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PACKAGING AND PACKAGING MATERIALS WITH SPECIAL REFERENCE TO THE PACKAGING OF FOOD

FOOD INDUSTRY STUDIES No. 5

UNITED NATIONS

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UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION, VIENNA

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FOREWORD

This monograph is one of a series of studies designed for the use of the food-processing industries of developing countries. The approach used and the criteria followed are based on the concept that processes and techniques must be adopted that will produce goods that can compete in quality, price and reliability of supply with goods from countries whose industrialization began earlier. This concept is considered valid even when capital for investment and skilled labour may be in short supply and present markets for the products limited or even non-existent. No country, and especially no developing country, can afford to waste its resources by building industries whose products are too high in price and/or too low in quality to gain acceptability in the world market.

The objective of UNIDO in publishing this series of studies in the food-processing industry is therefore to help the developing countries to gain good technical insights into selected areas of food-processing and to avoid obsolescent procedures and processes. It is hoped that these studies will provide reliable and practical information for governmental authorities and for potential private and institutional investors.

The present monograph was prepared by Mr. Anton Petrišić of the Institute for Processing Techniques, Zagreb, Yugoslavia in the capacity of consultant to UNIDO. The views and opinions expressed in this paper are those of the consultant and do not necessarily reflect the views of the secretariat of UNIDO.

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INTRODUCTION

Recent dramatic increases in world population have not been accompanied by corresponding increases in the production of food which is a basic necessity of life. Not only is food production inadequate to meet total needs, but also, because of faulty preservation, immense quantities of foodstuffs are lost. Thus, the preservation and conservation of food are no less important than its production.

Food conservation is not a simple task, for food represents a biological complex that is influenced by a great number of factors. Methods of food preservation depend on the properties, ambient conditions and shelf-life of the food. Certain foods can be preserved by various methods at relatively low cost for a given time, e.g. cereals and sugar preserved in silos. Other foods, such as eggs, some vegetables and fruits can be kept at somewhat higher cost in air-conditioned stores where the temperature is slightly above 0°C. Far higher is the cost of preserving foodstuffs such as fresh meat and some fruits and vegetables by deep-freezing them in freezing chambers at temperatures as low as -40°C (and even lower) and then storing them at somewhat higher temperatures. As this method of food preservation involves high costs, the cost of the food increases accordingly.

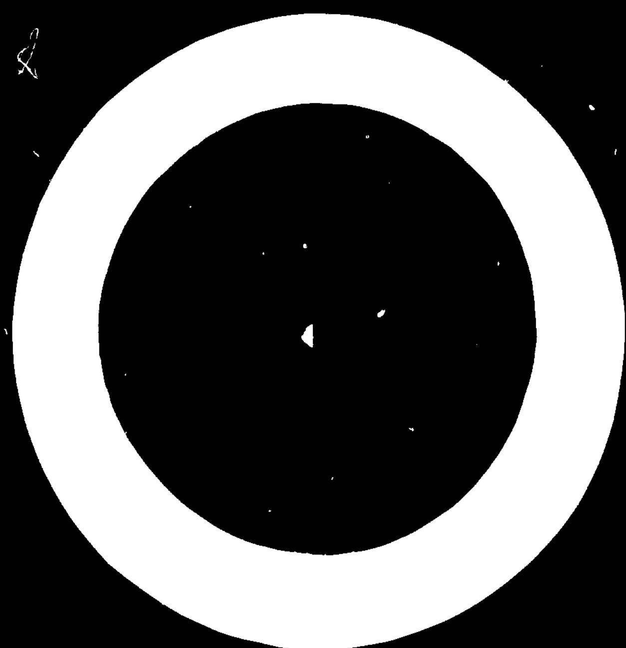
Natural, unprocessed food has the highest nutritional value, but owing to the expense of preserving the food in its natural state, the price of such food is often beyond the customer's buying potential.

This report does not deal with the problems of food storage, food preservation by means of stores, the system of refrigerated stores and the various means of external and internal transport; its aim is to discuss the packaging of processed food as a means of safeguarding nutritional quality and durability. It is our intention to present, from a practical rather than a theoretical point of view, the fundamental problems related to packaging, packages, and shipping containers in order to assist the reader in choosing packaging materials and methods.

Food is processed in various ways: by drying, evaporation (i.e. concentration), spraying, lyophilization (freeze-drying), boiling, roasting and so on. Industrial food processing employs the latest scientific research so as to retain the natural properties of food (colour, taste, smell, proteins, sugar content etc.).

The technology of food-processing equipment is developing at a rapid pace; new and more sophisticated equipment reaches the market every day. It is necessary to choose equipment that will ensure high quality products, which must in turn be competently packaged to safeguard their quality and durability.

Packages and shipping containers, packaging procedure, handling, storage and distribution are closely related, and a correct choice of packaging procedures and types of package facilitate the low-cost preservation of proteins, fats, vitamins, carbohydrates and other useful components of food.



PACKAGING OF FOOD

Motives and methods

Food is packaged for two main reasons: to preserve it and to present it in an attractive form to the buyer. It is not easy to define packaging and packing and there are various opinions in this respect. One definition states:

> "Packaging engineering comprises not only techniques used in packaging, but those used in packing as well. Packaging should not be confused with packing. Packaging may be defined as the protection of materials of all kinds by means of containers so designed as to prevent damage to the contents by outside influence. A package is generally designed for a great number of similar products and mass-produced by means of machinery. Packing, on the other hand, consists of enclosing an individual item, or several items, in a container, usually for shipment or delivery. This operation is done mostly by hand, machinery being only slightly involved . . . . . . Such packages and cases are also known as primary and secondary containers . . . ."[1]

By the term "packaging" we understand the use of primary and secondary containers and the operations of packaging and packing (preparation of packages, putting a given commodity into the package, sealing the packages, putting the packages into the transport containers and closing them).

A package is the material in which the commodity is wrapped, boxed, filled etc., whereas a pack is a container (case, crate etc.) into which single items or packaged goods are placed to protect them during transport. Packaging and packing containers can be divided into two groups: commercial packages and transportation containers.

Goods are packed in commercial packages in the small quantities required by the direct consumers. These packages protect the product, guarantee its quality and quantity, and provide written information to the customer on the commodity, its composition, mode of use and, occasionally, its price. Packages are produced from different materials in a variety of types, e.g. bags, cartons, glassware, cans, aerosol spray dispensers and tubes.

Transportation containers are used to pack small commodity units collectively or to pack big items individually for transportation to their place of use. During the

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[1] "Packaging Engineering" by Louis Barail, Reinhold Publishing Corporation, New York (1954).

transport operations – loading, unloading and storing – the containers protect not only the commodity itself, but also other goods, the transportation facilities and the personnel handling the containers.

The type of packages and shipping containers and the technique of producing them depend to a great extent on the material of which they are made and packages and containers may be classified accordingly, for example, glass, metal, paper, plastics, textiles and wood. There are also combinations of more than one material such as various laminates.

As pointed out, packages and shipping containers serve to protect the goods from external influences and this is of special importance where food is concerned, for it must be protected against atmospheric conditions, micro-organisms, light, air, insects, rodents, noxious influence of other products (odours, tastes and even eventual poisoning effects) mechanical forces, and stealing and pilfering.

Packaging and packing materials

The prime requirement of packaging and packing material is that they must provide absolute protection to the contents of the package. The choice of materials for packaging and packing is important, for the cost of packaging increases the price of the commodity.

There are two main groups of material:

soft: cellophane, paper, paperboard, plastic foils and films, textiles etc.;

hard: wood, glass, metal, hard plastics etc.

The choice of material depends upon the degree of protection required. For products which need little protection soft materials such as cellophane, paper, or plastic foils are sufficient; when major protection is needed, harder materials must be used.

The materials used in packaging and packing have to be specially treated in order to provide permanent protection of the commodities as the packaging and packing materials themselves are subject to corrosion and are affected by moisture, micro-organisms, insects and rodents. Transport containers to be used in overseas transit and in tropical climates–in conditions of extreme humidity and temperature–are especially exposed to these unfavourable effects. Difficulties arise if cases or sacks are stored on earthen or wooden floors, for there is a constant danger of infestation by micro-organisms. If the stores have floors of concrete or steel such dangers are minimized.

Air freight is the safest means of transport, and sea freight fraught with the greatest danger.

Chapter Two

FOOD PROTECTION MEASURES

Protection from micro-organisms

Micro-organisms, including mould and yeast bacteria, develop rapidly under favourable conditions. Their control must start at the packaging plant where the use of germicides and fungicides should be part of the packaging procedure. Fungicides and germicides, applied by dipping, brush coating, soaking, slushing, spraying or lamination, can exert germicidal, fungistatic or fungicidal effects. Control measures become more intricate with the increasing number and variety of commodities to be packaged.

The choice of germicidal and fungicidal compounds depends on the relevant micro-organism. When a short period of transportation is expected, it is possible to apply low concentrations of cheap chemicals. If transport is effected under difficult conditions and over a long period of time, it is necessary to apply highly concentrated chemicals with long-lasting effects; this involves high costs, but such compounds will prolong the durability of the shipping containers and the protection of the packaged goods.

There are four basic groups of germicidal and fungicidal compounds:

(a) *Phenols:* These are the oldest compounds known and are extremely effective. Some of them are too potent to be applied without special precautions. Although phenols are inexpensive and effective, their application is limited owing to the phenol odour and colour which affect packing material such as paperboard, textile and wood. They are unsuitable for food packaging.

(b) *Derivatives of heavy metals:* This group is composed of organic and inorganic salts or of derivatives of a great number of metals, especially copper and mercury. Typical examples are: copper naphthenates, phenylated mercury compounds and mixtures of other organic mercury compounds. Their fungicidal properties against moulds are long lasting, even at high temperature and humidity and in spite of the effect of solvents.

(c) *Aromatic compounds:* These are expensive and not very effective.

(d) *Quarternary ammonium compounds:* Although these compounds have been known for a long time, their application as fungicides is of a relatively recent date.

Protection from insects and rodents

Considerable damage is caused to packaging materials by insects and rodents. Rodents destroy them to get to the food, and they may even feed on the packaging materials, especially if these contain glues of animal or vegetable origin.

In the United States of America annual losses to food and packaging materials caused by insects, rats and mice amount to $7,000, $3,000 and $1,800 million respectively. These figures do not include the costs of damage to walls and shelves of storehouses and to other materials nor the cost of secondary damage from faecal contamination.

Mice and rats cause damage to practically all materials and it is difficult to say which are more destructive. With regard to food, mice are less selective than rats; on the other hand they are less voracious. Both kinds of rodent when starving will eat anything wood, plastics and even metal and glass wool.

Rodent control is very difficult and the problem of food protection is complicated by the fact that all rodenticides and repellents are toxic to warm-blooded animals and human beings. There is, however, one very expensive repellent on the market under the commercial name *Laminite* that is not harmful to food or to humans and can be used on corrugated walls. In rodent control the only reliable solution is the organized extermination of rodents in towns, storehouses and ships, together with stringent measures and precautions against the contamination of food.

Flies, cockroaches and ants are foremost among the insects that cause damage to packaging materials. Flies attack mainly carbohydrates, while American, German and Oriental cockroaches cause serious damage to food and packaging materials (such as textiles, cellulose materials, protein, animal glues and synthetic protein fibres). Because of their organized life and mass invasions, ants are a special threat.

