of customers, and the financial resources required.

Vertical integration

A vertically integrated enterprise manufacturing packing cases purchases the timber in the forest, conducts the manufacturing processes in one place and sells the finished cases. At first sight, vertical integration seems desirable, as it should make possible better organization of the enterprise, permit more opportunities for mechanization and eliminate the middleman. It does, however, imply the selection of a given location for the factory.

To avoid transporting logs over long distances, a factory must be built close to the place where the timber is felled. However, although the cost of transporting logs may be high, the cost of transporting empty finished cases, with the exception of wirebound cases, pallets and nesting cases, may be even higher because of the great volume of empty wooden packing cases. The factory must therefore be located in an area that uses cases. If these two conditions can be met, then vertical integration is feasible. If the contrary is the case, there are no grounds for considering such integration desirable; but if such integration is decided upon, then only a factory producing wirebound cases, pallets or nesting packing cases could be situated in a lumbering area, for a factory producing light oblong cases or other packing cases must be located near its customers.

An effective solution for producing light oblong packing cases is to establish two separate manufacturing units. In the first unit, which should be located in the forest area, the logs are sawn and made into panels. As light packing cases are primarily designed for perishable agricultural products, they can be standardized quite easily. It is therefore possible to envisage quite large sawmills manufacturing panels (bottoms, sides and ends), which would be dried and then sent to the area of use, where they would be assembled in special factories whose size would depend on the amount of goods to be packed. Standardized, mass-produced nailed sawnwood cases could be manufactured in this way. For many types of nailed cases, however, which are manufactured in small or medium-sized series and used to transport industrial goods, the manufacture of the panels at a point distant from the place of assembly would involve great difficulties, in particular lengthy delays in supply. This type of packing case generally must be delivered promptly. There would also be a risk of error in the dimensions. It is therefore preferable to cut up the wood accurately into a number of standard sizes in the forest area (provided that the quality of sawing is properly observed), dry the wood, and then manufacture the cases in workshops, substantially stocked with sawnwood and located in areas where the cases are used.

This system reduces substantially the transport cost of the product from the forest to the area of consumption. It also permits separate sawing units and assembly units of different capacities to be established, whereas in a single factory it is necessary to establish shops of related capacities. Large mechanized sawmills or cutting shops can thus be created while assembly workshops can be of a capacity required by local needs. On the other hand, the disadvantages of the system are that it requires preliminary drying of wood for light packing cases as well as double storage of the wood for the cases and complicates commercial relationships.

The integration of logging activities into a production line means that wood of many different qualities and dimensions is supplied, which results in poor utilization of raw materials.

Horizontal integration

Good utilization of the raw materials requires that each log or part of a log be assigned to the use for which it is best suited. The packaging industry, for example, requires logs of only medium diameter and medium qualities. The allocation of logs can be carried out at the logging depot, but the allocation of the various parts of individual logs can be carried out only at the sawmill in accordance with actual needs.

Many tropical forests contain many different species, which should be allocated for use in the light of their particular properties. Sorting, therefore, should be carried out at some point to ensure the best possible utilization of the wood. Logs intended for peeling, for example, should be allocated, depending on their quality and diameter, either for the manufacture of plywood or for the manufacture of packing cases. Frequently, the sorting of logs for sawnwood can be carried out only after the first sawing, so that it is necessary to set up a sawmill that can supply various industries, such as the furniture industry, joinery and the packaging industry.

The packaging industry, like most wood-processing industries, produces large quantities of wood waste. Some types of this waste can be used for the manufacture of particle board, others for fibreboard, and others for making paper; other types of waste are not suitable for any industrial purpose at the present level of technology. To recover wood waste, a certain amount of sorting is necessary, and frequently small units find that such work is difficult and of doubtful profitability.

The cost of transporting wood waste over long distances usually makes the recovery of such material uneconomic. Frequently, wood waste must be delivered in a form, such as chips or flakes, specified by the user and must, therefore, be processed before delivery. The installation and operation of chippers is feasible only when the amount of waste produced attains a certain level. Countries rich in timber resources are usually not interested in the recovery of wood waste nor to obtain better yields. It should be remembered, however, that the Food and Agriculture Organization (FAO) has pointed out that the medium-term prospects for the world supply of wood are not particularly favourable. Even in timber-rich countries in tropical regions there is, on the one hand, underutilization of forests through failure to exploit a considerable part of them, while, on the other hand, there is over-cutting and exhaustion of some forests that are being exploited. Plans should be made for recovering the wood waste produced by certain timber industries for use as raw material by other industries.

To secure better utilization of raw materials and to establish units of the optimal technological level, it is desirable to envisage the horizontal integration of complementary industries plus a system of vertical integration. This system of double integration may take the form of combines, which may, however, be cumbersome to manage and may be too large for developing countries, or it may take the more flexible form of the establishment of complementary enterprises in a limited area.

The integration of a packaging factory into a combine raises difficulties because of the difference in size of such a factory compared with, for example, a fibreboard or particle board factory. Moreover, the levels of investment required and the technical and commercial problems encountered by these industries are of a different order of magnitude. While it is desirable to assemble complementary activities, it is not desirable that one should be considered a subactivity producing a subproduct considered a "poor relation" for which no technical or commercial research effort is expended and no improvement of productivity or equipment is envisaged.

Economies of scale

Economies of scale can be financial, commercial or technical.

From the point of view of finance and management, it seems that a concentration of capital and possibly centres of general decision making are needed in the world of today. Centralization of secondary decision making at the level of the centres themselves, however, should be avoided. Certain decisions, such as those concerning standardization or forestry policy, can be taken only at a very high level.

From the commercial point of view, the size of a production unit is based on the quantity of the product consumed locally and on the possibilities of delivery to markets within a given area. The link between the production capacity and the capacity of the market to absorb wooden packing cases raises on the one hand the question of which type of case to produce (light cases, wirebound cases, board boxes), and on the other hand the question of vertical integration.

Research must be carried out even for a sector like that of the wooden packaging industry; the research must cover, *inter alia*, models and designs of cases to be manufactured, machinery required, organization of the workplaces, general organization of the enterprises and handling and over-all productivity. Through astute management, a small firm can increase its productivity, but the saving it would derive from devoting even a sizable part of its budget to research would be negligible compared with the cost involved. It is essential, therefore, that small and medium-sized enterprises in any given sector combine their research efforts for mutual benefit.

From the technical point of view, it is hard to speak of economies of scale except in respect of the manufacture of wirebound cases. In the manufacture of wooden cases factors vary, and a very small artisan-type enterprise can grow imperceptibly into a large enterprise.