Protection from insects can be achieved in two ways: first, by destroying the insects at the packaging plant prior to or during the packaging operations or, by treating the materials used for transport containers with insecticides; and second, by treating the plant and the packaging materials with repellents that do not kill the insects but hinder their access to the packaging plant or to the package.

It is recommended that the interior of the plant be treated with insecticides, mixed either with paint or with washing solutions or sprayed on the painted walls. DDT is one of the best known insecticides that can be mixed with paints or washing solutions; it can be used in concentrations of 5 to 10 per cent. Clordan is efficient in concentrations of 5 per cent. Since insects become immune to most insecticides after a certain time, the addition of pyrethrin, a vegetal insecticide, is recommended.

Many materials used for packaging are treated with toxic chemicals and cannot be used for the packaging of food. Where food is concerned, adequate insecticides dissolved in inorganic solvents should be chosen and the concentration must be lower than for goods other than food.

Most of the insecticides are rather effective, except where ants and American cockroaches are concerned, for these insects have a high degree of resistance. Tar derivatives are also effective as insect repellents, but they cannot be applied where food is concerned as their odour affects the food and makes it unacceptable.

Chapter Three

PAPER AND PAPERBOARD

Paper constitutes more than half of the total amount of materials used for packaging purposes. New processing methods and industrial developments have made possible the mass production of cheap paper, both for wrapping and for the manufacture of packages.

Description of various types of paper

Various paper qualities are obtained by combining various raw materials. The Federal Republic of Germany has standardized paper according to the following five classes of raw materials:

Class	*Raw material*
I	Rags (for linen paper)
II	Rags plus 50% cellulose
III	Cellulose without wood pulp
IV	Cellulose plus up to 50% wood pulp
V	Cellulose plus more than 50% wood pulp

Wrapping paper is divided into groups according to its composition, thus:

AP 1	100% mixed waste paper
AP 2	30% mixed waste paper, 70% higher quality waste paper
AP 3	25% second-class cellulose and 75% higher quality waste paper or 100% of latter
AP 4	30% pure cellulose and 70% higher quality waste paper or 100% of top quality waste paper
ZP 1	100% cellulose from knots (and up to 30% waste paper)
ZP 2	100% second-class sulphite cellulose (and up to 30% higher quality waste paper)
ZP 3	100% second-class sulphite cellulose; allowing for either 30% wood pulp or 30% higher quality waste paper
ZP 4	65% pure sulphite cellulose and up to 35% wood pulp
ZP 5	100% pure sulphite cellulose
NaP 1	100% pure sulphate or natron cellulose
NaP 2	50% sulphate or natron cellulose and 50% waste kraft paper

The following kinds of paper are used for wrapping purposes:

Cap paper	A special paper for making caps for bottles and other glass containers.
Bast paper	Machine-finished or glazed paper with additions of waste cellulose or of sulphite cellulose (group ZP 3); it is used in the manufacture of large bags.
Natural brown paper	Made of brown (steamed) wood pulp, glazed on one or both sides; it is used as wrapping paper (40 150 g/m^2) or as tissue paper (20–22 g/m^2).
Wrapping paper	Fine wrapping paper with usually only a small component of wood pulp.
Counter-reel paper	Smoothed on one side, finished paper (40–90 g/m^2) in reels of 30–70 cm width, mainly used in stores.
Java paper	A cheap paper made of waste paper with some minor additions of cellulose.
Packing tissue	Silky paper in various colours, with or without components of wood pulp, used as wrapping paper for fruit, glass bottles etc.
Fruit wrappings	Silky paper, mostly free of wood pulp, white or violet, weighing 20 g/m^2 (diphenyl impregnated paper is used also for preserving the freshness of fruit).

Other kinds of wrapping paper are:

Havana paper	A cellulose paper weighing 40–50 g/m^2. It is similar to parchment paper and almost impermeable to water and fat. Its glassy transparency is achieved by strong wetting and very bright supercalendering.
Parchment paper (glassine)	A highly transparent paper, cellulose-made, impermeable to fats, weighing 20–40 g/m^2 and used in bleached or unbleached condition.
Greaseproof paper (imitation parchment)	A milled paper, free of wood pulp, with properties similar to those of animal parchment.
Vegetable parchment	A cellulose paper made boilproof and impermeable to fats through sulphuric acid. It is used for packaging fats containing water (e.g. butter, margarine, soft cheese).
Twisting paper	A waxed paper used for wrapping candies. These wrappings are twisted at the ends, hence the name of this paper.
Wax paper (paraffined paper or twisting paper)	Made of cellulose paper, almost free of wood pulp, and treated with paraffin or wax to make it waterproof. It is used mainly for the packaging of food products.
Bright enamel paper	A specially brightly calendered paper, on which good shades of colour reproductions can be printed; it is used for labels and linings.

Enamel paper (chromo paper)	Nearly always contains some wood pulp, and as a rule is coated on one side so that it can easily be impressed and printed by multicolour technique. It is frequently used for lining boxes, for chocolate wrappings, labelling and so on.
Globular grease-proof paper (mostly imitation parchment)	Made of cellulose free of wood pulp with impressed semi-spheres or bulges. It is used as wrapping paper for candies or chocolate products.

There are also a number of other kinds of paper that are not used solely for wrappings and from which corrugated boards are produced, the latter being widely employed in packaging. A few types of these kinds of paper are:

Kraft paper (kraft brown)	A strong, brownish coloured wrapping paper made of sulphate cellulose and weighing from 85–180 g/m^2. Kraft paper for sacks is produced in weights from 70–75 g/m^2. (The thinnest kraft paper (6–7 g/m^2) is used for the production of condensers.) Kraft paper may be bleached, but in this process it loses some of its strength. More than 60 per cent of the kraft paper output is used in the production of corrugated boards.
Paper from semi-chemical pulp	Used in the manufacture of corrugated board to give extra strength to the corrugated layer. Semi-chemical pulp for this paper is made of wooden fabrics not completely dissolved during the boiling-out process. This type of paper is produced in weights from 112–180 g/m^2. The properties and low price of this paper have led to its growing consumption.
Grocery paper (screenings or common paper wrapping)	Made of unsorted waste paper, cheap fillings and some additions of cellulose. It is grey or brown, weighing from 90–230 g/m^2, and is used in the manufacture of the flutes in corrugated boards. Its physical properties are inferior to those of paper made of semi-chemical pulp, and it is more commonly used in Europe than in the United States of America.
Straw paper	A yellow coloured paper made of straw and used mainly for corrugations in corrugated boards. Its mechanical properties are extremely low.

Improved paper

By various methods, paper and board can be made resistant to insects, bacteria, steam, fat, water, air and light. Such processes also increase the mechanical properties of the paper product. Especially for the packaging of food, impermeability to gases, steam, moisture, odours and light are of extreme importance. In addition, waterproof paper must not lose its properties in a humid atmosphere. Materials used for improving paper, such as paraffin, wax, resins, bitumen and synthetics, can either be added to the paper mass during the production process or applied to the ready-made paper. The ready-made paper can also be soaked or dipped into these improving materials as is done with cartons and packages. The various materials used for improving the quality of paper are briefly discussed below.

Paraffin is produced from crude mineral oil or tar from brown coal. It has a high degree of penetration and its melting point lies between 52 and 56°C. It is applied to paper in a liquid state by dipping, spraying or by means of hand rollers. The flow chart of one of the various processes of applying paraffin to paper is shown in figure 1. Several kinds of paraffin are used for improving paper; the food processing industry employs pure. refined and microcrystalline paraffin with a high melting point.

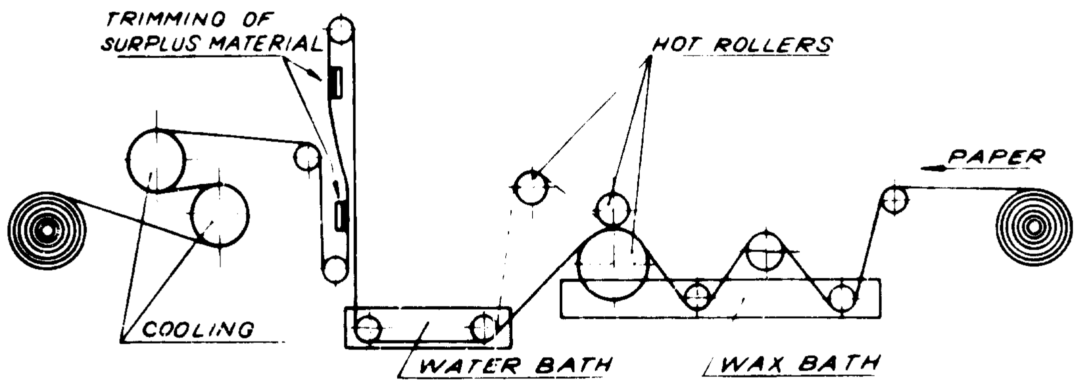


Figure 1. Application of paraffin to paper

Wax is an amorphous material of vegetable, animal, mineral or synthetic origin. For paper improvement, mineral or synthetic wax is used with a melting point above 60°C. Wax can be applied to paper in the same way as paraffin; frequently it is applied by means of an emulsion, without increasing the temperature.

Resins can be of fossil, rubber or synthetic origin. At present synthetic resins, such as phenolplast, aminoplast, and especially melamine are used to improve paper. Resins are usually added to the paper mass, but can also be applied by coating. The resin-improved paper is used primarily in the production of corrugated boards and common cardboards for transportation packs.

Bitumen is a mixture of carbohydrates of the paraffin and naphthenic order with a melting point of about 80°C. When heated it is applied, either melted or as an emulsion, to paper. Frequently it is applied as a glue between two sheets of paper. Such paper can serve for wrapping purposes or as the outer layer of corrugated board. Its production costs are very low and it is much used in overseas transportation and in tropical conditions. For the packaging of food it can only be used for transportation packs, and even then only with caution, because of the penetrating smell of bitumen.

Synthetic materials are available in a wide choice (such as vinyl chloride, polyvinyl acetate, polyvinyl acrylate, polyethylenes, cellulose, ethers, latex, silicons) and are frequently used for the production of fancy packages. Layers of synthetic materials are often superposed on paper and compressed under heat. Paper thus treated (laminated paper) is generally used for the production of welded bags and boxes. An example of the method of polyethylene application to paper is given in figure 2. This method, for instance, is used in the production of **TETRA PAKS**, which are widely used for packaging milk, fruit juices and similar products. The **TETRA PAK** consists of paraffined cellulose paper covered by a layer of polyethylene.

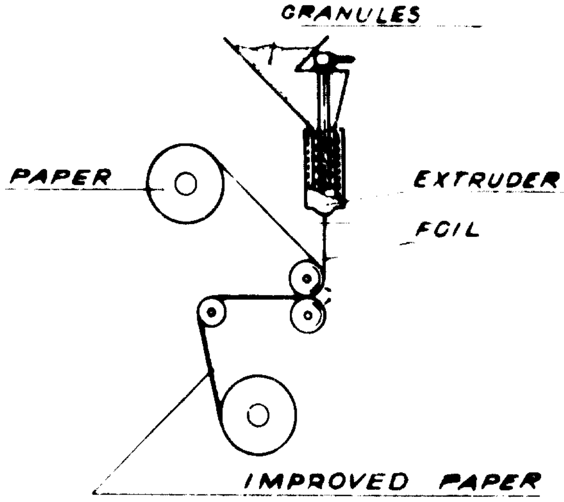


Figure 2. Application of polyethylene to paper

Aluminium foils are also often used together with paper. For instance, improved paper can consist of three layers, the first layer is usually an aluminium foil; the intermediate layer, a sheet of paper; and the third layer, a polyethylene foil. The end product is a sturdy material which is impervious to water vapour and gas, and highly suitable for the packaging of food articles.

Paper packaging containers

The use of paper is not confined to wrapping, but is often employed in the production of such final products as bags, cartons and trays.

Small paper bags (grocery type) are made by special machines from paper sheets, or from paper coiled into tubular shape. Such machines are capable of simultaneously decorating the bags by printing in one or more colours. Figure 3 shows the principal types of small paper bags. Machines for the manufacture of small paper bags have an output of 5,000 to 15,000 pieces per hour, depending on the size of the paper, the type of bag and the system of printing. (Packaging in cellophane and plastic bags is used increasingly, especially by the manufacturers of certain goods and by supermarkets with self-service.)

A = Cone
B = Bag with bottom gussets
C,D,E = Flat envelopes
F = Bag with side gussets
G = Bag with side and bottom gussets

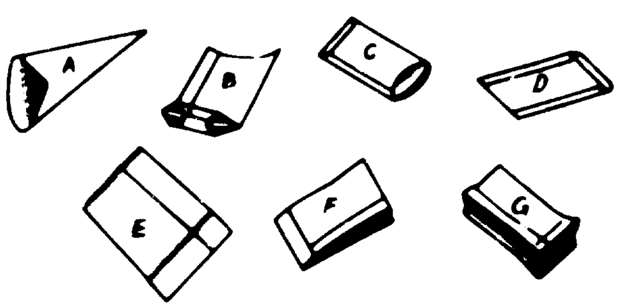
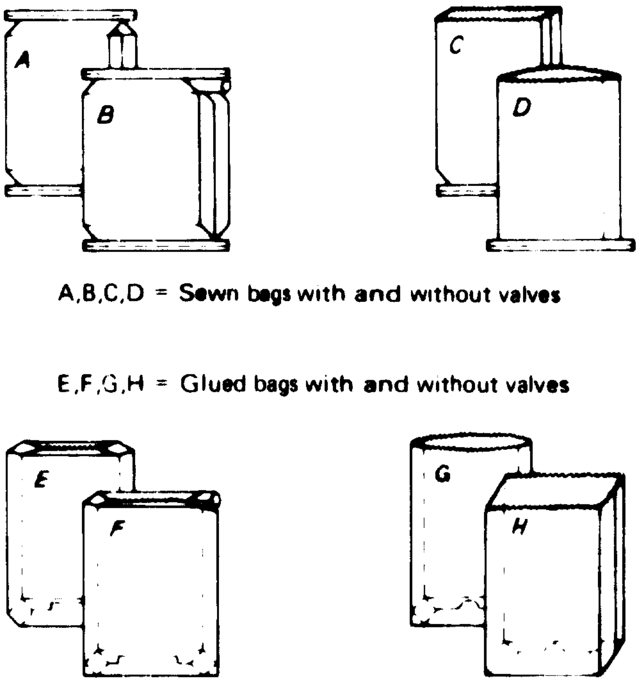


Figure 3. Basic types of paper bags

Transportation paper bags are made of especially strong kraft paper which is sewn or glued. Two types of kraft bag can be distinguished: light (consisting of one or two layers of paper) and multilayer (with three or more layers of paper). Experience has shown that greater flexibility and strength can be achieved by a larger number of lighter sheets of paper than by a smaller number of thicker ones. Sometimes sheets of different weight paper are combined and layers of improved paper (e.g. waxed or bituminous paper) inserted. Metal or plastic foils, or paper lined with such materials, can also be used as protection layers.



A,B,C,D = Sewn bags with and without valves

E,F,G,H = Glued bags with and without valves

Figure 4. Basic types of sewn and glued bags

Figure 4 above shows examples of sewn and glued bags. Drawings *A* and *E* show bags with valves in one of their top corners. These valves are closed by the pressure exerted by the content once the bags are filled. Drawings *B* and *F* depict bags with sleeves used for filling, then folded and pushed into the filled bag, thereby closing the bag. The drawings *C, D, G* and *H* show bags with open tops which can be tied or sewn shut. The sewing is done by portable or fixed sewing machines, normally using cotton thread. Transportation bags are made for loads of up to 50 kg.

Paper bags are filled and closed most easily when the moisture content of the paper is between 6 and 7 per cent. Paper that contains less moisture tends to become brittle. Empty bags should therefore be stored at a room temperature of 20°C and at a relative humidity of 50 to 60 per cent.

Description of various types of paperboard

In practice, the following paper products are classified as boards:

(a) All kinds of millboards, from thin grocery paper (300–350 g/m^2) to thick binder's board (4,000–5,000 g/m^2);

(b) Uncovered boards without top layer, such as boards from straw, machine-made leather and grey board, irrespective of their gram weights.

If machine-made board is improved, however, either by introducing a quality raw material or by adding a quality top layer, it becomes cardboard irrespective of its gram weight. According to the production process a distinction is made between millboards (which are removed by hand from the cylinders) and machine-made boards.

Chromo board, a fine full-glue type of cardboard, is coated on one side and is used for producing collapsible cartons of better quality. Its weight varies from 220 to 600 g/m^2; it is often used for quality printing.

Imitation chromo board is made of mill blank (multi-layer board,) white on one side and very smoothly finished. The single layers consist of a mixture of fibres, fillings and glue. The top and bottom layers are usually of pure cellulose, whereas the middle layers are made of waste paper. Imitation chromo board is produced in specific weights from 200 to 700 g/m^2, weights from 200 to 350 g/m^2 being the most frequently used.

Corrugated board

Corrugated board is especially important in packaging. It is a paper product obtained by gluing a fluted sheet between two liners. Of all packaging materials, corrugated board has undergone the greatest development in this century. It is machine produced at a speed of 50 to 200 m per minute, in widths of more than 2m, and is available in three, five and seven layers. The strength properties of corrugated board depend on the kinds of paper used, the contours of corrugation and the quality of gluing. The corrugations are arc-shaped to give the highest possible resistance to pressures (as arched bearers in civil engineering constructions). As shown in figures 5 and 6 and table 1 below, the shape of the corrugations or flutes gives strength and elasticity to the construction.

The required strength of corrugated boards depends on the kind of load and mode of loading. Figure 6 depicts shock and pressure resistance of corrugated board. Referring to figure 5 and table 1

Type *A* flutes have the best shock-absorbing properties and corrugated board with such flutes is therefore used for packing goods easily affected by shocks.

Type *B* flutes are also shock absorbing but bear greater weights than type *A* flutes; thus corrugated board with type *B* flutes is used mainly for packaging heavy objects such as tins.

Type *C* flutes combine the properties of type *A* and *B*.

Type *E* flutes are used in the manufacture of corrugated board for commercial packaging containers.

The flute characteristics also determine the basic construction of boxes made of corrugated board. A correctly designed carton, with the directions of the flutes indicated by arrows, is pictured in figure 7.