To manufacture corrugated board, a corrugating machine is required that costs approximately $1 million and has a production capacity of 2,500 tons per month; for larger production, a second machine is needed. The investment for the production of wooden packing cases is far less. An assembly workshop for light packing cases can be set up with only two single-head stapling machines for the frames and bottoms and involves an investment of only about $2,500. For example, one set of machines has a production capacity of 2,000 apple boxes per day; two sets 4,000; and so on. The same applies to investments for the production of panels. It is possible to produce 6,000 panels per day with one multiple-head, intermittent-advance stapling machine costing $3,000; 12,000 panels with two such machines; 24,000 panels with three machines ($9,000); and 40,000–50,000 with three continuous-advance machines ($20,000). The production of cases and pallets can also be increased by small gradual steps. Thus, by increasing the number of machines, production can be increased in a manner that can be considered almost continuous.

In reality, the optimum production level for a production unit is determined by the balance that can be achieved between the subdivisions of the unit, such as cutting, panel-making and assembly. Frequently, it is only one machine that creates a bottleneck, and often that machine is the one that has cost the most, such as the peeling lathe in the manufacture of light packing cases or the log band saw in the manufacture of other cases. Balance between the subdivisions of a production unit can sometimes be achieved by procuring elements from the outside, such as square stock for cleats or shooks for light packing cases. Sometimes an increase in the operation of one subdivision over the others can also prevent a production delay. To prevent a bottleneck in peeling, for example, it may be preferable to operate the peeling shop for ten hours a day instead of eight than to purchase an additional peeling lathe.

Frequently, at certain levels of production a decision must be made whether to increase the number of machines in operation or to choose more highly automated machines. The same applies to the decision whether to mechanize a factory. For example, it must be decided whether it is better at a particular level of production to have two log band saws or a single saw with mechanized handling facilities; whether to increase the number of nailing machines needed to manufacture pallets or to adopt an automatic production line; or whether, in the manufacture of light packing cases, to have 8 assembly units capable of producing 16,000 apple boxes per day, involving an investment of $20,000 and requiring 16 workers directly concerned with the assembly, or 8 stapling machines for the frames and an automatic machine for making bottoms that would require an investment of $30,000 for the same production capacity but would require only 9 workers.

The last example shows that the level of production of a unit, from a technical point of view, depends on the profitability of the investment in machinery and mechanization compared with the cost of labour. It may be that the purchase of an automatic machine for making bottoms would prove to be less advantageous than the continued use of sets of individual stapling machines. In this event, to reduce the cost of transporting empty assembled packing cases, several workshops could be so located that each unit would serve an area with a radius of perhaps 15 km rather than establishing a single unit that would be obliged to serve an area with a radius of 50 km.

In general, increasing the scale of a unit leads to an increase in the absolute value of the investment required, a slight reduction in the relative cost per unit produced, and a substantial reduction in the relative labour costs. There are, however, certain optimum levels of economies of scale. This study will attempt to identify them for only the following. pallets, light packing cases (taking apple boxes of 15 kg capacity as the standard product) and wirebound cases (taking citrus fruit cases of 20 kg capacity as the standard product). For each product the production unit in question will be assumed to be an integrated unit covering the entire production process from the log to the finished product.

Pallets

The optimum level of production of pallets depends essentially on the type of head machine used, i.e. the log band saw. As this machine determines the volume of logs that can be sawn, the other machines must be adapted to the output of this machine. The following types of head machine can be used: a light log band saw capable of sawing 10 m^3 of logs per day; a modern log band saw capable of sawing 20 m^3 of logs per day; a modern log band saw and mechanized sawmill equipment capable of sawing 35 m^3 of logs per day.

A further alternative that should be considered is an installation equipped with an automatic nailing line. As it is estimated that a pallet requires 0.1 m^3 of roundwood, the daily production of units equipped with the log band saws mentioned above will be 100, 200 and 350 pallets, respectively; a unit equipped with an automatic nailing line will produce 1,500 pallets daily.

Depending on the number of pallets manufactured per day, the equipment required is as follows:

50 pallets: light log band saw, resaw, chain crosscut saw, light edging saw, spindle moulding machine, boring machine, portable nailing machine;

100 pallets: same equipment;

200 pallets: modern log band saw, resaw, multi-blade crosscut saw, multi-blade edging saw, spindle moulder, boring machine, two portable nailing machines;

300 pallets: mechanized sawmill, stationary nailing machines;

1,500 pallets: mechanized sawmill, automatic nailing line.

Table 5 gives an approximation of the investment required for the equipment directly involved in the production process and the minimum number of workers required.

TABLE 5. INVESTMENT AND LABOUR REQUIRED FOR THE PRODUCTION OF PALLETS

Output per day	*Logs required (m^3(r))*	*Investment (dollars)*	*Investment per pallet produced daily (dollars)*	*Minimum number of workers*	*Output per worker*
50	5	20,000	400	10	5
100	10	20,000	200	15	6.7
200	20	35,000	175	20	10
350	35	60,000	170	25	14
1,500	150	240,000	160	40	37.5

The above table shows that the minimum production for a vertically integrated unit should be approximately 100 pallets per day, which should correspond to a minimum log-processing capacity of 10 m^3 per day. The table also shows that the level of investment per production unit diminishes by 20% from 100 to 1,500 pallets per day, while the labour productivity increases by a factor of almost 6 from 100 to 1,500 pallets per day.

Light packing cases (apple boxes)

The level of production of light packing cases is determined by the production capacities of several types of machines, especially the peeling lathe and the multiple-head stapling machines. Every effort must be made to arrive at a suitable balance among these production capacities.

The minimum size of the sawing unit is determined by the head saw, which must be at least a saw with a hand-fed carriage. Starting from the basis of the production capacity of the peeling lathe, and determining the number of various other machines with the output of the peeling lathe, the following levels of daily production, requiring the following equipment, can be arrived at:

2,000 apple boxes per day: peeling lathe of 0.80 m diameter; saw with a hand-fed carriage; two multiple-head, intermittent-advance stapling machines; cleat-making machine; 1 assembly unit;

4,000 apple boxes per day: barking machine; peeling lathe of 0.80 m diameter; saw with a hand-fed carriage; 3 multiple-head, intermittent-advance stapling machines; cleat-making machine; 2 assembly units;

8,000 apple boxes per day: barking machine; peeling lathe of 1.40 m diameter; saw with a hand-fed carriage; 1 multiple-head, intermittent-advance stapling machine; 2 multiple-head, continuous-advance stapling machines (one for the ends); 4 assembly units;

12,000 apple boxes per day: barking machine; peeling lathes of 1.40 m and 0.80 m diameter; log band saw; 5 multiple-head, continuous-advance stapling machines (two for the ends); 6 assembly units;

16,000 apple boxes per day: barking machine; one peeling lathe of 1.40 m diameter; two peeling lathes of 0.80 m diameter; log band saw; 6 multiple-head stapling machines (two for the ends); 8 framing machines; 1 automatic machine for making bottoms.

Table 6 gives the investment and the number of production workers required for the production of light packing cases. It shows that the level of investment per unit of product manufactured remains practically constant from a production level of approximately 20 m^3 of logs per day (about 1 million cases per year) onwards, but that the labour productivity, in contrast, increases as a function of the scale of production. An output of 2,000 cases per day indicates poor utilization of equipment and labour; 4,000 cases per day permits good utilization of labour if multiple-head, intermittent-advance stapling machines are used; with 8,000 cases per day the labour productivity is increased by the use of multiple-head, continuous-advance stapling machines; but an output of 12,000 cases per day, in contrast, brings with it practically no improvement. Finally, an output of 16,000 cases per day permits the effective use of an automatic machine for making bottoms.

TABLE 6. INVESTMENT AND LABOUR REQUIRED FOR THE PRODUCTION OF LIGHT PACKING CASES

Output per day	*Wood required (m³)*		*Investment (dollars)*	*Investment per case produced daily (dollars)*	*Minimum number of workers*	*Output per worker*
	Peeling	*Sawing*				
2,000	6	2.5	37,000	18.5	20	100
4,000	12	5	50,000	12.5	30	133
8,000	24	10	76,000	9.5	50	160
12,000	36	15	120,000	10	70	170
16,000	48	20	160,000	10	80	200

For vertically integrated units producing light packing cases, three levels of production have been found advantageous: those corresponding to a daily log-processing capacity of 15–20 m^3, 30–40 m^3, and 70 m^3, respectively. It should be noted, in contrast, that if the processes of panel manufacture and assembly are separated, the units producing the panels will be subject to the above levels, whereas for the assembly workshops there will be only two levels: that corresponding to the smallest level (2,000 cases per day) and that corresponding to the highest level involving use of an automatic machine for making bottoms (16,000 cases per day).

Wirebound cases

The volume of production of wirebound cases is determined by the sheet-manufacturing machine; all other equipment must be adapted to its output. As the smallest viable unit for the manufacture of wirebound cases comprises a machine producing a single sheet, three production possibilities are considered below: production unit with one single-sheet machine; production unit with one double-sheet machine; and production unit with three double-sheet machines. The calculations are based on the production of citrus fruit boxes of a capacity of 20 kg each representing a consumption of 4.2 dm^3 of logs for peeling and 1.8 dm^3 of logs for sawing:

(a) A single-sheet machine produces 5,000 cases per day and requires a barking machine, a 1.40 m peeling lathe, a dryer and a saw with a hand-fed carriage.

(b) A double-sheet machine produces 10,000 cases per day and requires a barking machine, two peeling lathes, two dryers and a log band saw.

(c) Three double-sheet machines produce 30,000 cases per day and require a barking machine, 5 peeling lathes, 6 dryers and a mechanized sawmill.

Table 7 gives approximate details of the investment required and the number of workers employed for each of the three production units.

TABLE 7. INVESTMENT AND LABOUR REQUIRED FOR THE PRODUCTION OF WIREBOUND CASES

Production unit	*Output per day*	*Logs required (m^3)*		*Investment (dollars)*	*Investment per wirebound case produced daily (dollars)*	*Minimum number of workers*	*Output per worker*
		Peeling	*Sawing*				
One single-sheet machine	5,000	21	9	120,000	24	30	167
One double-sheet machine	10,000	42	18	175,000	17.5	50	200
Three double-sheet machines	30,000	126	54	500,000	16.5	125	240

The above table shows that it is advantageous to manufacture double sheets whenever possible. The minimum production unit for wirebound cases should have a capacity of approximately 30 m^3 of logs per day, representing an output of 1–1.2 million cases (similar to those used for citrus fruits) per year, but a unit with a capacity of 2–2.4 million cases is preferable. Still larger units increase labour productivity through higher mechanization, but they can be envisaged only when the savings on labour are greater than the cost of mechanization.

The foregoing discussion of the problems of vertical and horizontal integration and economies of scale indicates that the final decision regarding the location and the size of production units must take account of the following factors:

(a) The geographical relation between the forest and the areas of consumption. This relation ceases to be important, however, for pallets, wirebound cases and, in general, all packing containers delivered flat or nested within one another.

(b) The level of consumption in the area under consideration. This area will be correspondingly small for oblong, rigid packing cases and much larger for other types of cases.

(c) The minimum economic manufacturing unit, depending on the technical possibilities of the various machines.

(d) The relationship between the total amount of investment and the production capacity on the one hand and the labour costs, specialization and production capacity on the other hand.

(e) Whether certain types of machines can be obtained in a country or whether they must be imported. Importation can involve monetary problems connected with foreign exchange, which may make it necessary to adopt solutions that do not appear to be well founded from a technical point of view but that are necessary for economic considerations of a very different nature.

(f) Problems of employment. In some countries it may be expedient to employ a maximum labour force rather than the minimum required. Although the adoption of such a solution may not seem to contribute towards the industrial development of the country, it may be necessary for sociological reasons.

It should be remembered, finally, that different levels of production may be justified, depending on whether they are viewed from a financial, commercial, research or production point of view.

Chapter 6

INTERNATIONAL REGULATIONS, INTERNATIONAL ACTIVITIES AND DOCUMENTATION

International regulations

Transport and handling are the subject of a great many national regulations. Few international regulations governing these matters exist, and those that do concern only transport and have merely the force of recommendations. Such regulations are binding only in countries that formally agree to make them applicable in their own territory.

Ordinary goods

Rail transport

International rail transport is subject to the Berne Convention, known as the CIM Convention (International Convention concerning the carriage of goods by rail), which was concluded on 25 February 1961 and came into effect on 1 January 1965, with 37 signatories.

This convention deals with the transport contract, the execution of and modifications to this contract, responsibility, administrative claims, legal action, procedure and regulations. The subject of packaging is dealt with only in article 12, which merely states that when goods are of such a nature as to require a packing case, the sender must pack them in such a way that they are protected from total or partial loss or damage during transport and cannot cause damage to persons, equipment or other goods. The packing case must conform with the tariff specifications and regulations of the railway on which the goods are dispatched.

Road transport

Road transport is dealt with in the Geneva Convention which was signed on 19 May 1956 and came into force on 2 July 1961. This convention does not consider the problems of packaging. The title, "Convention on the contract for the international carriage of goods by road", is generally designated by the initials CMR.

River transport

River transport is not covered by any international convention.

Air transport

Air transport is covered by the Warsaw Convention of 12 October 1929.

Sea transport

Sea transport is the subject of the Brussels Convention of 25 April 1924. Like the preceding conventions, the Brussels Convention does not deal at any length with packaging problems. It simply states, in subparagraph 2 of article 4, that neither the transport company nor the vessel owners shall be responsible for any loss or damage resulting from or caused by inadequate packing.