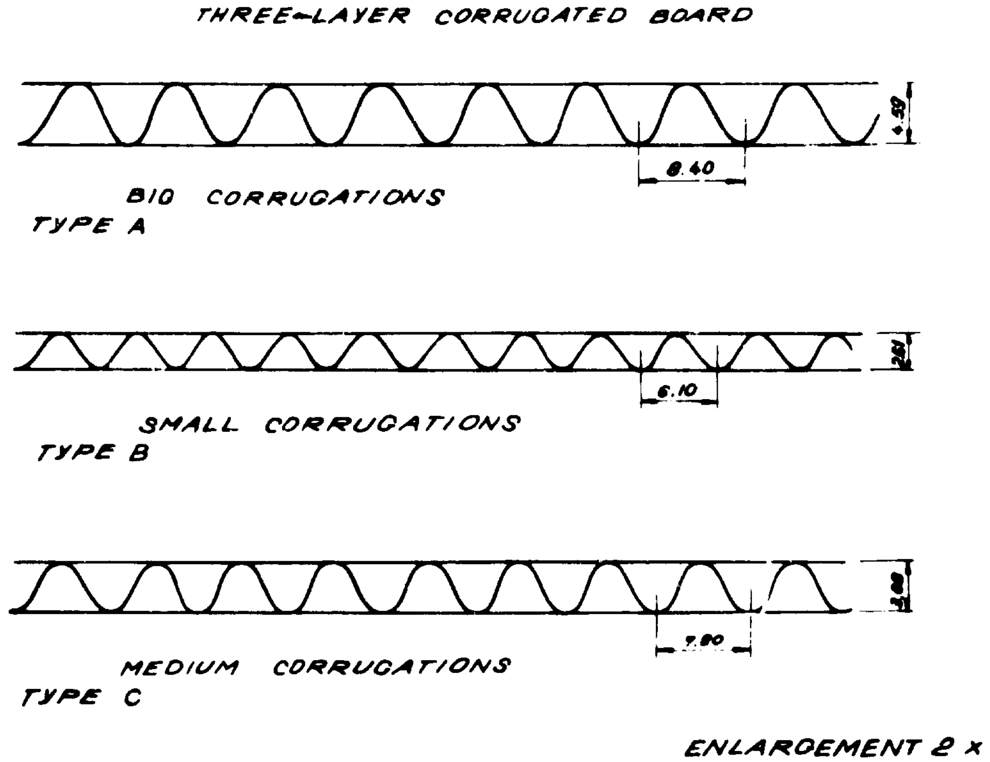


Figure 5. Types of three-layer corrugated board

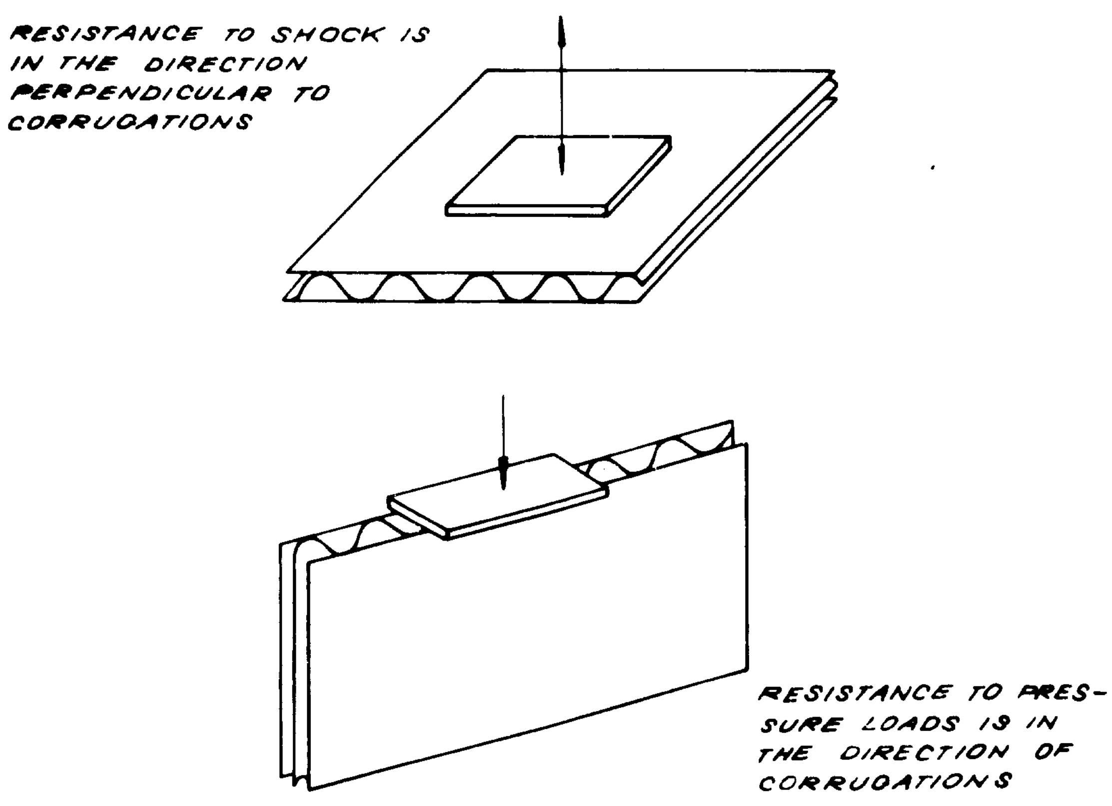


Figure 6. Pressure and shock resistance of corrugated board

TABLE 1. FLUTE CHARACTERISTICS OF CORRUGATED BOARD

		American standard measures (in mm)				*French standard measures (in mm)*			
Designation	*Type*	*height*	*length*	*thickness*[a]	*nos. of flutes/ metre of length*	*height*	*length*	*thickness*[a]	*nos. of flutes/ metre of length*
Large	A	4.59	8.40	5.63	up to 120	5.0	9.10	–	up to 110
Small	B	2.61	6.10	3.65	up to 164	3.0	5.47	–	up to 182
Medium	C	3.68	7.20	4.72	up to 140	4.5	7.30	–	up to 137
Fine	E	1.20	3.20	–	312	–	–	–	–

[a]Theoretical

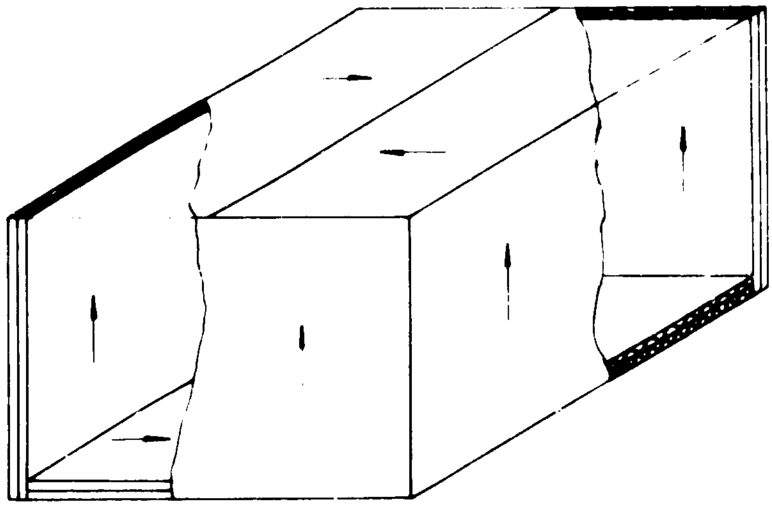


Figure 7. Basic box construction (direction of corrugation indicated by arrows)

In designing cartons, account has to be taken not only of their stability against shocks and weights, but also of the optimal volumetric use (i.e. the optimal ratio between the surface of the corrugated board enclosing the packaged goods and the packing volume of the carton). The food-processing industry uses mainly round containers, bottles and tins, for products which are difficult to box. Round containers can be packed either squarely or diagonally, as shown in figure 8.

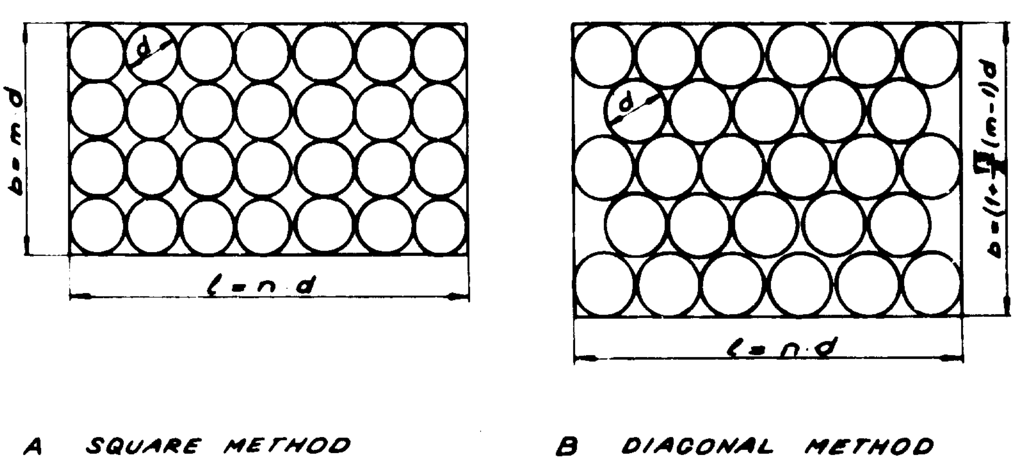


Figure 8. Packaging methods for round containers

The relevant optimal packing method (square or diagonal) can be calculated by means of mathematical formulae. In the formulae given below the symbols stand for:

b	=	Width of the corrugated board carton
d	=	Diameter of container
h	=	Height of container (if containers are boxed in one tier only, this represents also the height of the carton)
l	=	Length of the carton
m	=	Number of tiers
n	=	Number of containers per tier
N	=	Total number of containers
P	=	Area of the total carton surface
V	=	Volume of the carton

$$f = \frac{Nd^2}{lb}$$

Square packing method

$$N = mn \qquad V = Nd^2h \qquad f = \frac{Nd^2}{mnd^2} = 1$$

$$l = nd \qquad P = 2d(hn + hm + Nd)$$

$$b = md$$

Diagonal packing method

$$N = mn - \frac{m-1}{2} \text{ (if } m \text{ is an odd number)}$$

$$N = mn - \frac{m}{2} \text{ (if } m \text{ is an even number)}$$

$$l = nd$$

$$b = d\left[(m-1)\frac{\sqrt{3}}{2} + 1\right] = d(0.86603\,m + 0.13397)$$

$$V = hnd^2(0.86603\,m + 0.13397)$$

$$P = 2d[(0.86603\,m + 0.13397)(h + nd) + nh]$$

$$f = \frac{Nd^2}{lb} = \frac{N}{n(b/d)} \leqslant 1.155$$

The advantages of boxing in the diagonal method are realized in cases when

(i) $n > 4$

(ii) $m = 2$ and $n > 8$;

$4 < m < 14$ and $n > 5$;

$m > 16$ and $n > 4$

Table 2 below lists packing data according to the square and diagonal methods for cartons holding from 3 to 25 containers.

By using the above formulae one should theoretically obtain the characteristic superficies of the widely used American-type cartons. Figure 9 below shows a pattern for American-type cartons.

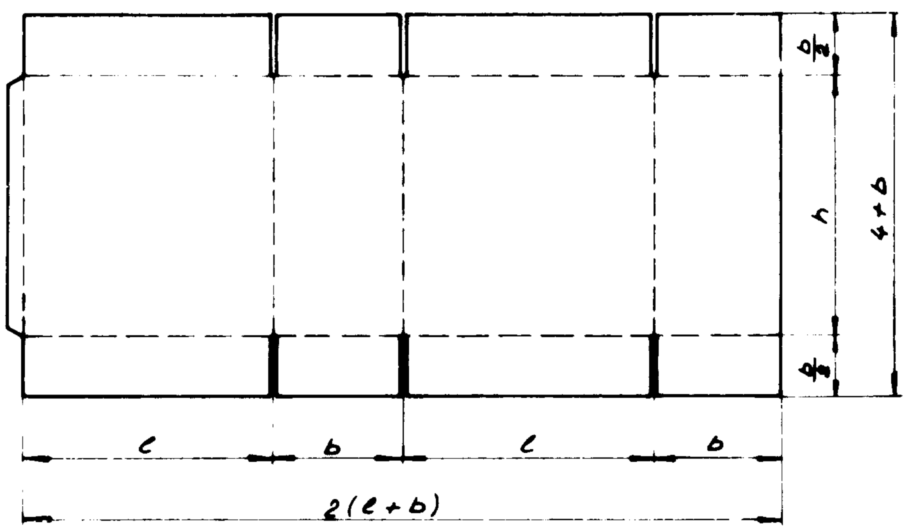


Figure 9. Cut of American-type carton

The surface measure of the carton areas can be computed by two simple formulae:

(a) for the square method – $P = 2(h + b)\,(l + b)$

(b) for the diagonal method – $P = 2(h + b) - (l + b)$

e.g. for formula (a):

$$P = 2[h + d(0.86603\,m + 0.13397)]\,[l + d(0.86603\,m + 0.13397)]$$

TABLE 2. DATA ON SQUARE AND DIAGONAL PACKING METHODS FOR ROUND CONTAINERS

No. of containers (N)	*Method*	*No. of tiers (m)*	*No. of containers per tier (n)*	*Width/length (b/l)*	*Proportion* $\left(F = \frac{Nd^2}{lb}\right)$
3	S[a]	2	2	1.866	0.804
4	D[b]	2	2		1.000
5	S	2	3	1.866	0.893
5	S	3	2	2.732	0.915
6	D	2	3		1.000
6	S	4	2	3.598	0.834
7	S	2	4	1.866	0.938
8	D	4	2		1.000
8	S	3	3	2.732	0.976
8	S	5	2	4.464	0.896
9	D	3	3		1.000
9	S	2	5	1.866	0.965
9	S	6	2	5.330	0.844
10	D	5	2		1.000
10	S	4	3	3.598	0.926
11	S	2	6	1.866	0.982
11	S	3	4	2.732	1.007
11	S	7	2	6.196	0.888
12	D	6	2		1.000
12	D	3	4		1.000
12	S	8	2	7.062	0.850
13	S	5	3	4.464	0.971
13	S	2	7	1.866	0.995
14	D	2	7		1.000
14	S	9	2	7.928	0.883
14	S	4	4	3.598	0.973
14	S	3	5	2.732	1.025
15	D	3	5		1.000
15	S	10	2	8.794	0.853
15	S	6	3	5.330	0.938
15	S	2	8	1.866	1.005
16	D	4	4		1.000
17	S	11	2	9.660	0.880

TABLE 2 (continued)

No. of containers (N)	Method	No. of tiers (m)	No. of containers per tier (n)	Width/length (b/l)	Proportion $\left(F = \frac{Nd^2}{lb}\right)$
17	S	3	6	2.732	1.037
17	S	2	9	1.866	1.012
18	D	2	9		1.000
18	D	3	6		1.000
18	S	12	2	10.526	0.855
18	S	7	3	6.196	0.968
18	S	5	4	4.464	1.008
18	S	4	5	3.598	1.001
19	S	2	10	1.866	1.018
20	D	2	10		1.000
20	D	4	5		1.000
20	S	13	2	11.392	0.878
20	S	8	3	7.062	0.944
20	S	3	7	2.732	1.046
21	D	3	7		1.000
21	S	14	2	12.258	0.857
21	S	6	4	5.330	0.985
21	S	2	11	1.866	1.023
22	D	2	11		1.000
22	S	4	6	3.598	1.019
23	S	15	2	13.124	0.876
23	S	9	3	7.928	0.967
23	S	5	5	4.464	1.030
23	S	3	8	2.732	1.052
23	S	2	12	1.866	1.027
24	D	2	12		1.000
24	D	3	8		1.000
24	D	4	6		1.000
24	S	16	2	13.990	0.858
25	D	5	5		1.000
25	S	10	3	8.794	0.948
25	S	7	4	6.196	1.009
25	S	2	13	1.866	1.031

[a]Square packing method. [b]Diagonal packing method.