Because of the reservations that shipping companies enter on their bills of lading in order to free themselves from responsibility for damage resulting from inadequate packing, the damage to goods transported by ships, as well as by other means of transport, is frequently grounds for dispute between the various parties to the transport operation—the shipper, the forwarding company, the shipping companies and the receiver. However, the situation is a complicated one for the sender, as there are no specific packaging regulations for shipments transported by sea, land or air except for goods that are dangerous. An empirical evaluation must be made in each case to decide whether the packing case was adequate to protect the goods against the risks inherent in the form of transport envisaged. In this connexion, normal commercial practice is a valid criterion, and thus a transporter cannot claim inadequacy of packaging as grounds for rejecting a damage claim when it can be established that the packaging was in conformity with normal commercial usage. This usage, however, may vary from one country to another.

Dangerous goods

The conditions of transport and packaging for dangerous goods are covered in four sets of regulations, one for road transport, known as the regulations of 15 April 1945; one for rail transport, known as the RID regulations (Règlement international concernant le transport des marchandises dangereuses); one for sea transport; and one for air transport (the regulations of the International Air Transport Association (IATA)). These regulations are amended regularly to take account of new developments in transport and packaging methods. They include a classification of goods and specify the type of packaging to be used for each product, the general characteristics of the packing case and its total permissible gross weight as well as certain strength tests that vary from regulation to regulation.

The expert committee on the transport of dangerous goods of the United Nations Economic and Social Council has undertaken a study of recommendations on the packaging of dangerous goods that would be applicable to all forms of transport.

Perishable goods

The packaging of fruits and vegetables has been the subject of long discussions in ECE, and its Inland Transport Committee adopted on 19 January 1967 resolution 203 on "The standardization of wooden packaging for fruits and vegetables used in international transport and trade".

International activities and documentation

Apart from the foregoing international regulations, international work on packaging is carried on by the International Organization for Standardization (ISO) through its various technical committees.

ISO–Technical Committee 51 is studying the problems of standardization of pallets and has published the following recommendations:[6]

- R 198: Double-deck flat pallets for through transit of goods;
- R 329: Large pallets for through transit of goods;
- R 509: Standard dimensions of pallet trucks;
- R 445: Vocabulary of terms relating to pallets.

ISO–Technical Committee 104 (freight containers) has published the following recommendations:

- R 668: Dimensions and maximum gross weight of freight containers;
- R 790: Marking of freight containers, series 1 and 2;
- R 830: Terminology relating to freight containers.

ISO–Technical Committee 104 has adopted the following drafts:

- DR 1019: Specification of corner fittings for series 1 freight containers: 1A, 1B, 1C and 1D;
- DR 1496: Specifications and testing of series 1 freight containers;
- DR 1497: Specifications and testing of series 2 freight containers.

ISO–Technical Committee 122 (packing cases) was set up too recently to have been able to issue any recommendations. Subcommittee 1 of this Technical Committee is studying the problems of the dimensions of packing cases. Subcommittee 3 has adopted drafts on methods for tests for compression, free fall, vibration, horizontal shocks and inner wrappings. It is at present studying programmes of tests designed to reproduce in the laboratory the stresses to which packing cases are subjected during transport.

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[6] These documents can be obtained from national standardization organizations or from the Central Secretariat of ISO, 1, rue de Varembé, 1211 Geneva 20, Switzerland.

Documentation

From the point of view of documentation proper, there are no international publications apart from those referred to above. However, studies, research results and specifications have been published in many countries. Unfortunately, not even a partial list of these is available, although such a list would make it possible to avoid duplicating studies that have already been carried out.

All that can be done at present is to indicate the main sources of documentation, which are of two types: national standardization organizations; and laboratories or research centres,[7] in particular the Forest Products Laboratory at Madison, Wisconsin, USA; the Kaluga Laboratory in the USSR; the Virginia Polytechnic Institute in Blacksburg, Virginia, USA; and the Centre Technique du Bois, Paris, France.

[7] See list of research laboratories in the annex.

Chapter 7

TRENDS IN THE USE OF WOOD FOR PACKAGING IN DEVELOPING COUNTRIES

The long-term evolution of the use of wood for packaging in the developing countries is linked with the present level of development and the general evolution of these countries. A realistic policy in packaging matters will assist the development of a country, and, conversely, the development of a country will bring about an expansion of the market for packing cases. Other factors enter into the evolution of the use of wood for packaging, however, one of the most important of which is the availability of raw materials in the form of forests that are already being exploited. Second, the climate can be of great importance. Corrugated board boxes are sensitive to dampness and consequently will become popular less quickly in countries with a humid tropical climate than in countries with a dry climate. Thus, wooden packing cases will compete better with corrugated board packing cases in certain countries. Finally, the evolution of the use of wooden packing cases will be linked with the form and direction of national development. The development of agriculture in a country will be more favourable to the use of wood for packing cases than the development of the manufacturing industry. It is difficult to define a general line of evolution of the use of wooden packing cases without taking these different factors into account and without having an accurate knowledge of the evolution of each individual country concerned, which would necessitate a country-by-country economic study.

Economic factors affecting evolution

The economic development of a country brings about increased production; greater consumption; more trade; and increased labour costs, leading to the mechanization of manufacturing and handling processes. On the basis of these considerations the evolution of the use of wooden packing cases in the light of their design and of the manufacturing processes available is outlined in the following pages.

The introduction of mechanization results in an increase in the average weight of a load unit, which can be dealt with basically by two means: palletization and containerization.

Palletization will certainly be the first method to be used, as it requires only a moderate investment and can be carried out initially by single enterprises. Palletization permits the handling of load units of the order of one cubic metre or one ton, which correspond to certain definite marketing possibilities, for the marketing units used depend on the size of the market; a large market makes it possible to use large marketing units.

When a country has reached the stage of development at which palletization itself represents a new factor in development, it will be used more generally. A considerable reduction in the stress caused by falls may then be expected because palletization eliminates many handling operations. Falls caused by faulty use of pallets, however, must be considered accidents. Palletization does not reduce stresses caused by vibration during transport; these stresses may be reduced by improving the road network and the vehicles used for transport. Palletization, however, leads to an increase in stacking heights and thus to an increase in compressive stress; packing cases can be made lighter, but they must also be made stronger at the same time. This may seem contradictory, but what it really means is that sawnwood cases will be replaced by cases that stand up well to compression, such as plywood and wirebound cases.

Containerization, which is still in its initial stage, is expected to develop greatly in the trade among the industrialized countries and then extend gradually to the whole of world trade, country by country as each country develops. However, large investments are required for containerization, and marketing units must be between 15 and 30 tons. In general, packing cases are still needed with containerization. The use of containers virtually eliminates stacking stress and stress caused by falls, together with certain climatic stresses such as exposure to sunshine or rain. Stresses caused by vibration remain, however, and the stresses caused by side shocks during handling will increase. Since the use of containers brings about a substantial loss of useful volume in ships, packing cases placed in containers should have the highest possible ratio of useful volume to over-all volume. Containerization will result in a decline in the use of sawnwood cases and an increase in the use of plywood cases (especially those with metal stays), wirebound cases, corrugated board boxes and other packaging techniques such as shrinkable plastic.

Rising labour costs lead manufacturers to increase the mechanization of operations and to manufacture only those types of packing cases that require the smallest labour component or those whose labour content can be reduced. The higher the cost of labour in the total cost of a packing case, the more vulnerable that type of case is to replacement by a more favourable type. Sawnwood cases require a great deal of labour, and the possibilities for mechanizing their manufacture are relatively small. A large part of the cost of plywood cases, however, is the cost of the plywood itself, and their manufacture can be mechanized. Metal-framed plywood cases manufactured on a production line are more easily produced than battened cases.

Although a certain degree of mechanization in the manufacture of light packing cases has been achieved, a higher level of automation in their production is being attempted. A satisfactory degree of mechanization has been achieved in the manufacture of wirebound cases, but, like light packing cases, it will never be equal to the level possible in the manufacture of corrugated board boxes or cases made of moulded plastics such as expanded polystyrene.

A rise in the standard of living brings about an increasingly high consumption of goods, and the production of packing cases increases even more rapidly than consumption. Mass production works to the advantage of large units capable of supplying the market requirements, and these units lend themselves better to mechanization and a higher degree of automation than small units. This phenomenon will therefore strengthen the tendency to mechanization referred to above and will favour certain types of packing cases over others.

As the *per capita* gross domestic product increases the use of one-way packing cases grows at the expense of reusable cases. Thus, it becomes necessary to produce increasingly light packing cases at lower and lower prices in larger and larger quantities. Sawnwood cases can be made lighter, as recent studies have shown; but even when they have been lightened to the maximum, they cannot possibly achieve the lightness and low price needed to keep them competitive with corrugated board boxes. Plywood cases, particularly those with metal frames, can be competitive with corrugated board boxes from the point of view of weight, but they will always be more expensive to produce. When production conditions are favourable, the weight of light packing cases and wirebound cases can be kept down to about the weight of corrugated board boxes. The cost of light packing cases is likely to remain competitive with that of corrugated board boxes for a long period, while that of wirebound cases will be higher.

Technical factors affecting evolution

Some idea of the evolution of wooden packing cases and of the structure of the units that produce them can be gained from the rapid analysis of the consequences of the increase in the *per capita* gross domestic product referred to above; but before any conclusions are drawn it is necessary to take into account a number of technical problems that also have a strong influence on the evolution of wooden packing cases and their position with respect to packing cases made from other materials.

A rise in the standard of living brings about not only the mass production of articles for mass consumption, but also an increase in consumption of articles for specialized uses, such as machine tools. Thus, it is necessary to undertake not only the mass production of standardized packing cases, but also the production of made-to-measure packing cases for special purposes. Production of made-to-measure packing cases or cases produced in only small runs may not be feasible in large production units using high-output machinery, and it may be necessary to maintain, side by side with these large units, small units capable of doing this specialized work. The branch of the packing case industry producing wooden cases, especially nailed wooden cases and battened plywood cases, can be much more easily adapted to made-to-measure work than the branch producing corrugated board boxes or, still more so, moulded plastic cases.

Regardless of their type, packing cases must be able to stand up to the stresses of transport. For one-way transport of goods on the home market, double-layer or triple-layer corrugated board boxes are generally strong enough (although their strength depends on their quality), but they can be used only for the transport of goods weighing up to about 60 kg or of unit products such as household appliances, cooking stoves and refrigerators, fixed on a wooden base. As soon as the level of development required for the adoption of one-way packing cases is reached, corrugated board boxes will take over a very large part of the packaging sector, but wooden cases will still be used for products weighing over 60 kg.

Sea transport causes stresses both transport stresses proper and handling stresses – that are much more severe than those encountered during land transport. In sea transport, there are more and rougher handling operations, the heights of the holds are greater than those of vehicles used on land, and the movements of the ship give rise to stresses that are much more severe than those produced by railway wagons or trucks. For this type of transport, therefore, wooden packing cases (especially sawnwood cases, plywood cases and wirebound cases) remain preferable to corrugated board boxes.

As the cost of sea transport is based on volume, plywood cases and wirebound cases are preferable to sawnwood cases because of their greater useful volume. Wooden cases, however, may one day experience competition from triple-layer corrugated board boxes when the production of these boxes, which have been introduced only recently in the industrialized countries, is fully developed for sea transport. This type of box could be used instead of wooden boxes to transport by sea products for which the double-layer corrugated boxes are used for internal transport.

In addition to the mechanical stresses that packing cases are exposed to during transport, they are also subjected to climatic stresses such as rain, cold, heat or moisture. Corrugated board boxes are sensitive to moisture; if they are exposed to rain or even to dampness their resistance is greatly reduced. Thus, they must be protected from rain and humidity. Protection from rain is often possible, but protection from humidity is practically impossible. In humid tropical countries corrugated board boxes will face technical difficulties, so their use in these countries will be limited unless they have been given a special protective treatment, which increases their price substantially. Plastic cases now on the market are sensitive to cold, which makes them brittle, and to heat, which makes them soft and causes them to lose much of their resistance to compression; their use in tropical areas will therefore be very limited. Climatic stresses, which act over and above mechanical stresses, limit the development of certain types of packing cases, which, on purely economic grounds, would replace wooden packing cases.

Besides being able to stand up to the stresses of transport, packing cases must also be adapted to the products that they transport. The fragility of the products will not greatly influence the type of packing case used, since the products can be easily protected against shock by internal packing and protected from external moisture by some form of barrier (foil). Many products, however, especially perishable goods such as fruit and vegetables, poultry and fish, give off either moisture, which is transmitted to the packing case, or gases, which, in a confined space, cause a rise in temperature and accelerate decay.

Because they give off both moisture and gases, fresh fruit and vegetables need ample ventilation even when under refrigeration. Corrugated board boxes, therefore, cannot be used unless they have been treated against dampness or unless the products can be packed in moisture-proof wrappings without the risk of a dangerous rise in temperature. The likelihood of deterioration of the corrugated board box depends on the duration of transport and the rate at which the products give off moisture. Cases made of expanded polystyrene, used because of its heat-insulating properties, do not permit sufficient ventilation and retain the heat given off by the product; this causes products to deteriorate.