Figure 10 below shows a folding carton. For the following discussion it is important to note that the flap must be arranged parallel to the length of the carton, i.e. to the side marked *l* as depicted in figure 9. The optimal utilization of material is obtained when the ratios between the length, width and height correspond to the data given in figure 11 below.

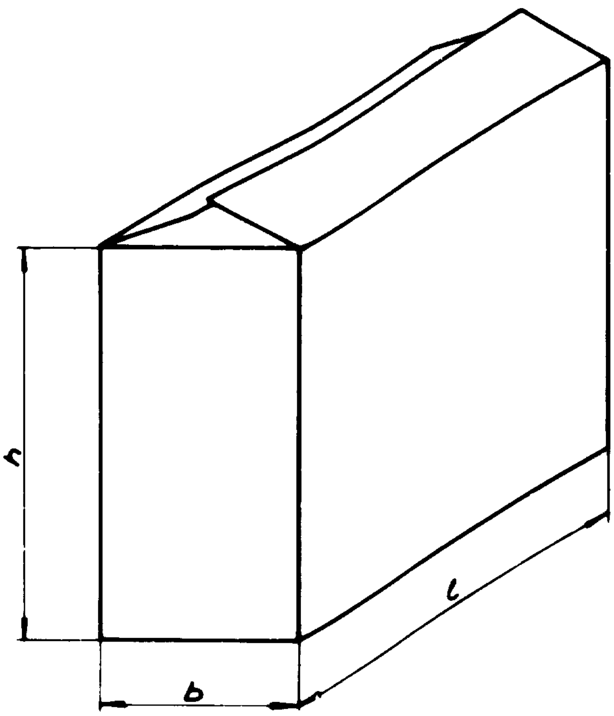


Figure 10. Basic construction of a folding carton

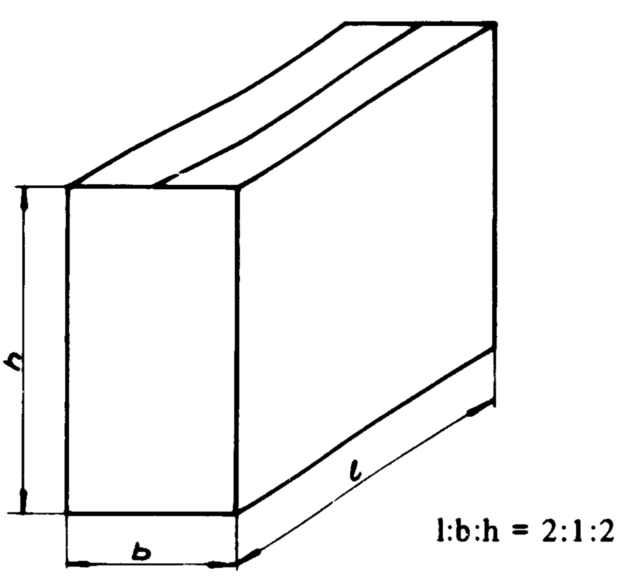


Figure 11. Correct ratio between the length, width and height of a folding carton

The ratio 2:1:2 between length, width and height ensures optimal box volume with minimum box surfaces, thus an optimal use of material. If the ratio, for example, is altered to 2:2:1, 33 per cent more material is used; for a ratio of 1:1:1, 12 per cent more material is used. By means of the SELIN nomogramme (figure 12 below), increased material consumption at different ratios for varying carton dimensions can be determined. The ratios *h/b* and *l/b* should be applied on the lines marked *x* and *y* respectively. By connecting the points on lines *x* and *y*, the percentage of material used in excess of the ideal case can be read off the scale marked %.

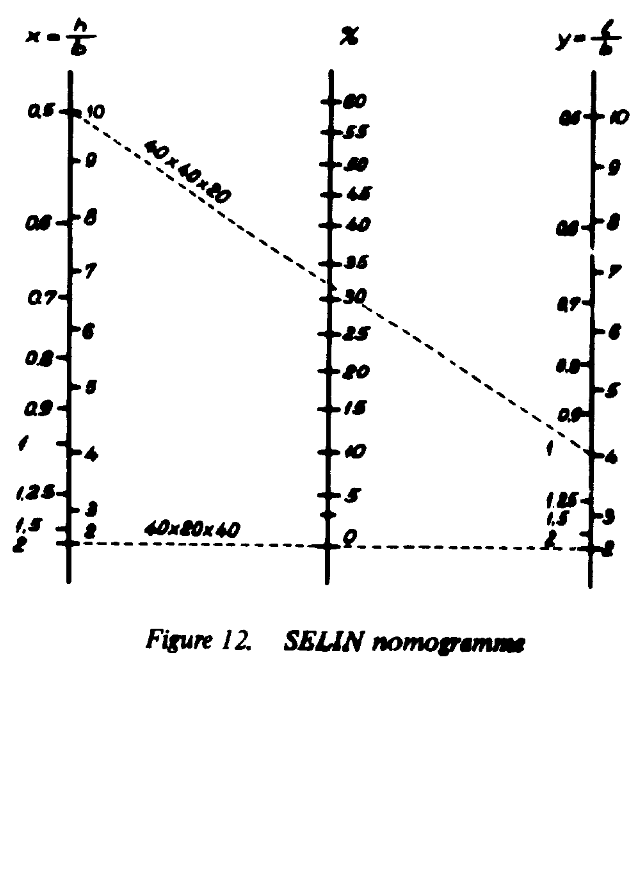


Figure 12. SELIN nomogramme

Chapter Four

METAL AND METAL CONTAINERS

Food can be sealed hermetically in containers made of metal, glass, plastics or combinations of such materials. Metal containers have the most favourable properties for resisting physical forces. Aluminium, steel and tin are the main raw materials used in the production of metal containers and packaging materials such as cans, drums, tubes, closing caps, aerosols, deep boxes and foils

Tinplate

Cans made of tinplate are of great importance for food packaging. An increasing number of articles (Hartwell estimates about 2,000 different products[2]) are now packed in tin cans. By this method, sterilized food, if hermetically sealed, can be preserved two years and longer. Moreover, cans stand up well to the wear and tear of storaging and transportation.

Tinplate is a laminated product made of soft steel sheets, tinplated on both sides by means of either electrolytic or hot-dip processes. This plate has a thickness of less than 0.5 mm. Tin employed in the manufacture of tinplate has to have a purity grade of at least 99.75 per cent. These standards, set by EURONORM, are applicable to tinplates not exceeding 1,000 mm in length and 850 mm in width. EURONORM standards also apply to products, the surfaces of which are specially treated, lacquered or printed (lithographed)

Originally the food-processing industry used only tinplate obtained through the hot-dip production process in which the basic steel sheets are cut to the required dimension and, after pickling, are tinplated by being dipped into a tin bath. The quantities of tin used per m^2 of hot-dipped sheet vary from 24 to 34 g. For military purposes, charcoal tinplate was used with up to 62.78 g of tin per m^2.

As tin is a scarce and expensive raw material, manufacturers tried to reduce tin consumption by introducing the electroplating process. Now galvanized sheeting, i.e. cut steel sheets dipped into an electroplating tin bath, makes up the lion's share of tinplate production. The production of galvanized tinplate, introduced just before the Second World War, accounted for 45 per cent of the total output of tinplate in 1950 and for 70 per cent in 1960. This development was even more marked in the Anglo-Saxon countries where galvanized sheeting made up about 85 per cent of the tinplate production in 1960.

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[2] **A. Nenime (1965) Contribution to investigation on minimum thickness of tin layer for cans made of tinplates, assigned to some vegetables and animal products, Ljubljana (doctoral dissertation).**

TABLE 3. STANDARDIZED QUANTITIES OF TIN PER BASE BOX (HOT-DIP METHOD)

United States of America				United Kingdom			
grade	*commercial name*	*pounds of tin per base box*	*grams of tin per m^2*	*grade*	*commercial name*	*ounces of tin per base box*	*grams of tin per m^2*
A	Common coke	0.85	19.55		–	–	–
A	Standard coke	1.05	23.54		Coke quality	16	22.63
Az	Best coke	1.19	26.68	A	Special coke	20	28.03
A3	Kanner's special coke	1.40	31.39	B	Special coke	24	33.63
B	la Charcoal	1.80	40.36	C	Special coke	28	39.23
C	2a Charcoal	2.30	51.77	A	Charcoal	32	44.84
D	3a Charcoal	2.80	62.78	B	Charcoal	38	53.25
E	4a Charcoal	3.50	78.48	C	Charcoal	46	64.46
F	5a Charcoal	4.20	94.17		–	–	–
G	Premier charcoal	4.90	109.88		–	–	–

On the average, 13 to 14 kg of tin are used for the production of one ton of tinplate manufactured by the hot-dip method, whereas for electroplated tinplate only 4 to 5 kg are required.

The quality of tinplate is generally determined by the quantity of tin, per surface unit, applied on both sides of the steel sheet, the degree of hardness of the basic steel and its capacity for being deep-drawn. Tinplate production standards vary from country to country. This variation is partly due to the different systems of measurement used; British units, for instance, are used in United Kingdom and United States standards and the metric system in EURONORM. Thus in United Kingdom and United States standards the quantity of tin per surface unit is expressed in lb and oz per base box. A base box consists of 112 tin sheets measuring 20 X 14 inches (508 X 355.6 mm) each, or 56 tin sheets of 20 X 28 inches (508 X 711.2 mm). Tinplate is galvanized on both sides, meaning that a given amount of tin in a base box is spread over 435.56 ft^2 (40.464 m^2). Accordingly, the amounts of tin quoted in the production standards refer to the total surface of the base box or to one square meter (tables 3 and 4).

TABLE 4. STANDARDIZED QUANTITIES OF TIN PER BASE BOX (UNITED STATES GALVANIZING METHOD)

Grade no.	*Pounds of tin per base box*	*Grams of tin per m^2*
25	0.25	5.6
50	0.50	11.2
75	0.75	16.8
100	1.0	22.4
100/25	1.0/0.25[a]	22.4/5.6[a]

[a]Tinplate covered by 22.4 g of tin per m^2 on one side and 5.6 g per m^2 on the other.

The thickness of the tinplate is determined by the base weight. Thicknesses up to 0.013 in (0.33 mm) and the corresponding weights of base boxes are listed in table 5. Production standards cover thicknesses up to 0.0303 in (0.77 mm).

EURONORM states the following standard quantities of tin per surface unit:

"Tinplate manufactured by hot-dip method will be supplied in the usual way as:

F 24, with an average coverage of tin of 24 g/m^2

F 30, with an average coverage of tin of 30 g/m^2

Other coverages of tin can be supplied on request.

"The lower limits for average coverage of tin are:

for F 24 at 21 g/m^2

for F 30 at 26 g/m^2."