As fresh fish are always packed wet in ice, which melts to some degree during transport, corrugated board boxes cannot be used for this purpose without the interposition of watertight coverings. Cases made of expanded polystyrene, however, are well suited to such transport, for expanded polystyrene is not sensitive to moisture and its insulating properties help to reduce the amount of ice needed.

Because poultry gives off moisture and thus requires good ventilation, it cannot be packed in either corrugated board boxes or expanded polystyrene cases unless it is frozen or deep frozen.

The development and evolution of wooden packing cases depend to a great extent on the economic conditions relating to the supply of the necessary raw materials. Raw materials constitute the major part of the cost of all packing cases. Thus, the cost of a packing case will depend largely on the cost of the raw materials, i.e. wood, board and plastics, in the country in which it is manufactured. Cost remains one of the essential criteria in choosing which type of case to use (although the advantages a particular case will provide during its entire commercial cycle must also be borne in mind). In this connexion it is necessary to compare not only the purchase cost of the case proper but also the cost of the inner wrappings, of its transport, and, if applicable, of disposal after use – in other words, the total costs involved.

Competing materials

Among the materials competing with wood, this study has mentioned only corrugated board, expanded polystyrene and shrinkable plastics, since they offer the most competition to wooden packing containers. Bottles and jars of glass or plastic are used for packaging liquids in small quantities; but they are not normally considered transport packing containers, and no wooden container has ever been used for small capacities. A certain amount of competition between the transport of liquids in small units or in bulk using barrels or casks may have existed, but using wood for these purposes has now become outmoded by the use of metal drums and various types of bulk tanks, and even pipelines.

Paper is used for packing containers in the following forms:

(a) Corrugated or solid board boxes, which offer the most direct and active competition to wood, particularly on domestic markets and for industrial products;

(b) Light board, used in the form of boxes or folded sheaths as wrappings of products sold in retail stores; such wrappings do not compete with wooden packing cases;

(c) Large-capacity paper sacks used to transport powdery or granulated substances such as cement, fertilizers or chemicals that must be transported in airtight or waterproof containers; wooden cases are neither airtight nor waterproof.

(d) Small and medium-capacity paper bags and special wrapping papers.

The technical properties of metals vary greatly, and many different metals–steel, copper, aluminium, lead and tinplate– are used for different packaging purposes. Of these metals, the most widely used are aluminium, tinplate and sheet steel. Aluminium is used in the form of sheets, sometimes combined with other materials, or in the form of tubes and cans used as containers. Tinplate and steel sheet are used to manufacture containers such as cans for food or for paint or lubricants and aerosols or to manufacture barrels or drums for the transport of liquids. Such barrels could offer competition to wooden barrels and casks, if wooden barrels were not all but obsolete.

Because of the many kinds of plastics and the frequent discoveries of new uses for them, plastics form a dynamic sector of the packaging case industry. This study is concerned only with existing products. However, some authorities believe that in 20 or 30 years 50% of packaging will be done with plastic materials that are as yet unknown.

At the present time, plastics are used in the following forms:

(a) Sheets, which are used only for wrapping products, except for shrinkable plastics, which are used to cover load units, especially palletized loads. These shrinkable plastics are much more competitive with corrugated board boxes than with wooden cases. When the technique for using them is fully developed, they will compete with wooden packing cases in the same way that corrugated board now competes.

(b) Bags, which are used for the same purposes as paper bags.

(c) Moulded packing containers made either of expanded plastic, which may compete with wooden cases for the transport of fish and frozen poultry, or of polyethylene or polyvinyl chloride (PVC). In view of their cost and strength, they can be used only for reusable packing cases. Such use is, of course, contrary to the trend towards the use of one-way packing cases for transport.

On the other hand, moulded packing containers in the form of tote boxes or baskets are very useful for internal handling operations within enterprises and will probably replace wooden boxes and cases for this purpose at a certain stage in a country's development. The higher initial cost of plastic containers is compensated for, in internal use, by their longer life and the fact that they require no repair. Consideration has been given to the possibility of using plastic containers in developing countries instead of wooden ones during the period in which reusable packing cases are generally used. This would eliminate the need to develop a wooden packing case industry. The manufacture of moulded plastic containers, however, requires a large investment and little labour, and the cost of the raw material is high. The use of such containers becomes economic only when the cost of labour is so high that the cost of wooden cases approaches closely that of moulded plastic containers and the cost of repairs to wooden cases becomes prohibitive. However, in a country with a low standard of living, these expensive plastic containers are more prone to disappear during the commercial cycle than low-cost packing cases. The freight charges on this type of case would be substantial.

The use of plastic cases presents a paradox. When a country's standard of living is low, expensive packing cases are inappropriate for transport purposes. When the standard of living has risen and the price of these same cases has become relatively less expensive, they will not be used, since by then non-returnable packing cases will have become the accepted form of transport packaging. These plastic cases would, however, offer a major advantage for transport within warehouses or plants, i.e. as reusable tote boxes, the moment the price of wooden boxes approaches their cost.

When a careful study has been made of the economic factors, technical factors and competing materials, it is possible to forecast the general line of development of the wooden packing case industry in relation to the development of a country. It must be kept in mind that the conditions of development – orientation of production towards industry or agriculture, and orientation towards the internal market or the export market – will greatly influence the nature of the development of this industry. The stages of development are described briefly below:

First stage. In a developing country with a very low standard of living, reusable sawnwood cases and baskets made of wicker or other woven materials will account for almost all the containers used for transport.

Second stage. As the standard of living rises, and the consumption and export of agricultural goods increase, strong, reusable light cases and wirebound cases will be used for exports. Palletization will be introduced, but sawnwood cases will continue to be widely used for industrial products.

Third stage. Wirebound cases will be used on the domestic market; corrugated board boxes will begin to be used for industrial products on the domestic market, while plywood packing cases will be used for export. The use of pallets will be extended, and sawnwood cases will gradually begin to lose their importance.

Fourth stage. One-way packing cases will begin to gain a foothold on the domestic market, and corrugated board boxes will take over the market for industrial goods and will begin to be used experimentally for exports, although wooden cases (particularly plywood and wirebound cases) in general will still be used for exports. Agricultural products will continue to be transported in light packing cases, but these will be considerably lightened. While such cases will still be reusable, they will be capable of being used for only a few trips and only once for a long-distance trip, with subsequent use for short distances. Sophisticated wrapping materials such as plastics, paper, and composite materials will make their appearance, and because of this the percentage share of wooden cases will diminish substantially.

Fifth stage. One-way packing cases for transport will come into general use, and corrugated board boxes will take over almost the entire market for the transport of industrial products and common foodstuffs; they will, however, share this market with plastics either in the form of shrinkable plastics or expanded polystyrene. Mass-produced sawnwood cases will virtually disappear, and sawnwood cases will be used only for made-to-measure cases. Plywood cases will by this time have come into extensive use for the export of industrial products, together with wirebound cases, which will also be used for the transport of perishable goods. Light packing cases will be lightened still further and will dominate the market for the transport of perishable goods. Palletization will become general, and baskets and containers made of plastics will replace those made of wood for handling operations.

Sixth stage. Having reached a high standard of living, the country under consideration will make the final transition from reusable packing cases for transport to one-way cases. Paper and corrugated board will account for half the total value of packing containers; metal for 20%; and plastics, glass and wood for 10% each.

The use of sawnwood cases will diminish still further. The use of plywood cases will probably reach its ceiling because of the improvement in the quality of corrugated board cases, and the same will apply to wirebound cases. Light packing cases will lose some of their markets (fish and poultry) to plastic and corrugated board cases, which will also begin to make sizable inroads into the market for fruit and vegetable packing cases.

Palletization will develop considerably, and the production of pallets will make up for some of the losses of other outlets suffered by the wood industry. One-way pallets, which will come into general use for exports, will also make their appearance on the domestic market.

Seventh stage. Containers will be introduced on the domestic market, and one-way cases will be almost the general rule for transport. The wooden packing case industry will lose still more outlets, and wooden cases will account for only about 5% of the total value of the packaging industry. Wood will be used only for making made-to-measure cases for certain industrial products and for transporting certain fruits and vegetables. Wood will continue to dominate the market for pallets, however, even if some one-way pallets are made of other materials.

The development of wooden packing cases in respect to packing containers as a whole (both for transport and for inner wrappings) and the relationship of various types of cases making up the wooden packing sector are presented in figures 35 and 36. Although these figures indicate at what stage of development the various materials are introduced, the stage at which glass and metal containers are first used can vary considerably. As far as the various types of wooden packing cases are concerned, the development indicated represents countries with a substantial agricultural economy, that is to say, countries that are self-sufficient in the production of perishable goods, especially fruits and vegetables. For this reason an important role has been allotted to light packing cases in the figures. In countries that import fruits and vegetables, the share of the market accounted for by light packing cases would be reduced in proportion to the level of imports, as would the share of wooden packing cases in the packaging sector as a whole. Although the use of wooden packing cases diminishes from its initial level to 25% at the third stage and to 5% at the sixth stage, the wooden packing case industry is nevertheless expanding in absolute terms. At the third stage, where the annual expenditure on packaging is about $5 *per capita,* wood represents 25%, or $1.25, of this, while at the sixth stage the annual expenditure on packaging is $100 *per capita;* although wood represents only 5% of this, the figure is now $5 *per capita.* A country with 20 million inhabitants will have at the third stage a wooden packing case industry with a turnover of $25 million. If it is assumed that the annual rate of population increase is 2.5% at the beginning of a 20-year period and only 1.5% at the end of it, and if it is also assumed that during this period the country will pass from the third stage to the sixth stage, the population will then amount to 30 million, and the turnover of the wooden packing case industry will reach $150 million.

Parallel with this development, which will involve a transition in the transport packaging sector from sawnwood cases to reusable light packing cases and subsequently to wirebound cases, plywood packing cases and one-way light packing

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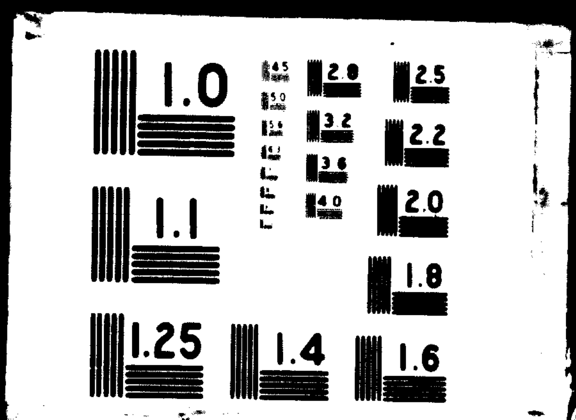