TABLE 5. WEIGHTS OF BASE BOXES ACCORDING TO AMOUNT OF TIN APPLIED

Nominal base weight in lb per base box	*Approx. thickness inches*	*mm*
55	0.0061	0.15
60	0.0066	0.17
65	0.0072	0.18
70	0.0077	0.19
75	0.0083	0.20
80	0.0088	0.21
85	0.0094	0.23
90	0.0099	0.25
95	0.0105	0.27
100	0.0110	0.28
107	0.0118	0.30
112	0.0123	0.31
118	0.0130	0.33

Lower limits of and average tin coverage by the electrolytic processing are given in table 6.

TABLE 6. GALVANIZED TINPLATE AMOUNTS OF TIN APPLIED

Grade	*Tin coverage* average (g/m^2)	lower limits (g/m^2)
Equal layers of tin on both sides		
E 1	5.6	4.9
E 2	11.2	10.5
E 3	16.8	15.7
E 4	22.4	20.2
Different layers of tin on each side		
E 3/1	16.8 and 5.6	15.7 and 4.5
E 4/1	22.4 and 5.6	20.2 and 4.5
E 4/2	22.4 and 11.2	20.2 and 9.5

Tin sheets are produced in following thicknesses (in mm):

0.18 0.20 0.22 0.24 0.26 0.28 0.30
0.32 0.34 0.36 0.38 0.40 0 ˉ 0.49

They are further classified into quality groups according to the hardness of the basic steel. The hardness can be measured in either Rockwell or Vickers grades:

	Rockwell	*Vickers*
A	48 – 56	80 – 110
B	54 – 61	110 – 135
C	57 – 65	120 – 155
D	66 – 73	160 – 210

The deep-drawing capacity is measured by the Erichsen method, using a plunger of 20 mm in diameter (for values see figure 13).

In the United States, tinplate is divided into two quality groups, "Prima" and "Secunda", according to the surface appearance. Tinplate of the "Prima" group must be free of blowholes, uncovered spots, metal sawdust, rounded corners, mill-scales, nipples and dark or light edges. In the "Secunda" group, slight defects such as uncovered spots, blowholes and traces of mill rolls are tolerated.

EURONORM standards distinguish three classes of tinplate manufactured by the hot-dip method and two classes of galvanized tinplate. The latter are called standard quality and reduced quality (or second class). The quality classes of the United States and EURONORM are very similar; EURONORM standards, however, lay down that

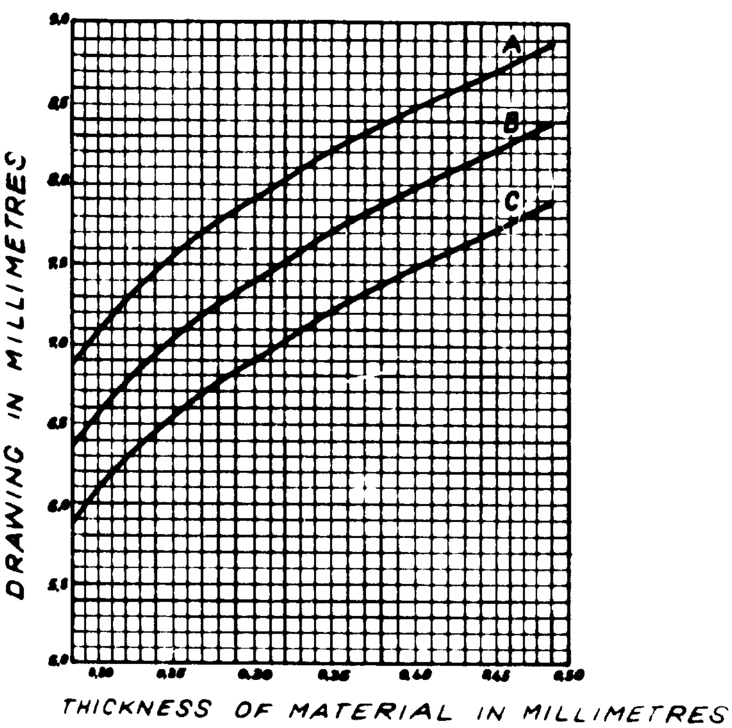


Figure 13. Values gained by the Erichsen test

first-class tinplate made by the hot-dip method must be suitable for lacquering and lithographing on its entire surface. Second-class material cannot be lacquered or lithographed on the entire surface, and third-class material is completely unsuitable for either process. The criteria for galvanized sheets are similar to those for hot-dipped sheets.

Although the quality of tinplate can be further improved by various treatments, the trend towards thinner layers of tin on the sheets threatens the protective quality of the food cans and makes special treatment of packaging material necessary. Resistance to corrosion is of prime importance in can production. The problem of corrosion is also accompanied by other phenomena, such as the durability of the tin layer and the varying resistance to corrosion according to type of steel used.

Two main types of external corrosion are observed with tins: rust caused by contact with moisture and air (due to insufficient drying of the tin after sterilization) and rust formed on spots where, due to traces of alkalis that enter the sterilizer in the water or steam, the sheet-steel has not been tin-plated. The latter type of corrosion is encouraged by the contact of the can with other metals.

Corrosion of the interior of the can occurs in different forms caused by a variety of processes that depend on the canned product and the type of can. Through internal corrosion, tin and steel are partly dissolved whereby hydrogen develops. This type of corrosion happens especially with acid food (pH less than 5) and causes the can to bulge. It can be prevented to a large extent by lacquering and printing (lithographing) the tinplate. Besides its anti-corrosive effect, lacquering improves the appearance of the interior of the can. Lacquer also greatly influences the durability of canned products and preserves the natural taste of food even under greatly varying conditions. Thus a suitable lacquer contributes to a better sale of the canned food.

Lacquering of tinplate

Various lacquers made from natural and synthetic resins can be used for treating hot-dipped and galvanized tinplate. Because of their appearance, they are often called "golden lacquers". Both types of lacquers can be pigmented.

Quick-drying oils are added to lacquers made of natural resins, and white spirit is used as a diluting agent. These lacquers have good covering properties due to their high percentage of solids; they are applied for the protection of the interior of fruit and vegetable cans. Their advantages lie in their low price, simple mode of application by means of a variety of lacquering machines (some of these machines have an output of 5,000 sheets per hour) and in the fact that they do not affect the gelatine and rubber rolls of the machinery.

Synthetic lacquers are made of synthetic resins, namely phenolic, epoxy and vinyl resins. For each type of synthetic resin a range of different compounds exists from which numerous kinds of golden lacquer are produced. Golden lacquers show a good resistance against *(a)* marmoration, *(b)* softening during the sterilization process, and *(c)* the effect of sulphur, acids and both salty and sweet stuffs. In addition they are taste-free and odourless (thus not affecting the canned goods), show a high elasticity (deep-drawing capacity) and are applicable to all types of sheet-steel.

Defects in coating can be caused by small craters and impurities in the sheet, scratches on the sheet, poor viscosity of the lacquer and damages during the can-manufacturing process. The first three defects can be eliminated by coating the sheets twice, which is done regularly.

After lacquering, the sheets are baked in an oven. Lacquers made of natural resins are dried usually for 15 to 20 minutes at a temperature of 160°C. Synthetic lacquers are dried for 15 to 20 minutes at temperatures from 160 to 200°C, depending on their composition.

Three types of oven are used for drying: stationary box-ovens, box-ovens with air circulation and tunnel-type ovens. The latter are the most efficient, both from the technological and from the economic point of view. They are provided with reliable automatic temperature controls which are of utmost importance for quality drying. Though the purchasing cost of tunnel-type ovens is very high (about US $60,000), these ovens have the lowest operational cost per quality-lacquered sheet.

Printing on tinplate

Printing on tinplate is done by offset printing machines. Modern plants use also two-colour and three-colour offset machines so that the printing can be carried out in one process. This contributes towards savings not only in the printing process, but also in the drying process. For printing on tinplate, two basic kinds of lithograph ink are used, one non-resistant and the other resistant to sterilization. In general, lithograph ink is adhesive, has a high spreading rate, is easy drying and permanent. Common printing ink is rarely used on tinplate.

In the normal printing procedures three layers (basic white lacquer, lithograph ink and colourless transparent lacquer) are applied on the sheet. Basic white lacquer is made from natural and synthetic resins, whereby titanium oxide frequently forms the base. Colourless transparent lacquer, normally of synthetic origin, is used for improving the appearance of the print and for making the surface glossy.

Tinplate treated as outlined above is suitable for further processing, e.g. the manufacture of tin cans (or just "cans")

Production of tin cans

Nicolas Appert (1804) and Peter Duran (1810) introduced the use of tin cans for food preservation. Though can production was very primitive in the beginning, the growing demand for food cans brought about a rapid development of this production line (table 7).

TABLE 7. CAN PRODUCTION IN EUROPE, 1840–1950

	Cans per hour	*Time needed per can*
1840	5	12 min
1870	60	1 min
1900	2,500	1.45 s
1940	18,000	0.2 s
1950	36,000	0.1 s

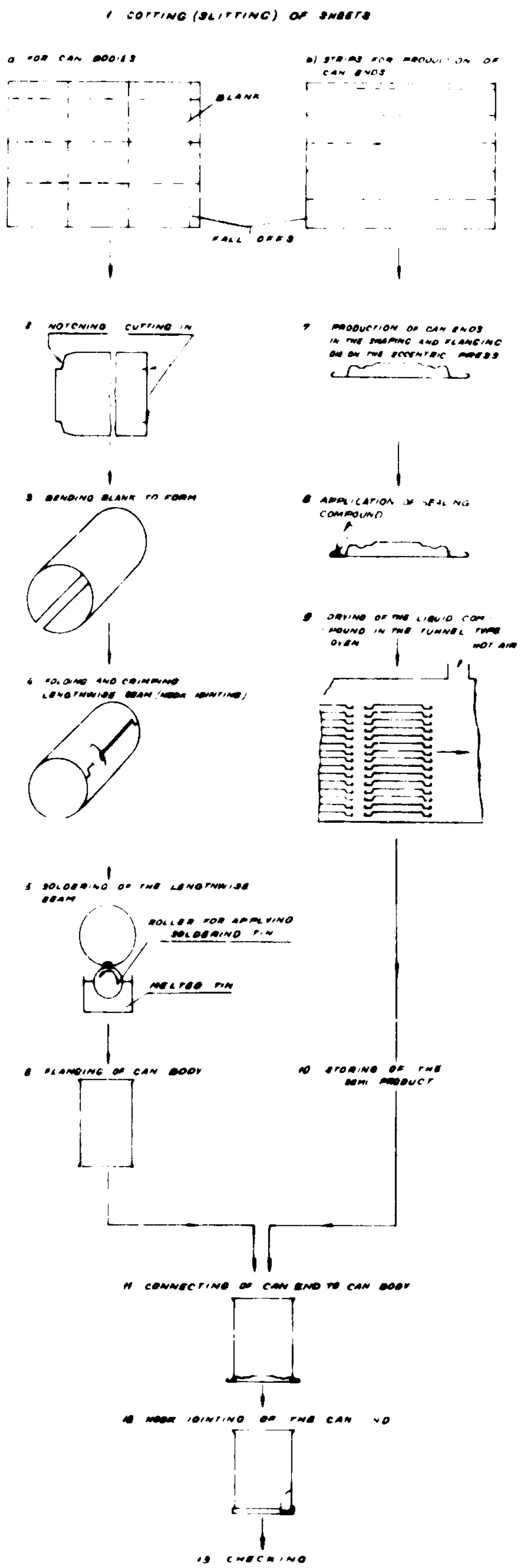


Figure 14. Can construction

Today we still distinguish between manual, semi-automatic and automatic processes for the production of cans. Regardless of the production method, the technological sequences remain the same as shown in figure 14 above. The basic operations can be modified according to the required shape of the can.