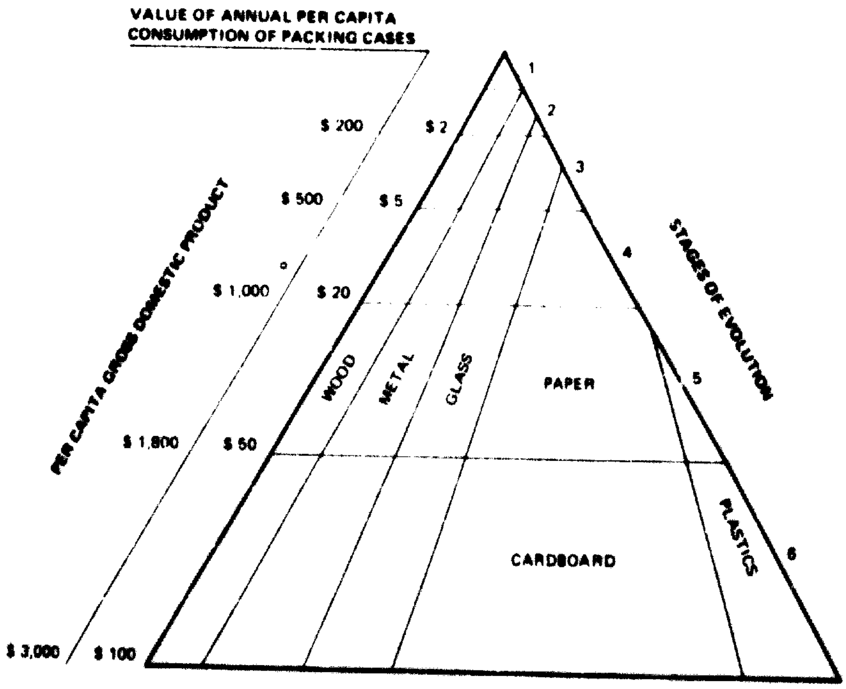


Figure 35. ***Evolution of wooden packing cases and competing materials***

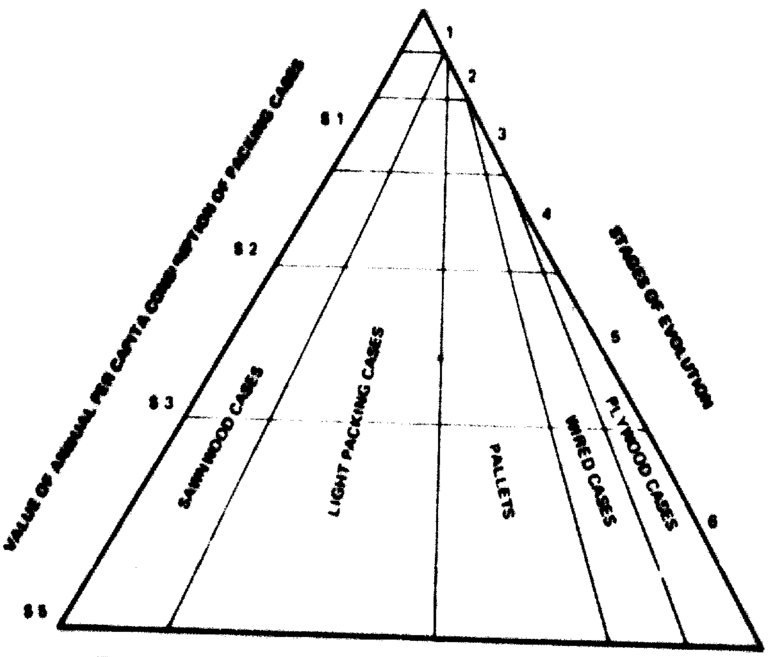
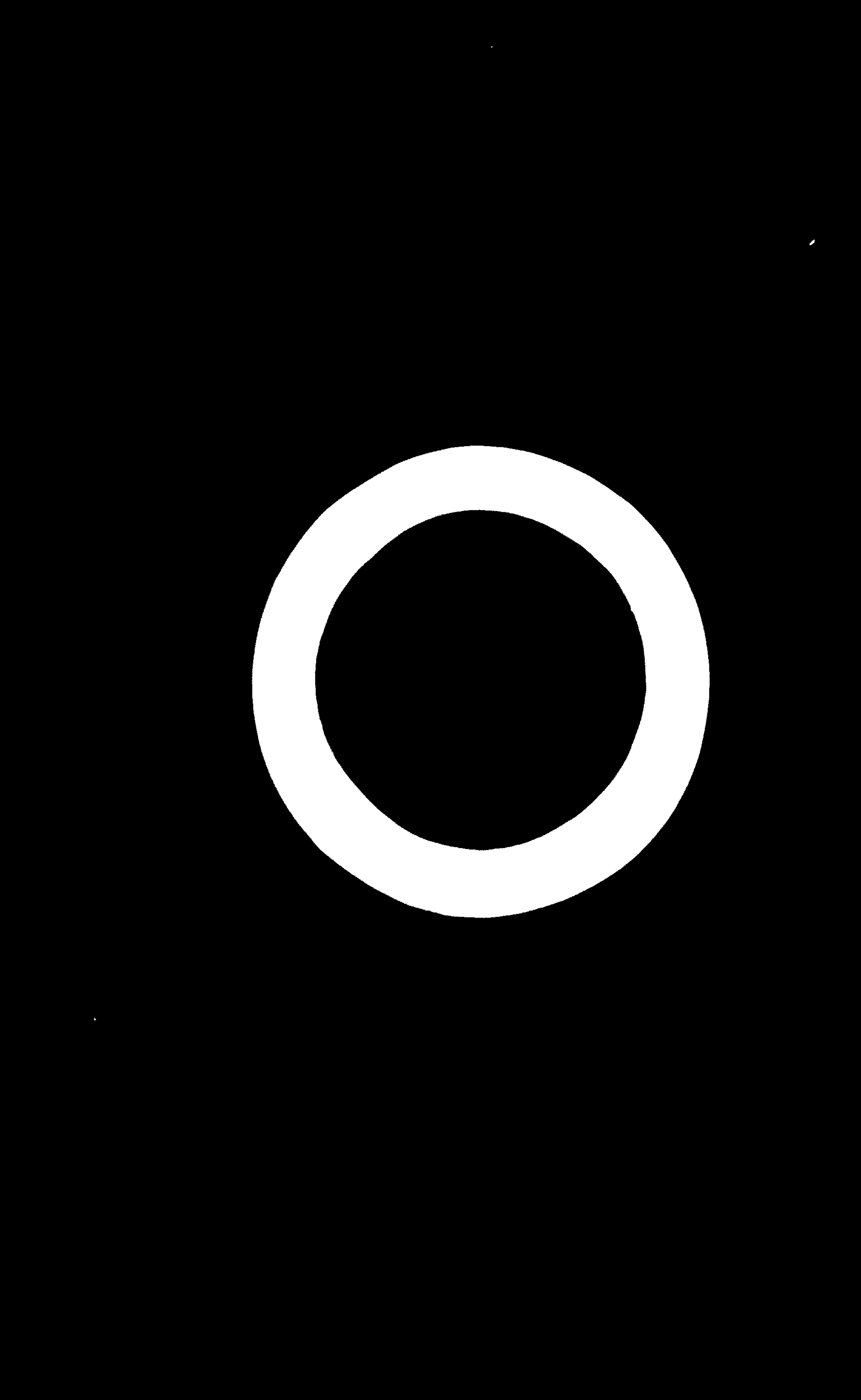


Figure 36. ***Evolution of types of wooden packing cases***

cases, the structure of the enterprises manufacturing packing cases will also evolve. In the first two stages, the enterprises will be entirely of the artisan type: they will have little equipment, will be very dispersed, and will require a large amount of labour compared with their production. In the third stage, some larger units will be established as wirebound case manufacturing enterprises are set up and as the light packing case enterprises increase their scale of production and progress from the artisan-stage to the small-enterprise stage. Pallets will be manufactured by small enterprises. At this level mechanization will not yet be economically justified, and the labour force of the enterprises will remain very large.

The fourth stage will be the most important and the most difficult to tackle. At this stage, countries will begin to envisage units that correspond, on the whole, to the minimum economic units defined in chapter 5 and that will gradually exceed this level to reach the level of economically more balanced enterprises. There will be a strong temptation to copy the corrugated board box manufacturing enterprises and mechanize production and handling; this mechanization may be accompanied by the retention of theoretically superfluous labour, thus leading to the appearance of enterprises that have not significantly reduced their labour costs, but have considerably increased their investments. The consequence of this haste to mechanize may be to cause the disappearance or stagnation of the best-equipped enterprises, unless these are artificially supported; it may subsequently hold up mechanization that is really necessary because of the relationship between investments and the cost of labour. At the same time, if suitable measures are not taken, there will be a proliferation of small enterprises that do not even reach the minimum desirable economic level, and the result of this will be to hold up the general process of development. A delicate balance must be found between the proliferation of small enterprises and the premature creation of large mechanized units.

From the beginning of the fifth stage onwards, however, it is possible and necessary to turn boldly towards mechanization and towards the establishment of large units. Small and medium-scale enterprises corresponding to the different needs of series production will nevertheless remain at this stage, but in the light of the present standards it can be considered that a country that has reached the fifth stage has attained the level of the industrialized countries.



Annex

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