An important question is the location of can production. There is no universal solution to the problem of the most economic location of can production, as location depends on given conditions. However, certain measures of rationalization should be taken. For a national economy it would be practical to have one or more factories (depending on transport facilities and distances) specializing in the production of can ends (also whole cans for the immediate region) which would be used by the larger food-processing industries with semi-automatic or fully automatic lines for the production of can bodies. Such specialization becomes necessary in view of the variety of machines necessary for the production of can ends, e.g. gang slitters, eccentric presses and dies, flanging machines, machines for applying liquid sealing compounds, tunnel-type ovens for drying the sealing compounds, and machine tools for maintenance and grinding.

Such an organization of the production processes offers several advantages:

Rationalization of the production of can ends and full utilization of plant capacity (e.g. presses with 300 strokes per minute);

Optimum utilization of transport facilities (e.g. packing of can ends into wooden cases or cartons made of five-layer corrugated board);

Avoidance of technical problems and of downtime at smaller food-processing plants.

Coating and printing of tinplate can be similarly rationalized by carrying out these two processes at modern production plants. It should be mentioned here, that if coated and printed tinplate is exposed to unfavourable transport conditions, paper should be inserted between the tinplated sheets to prevent damages; for transportation of cans, bags made of kraft paper can be used.

The production of cheap and good quality cans is only possible in modern plants with a high degree of automation; needless to say, marketing must be satisfactory in order to utilize the plant capacity. Automatically controlled production plants usually have a capacity of 150 to 600 cans per minute. Such plants require only small building sites and few workers in the production process, but highly skilled labour is needed for adjustment and maintenance work. As idle time can cause serious losses, emphasis should be put on the technical training of the maintenance staff.

A number of problems may arise from the transportation of empty cans from their place of production to the canning plant (e.g. damage, especially to the tin flanges or under-utilization of the loading capacities of lorries). It is possible to reduce the volume of space taken up by cans by flattening the can bodies after soldering the side seams (figure 15). Cans are then reshaped at the canning plant and

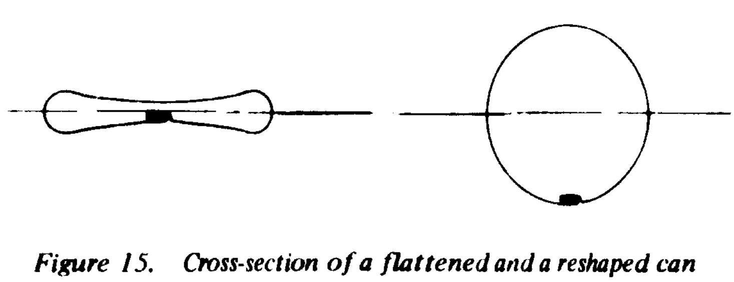


Figure 15. Cross-section of a flattened and a reshaped can

can-ends connected to the can body. However, this method increases the percentage of damaged cans and requires the installation of reshaping machines at the canning plants.

Figure 16 shows the machines used in an automatically controlled plant, in the following order (operations corresponding to those in figure 14 are indicated in brackets):

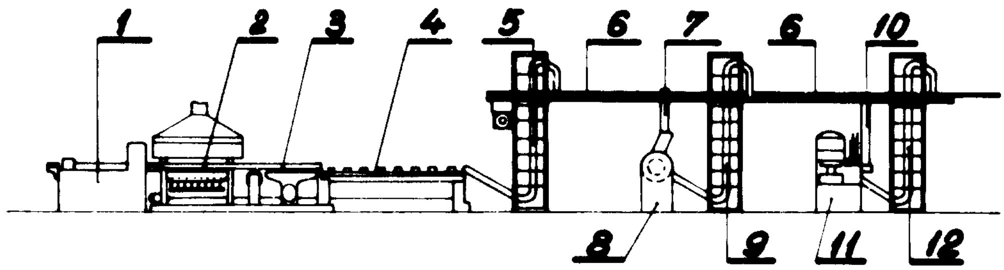


Figure 16. Can production. Flow chart of an automatically controlled plant

1	Automatic body-maker	(operation 2, 3, 4)
2	Automatic soldering attachment	(operation 5)
3	Cooling-down station for cans	
4	Conveyor	
5	Elevator	
6	Horizontal conveyor	
7	Feed channel	
8	Automatic flanging machine	(operation 6)
9	Elevator	
10	Feed channel	
11	Automatic can sealer	(operation 11, 12)
12	Elevator	

Though tin-can production as a whole seems to be very simple, it calls for precision in the design of cans and in each production operation; especially in tooling and adjustments high precision is required. A faulty can is usually not only a loss in itself but also destroys the preserved food, the value of which is usually higher than that of the can.

The sealing of the bottom and top can-ends presents many problems as the bottom is sealed by the tin-making industry and the top (the lid) by the food-processing industry. Due to faulty sealing, considerable losses are frequently incurred.

The sealing and connecting of can-ends to the can bodies are carried out on sealing machines. There are a great variety of hand-operated to fully automatic sealing machines on each of which a good seal can be made but at varying speeds.

Cans are sealed by placing the can on the lower seaming plate and by inserting the lid of the can; on the latter the sealing head is then applied with sufficient pressure (figure 17). All parts used in the sealing operation have to be perfectly made and well adjusted.

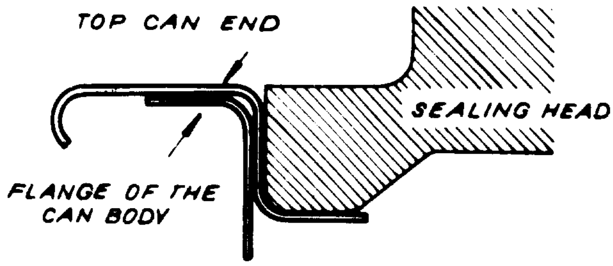


Figure 17. Sealing of top can-end

In figure 18 the first operation roller is set to roll around the periphery getting closer to the sealing head, thus effecting the first sealing operation.

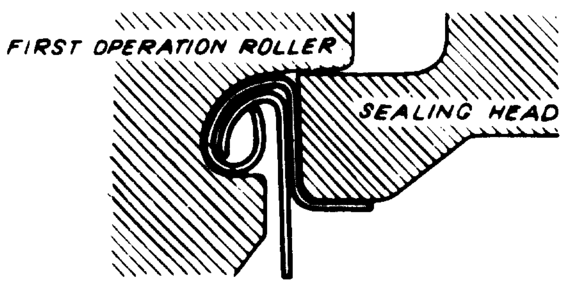


Figure 18. Sealing of top can-end. First operation

The final closing operation is carried out in the same way as the first one; however, the second operation roller has a different profile (figure 19).

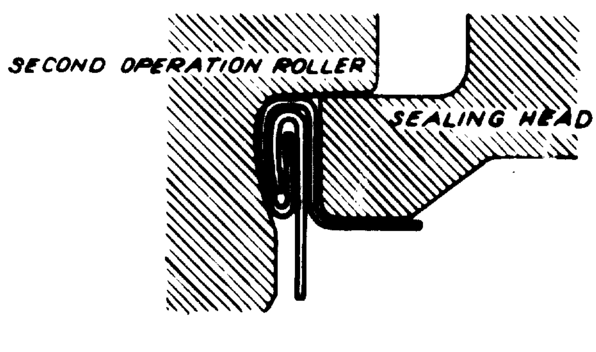


Figure 19. Sealing of top can-end. Second operation

With a can having a lengthwise seam of the hook-joint type, the double thickness of the can body enters the circumferential seam of the same joint type; this is shown in figure 20. At this particular seam, high pressures are applied and the material is more greatly pressed, often causing deficiencies.

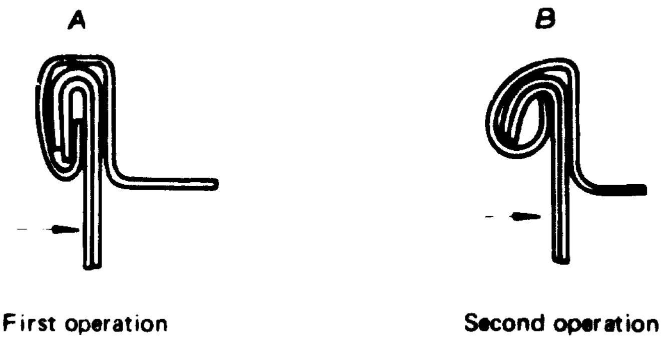


Figure 20. Double thickness of the lengthwise seam of the hook-joint type.

Sealing rollers have special profiles (figure 21). Though the contours of the sealing rollers may vary, they are very similar in shape. The contours and the dimensions depend on the thickness of the material used, precision soldering (amount of applied tin), the size of the can end and the shape of the flange. In figure 21, the contours are given according to American standards; the curve shown in this figure is called the "Angelus curve" (enlarged 20 times in the illustration).

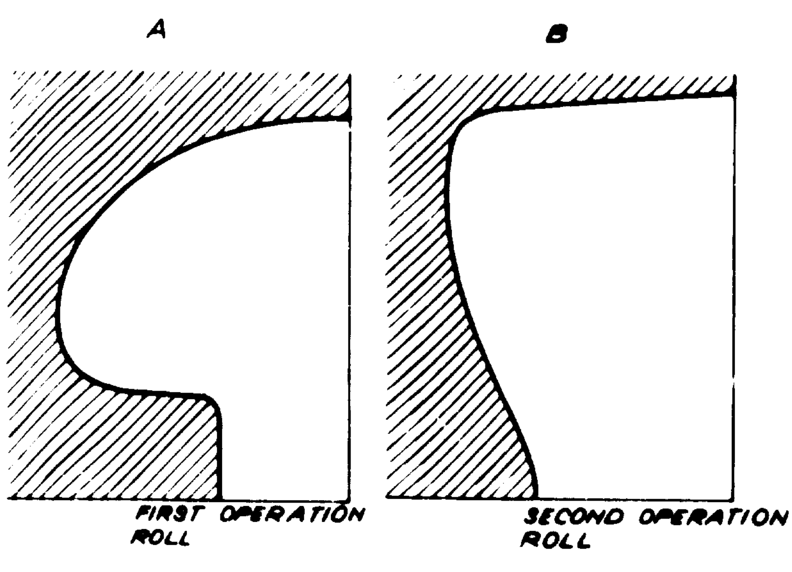


Figure 21. Contours of the first and the second operation rollers

The finished circumference seam of the hook-joint type can be checked by visual inspection from outside, by examining the dimensions and by visual inspection of the seam cross-section. By visual inspection from outside one of the basic defects can be detected on the lap seam; there the so-called droop appears (figures 22 and 23).

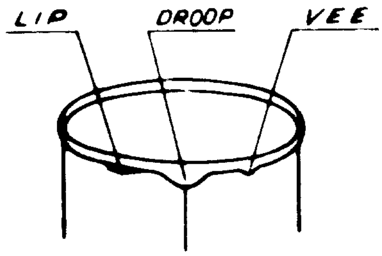


Figure 22. Circumference seam with droop defect

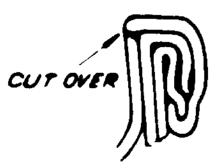


Figure 23. Double seam at lap cross-section

For checking the seam dimensions slide gauges and other special gauges are used. The dimensions of the seam shown in figure 24 are for cans with diameters from 54 to 108 mm.

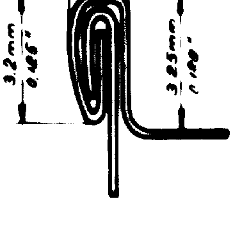
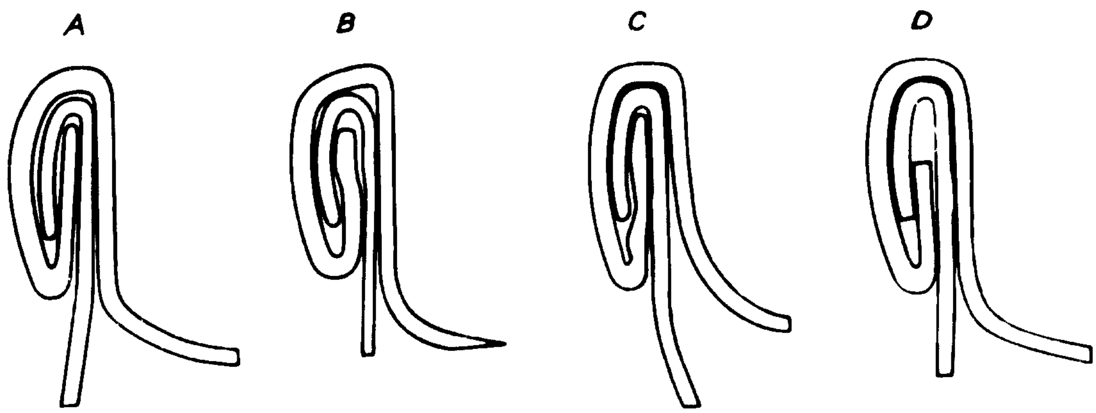


Figure 24. Seam dimensions

For the visual inspection of the cross-section of the seam, the circumference seam is cut in two by a saw. Due to the minuteness of this cross-section, inspection by the naked eye is virtually impossible. Usually, therefore, the cross-section of the seam is examined by means of a contour projector which magnifies the cross-section from 10 to 20 times its actual size. Given this enlargement, it is easy to detect a defect in the seam. Figure 25 shows cross-sections of correctly carried out and faulty circumference seams.



A: Both seaming operations carried out correctly
B: Second operation carried out slackly
C: Too high pressure applied during second operation
D: First operation carried out slackly

Figure 25. Cross-sections of seams

Other metal containers

Steel drums with capacities of 50, 100 and 200 litres are used for the transportation of food articles. These drums are made of pickled steel sheets and are coated inside with golden lacquer. There is also a special method of filling such drums with hot foodstuffs (e.g. tomato or fruit concentrates). The packaged goods are then pasteurized by heating the filled drums.

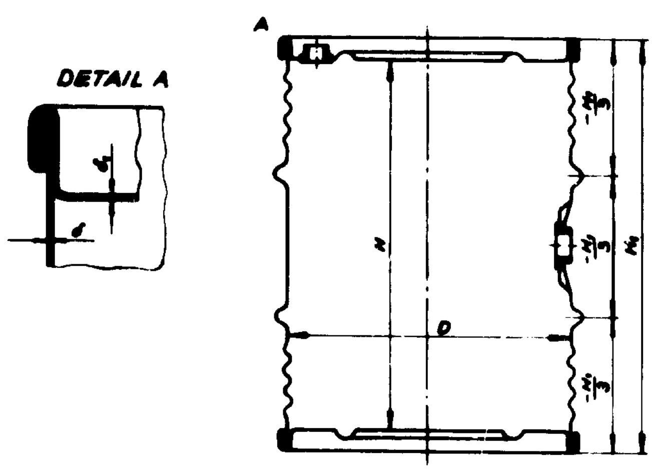


Figure 26. Circumference seam used for connecting top and bottom covers to the shell of steel drums

Figure 26 shows the method of connecting the top and bottom covers to the shell of pickled steel drums by the familiar circumference seam of the hook-joint type. The welded seam is used for heavier steel drums (figure 27). The side seams are joined together either by autogenous welding or electrically (lap-seam) by means of welding rolls.

Figure 27. Welded seam used for connecting top and bottom covers to the shell of heavier steel drums

Each drum is provided with two precision-made bungs. These bungs are usually placed on the top drum cover. There is a great variety of bungs, the best-known being that of the TRI SURE type (patented), shown in figure 28. The hexagonally shaped flange is pressed into the cover. TRI SURE bungs can only be used with drums made of pickled steel, as the deformation of the material can be significant.

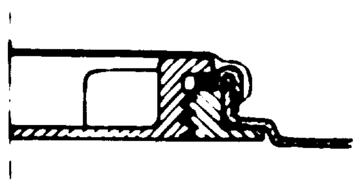


Figure 28. TRI SURE bung for pickled steel drums

If material of inferior quality is used, which cracks when pressing the recess for the TRI SURE type of bung, the solution shown in figure 29 (patented) can be followed for the plug.

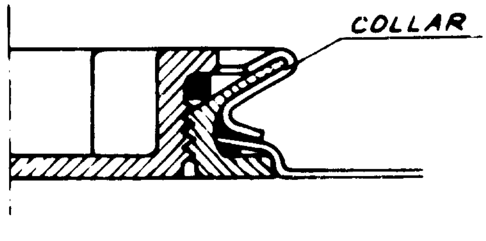


Figure 29. Pressing the recess for the TRI SURE bung when using second-grade material

In the case of steel drums containing food products, plugs should be sealed on the bottom part, so that the foodstuffs do not come into contact with the material of the plug which might, through this action, dissolve. Such a plug is shown in figure 30.

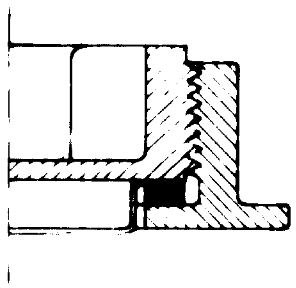


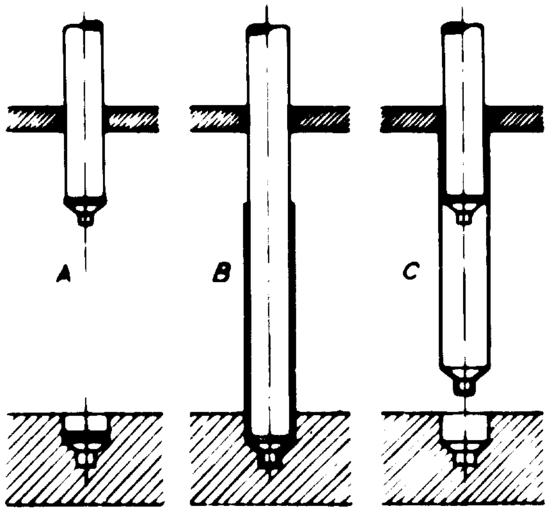
Figure 30. Sealing of plug

Aluminium, of 99.8 per cent purity, is a widely used material in the food-processing industry. It is applied as aluminium foil in various thicknesses from 8 microns upward. It has replaced tinfoil completely in the wrapping of chocolate and similar products and is used in manufacturing various receptacles for food. Aluminium foil lined with paper and plastics is an excellent packaging material for various food articles.

Aluminium in the form of aluminium sheets cannot be used so easily, for it is difficult to solder the side seams of aluminium cans. During the Second World War galvanic nickelling was introduced to treat those parts of cans used in hook jointing in order to make normal soldering possible. This process, however, proved too costly to be commercially exploited. Aside from the packaging of chemicals, aluminium drums are well suited as beer containers (beer barrels are manufactured in 25- and 50-litre sizes).

Today the production of tubes is based also mainly on aluminium. Only small quantities of tubes are made from tin for pharmaceuticals, or from lead and tin-coated lead for other products of the chemical industries.

The tube shape is obtained by pressing and stretching one disc in a single stroke of the die (figure 31). The average capacity of a tube press is 60 pieces per minute. Tubes are produced in various sizes ranging from 9 to 45 mm in diameter. They are painted on the outside and coated with golden lacquer on the inside. Tube ends are treated with a sealing compound to safeguard the seal after filling.



A = Insertion of disc into the die
B = Extrusion of semifinished tube by means of arbor
C = Removal of semifinished tube from arbor

Figure 31. Tube production

Chapter Five

OTHER PACKAGING MATERIALS

Glass

The basic materials for the production of glass are quartz sand, calcinated soda and limestone. To these basic materials dolomite, potassium carbonate, borax, potassium, sodium nitrates etc. can be added. This mixture, together with scrap glass, is then melted either in a batch operation or in a continuous oven. (The ovens can be either gas or oil fired.) In the first type of oven, glass is melted in pots made of fireclay at temperatures of 1,400 to 1,450°C. When the glass has melted, the oven temperature is reduced to about 1,150°C and the glass melt is ready for use. With the continuous type of oven, glass is produced in the so-called bath-oven. The continuous oven or bath-oven, also made of fire-resisting material, has a bath-tub shape with a frontal feeder for feeding the mixture of raw materials and an outlet for the molten glass. In the different zones of the bath-oven the temperature varies between 1,150 to 1,500°C.

The molten glass can be drawn off either by hand or mechanically, depending on the production method, i.e. manual, semi-automatic or fully automatic. Since manual production of glass containers is no longer profitable, it is now limited to carboys of 5- to 50-litre capacities and to odd-shaped bottles that cannot be produced mechanically. When using the manual production process, molten glass is drawn off by means of blowpipes through which air is blown. The initial forming is carried out outside the mould; the final form is obtained in the mould made of wood or cast iron.

In the semi-automatic production process, molten glass is drawn off manually by means of a steel rod and fed into the semi-automatic machine. In this machine the neck of the container is formed by means of a vacuum, and then the initial form is made by admitting compressed air. Afterwards the container is transferred by hand from the first mould to the second mould where the final shape is obtained, again by means of compressed air.

Automatic production consists of two principal methods, the first of which is the so-called suction method. The first mould of the automatic machine enters the oven and, by means of a vacuum, a fixed amount of glass is drawn off into the mould where the initial shape of the container is formed. The pre-moulded glass is then mechanically transferred into the next mould where the container receives its final shaping through compressed air. The main feature of the second method is the drawing off of exact amounts of molten glass by means of feeding attachments. Fully automatic machines have so-called feeders, i.e. special glass feeding attachments. A feeder consists of the feeding channel connected to the oven through which the glass, being heated to a certain temperature, is conducted to the filling device. From this device exact amounts of glass, in the shape of large drops, are fed to the first moulds. The rest of the production process is the same as that for the suction or vacuum method.

The automatic production of glass containers is technically the most perfect process and the most profitable from the economic point of view (table 8).

TABLE 8. OUTPUT OF BOTTLES ACCORDING TO PRODUCTION PROCESS

Process	*Hours*
Manual	720
Semi-automatic	320
Fully automatic	16

Glassware, including glass containers, produced by these methods possesses little strength because of the cooling-down conditions in the moulds, i.e. the internal stresses so produced. The cooling-down of glass is therefore carried out in tunnel-type ovens. There the glass containers are heated again to 500 600°C (depending on the glass composition) and cooled down gradually. In this way the internal stresses are eliminated and the glass containers made ready for use.

Shaping, tolerances and quality control

The term "technical shaping of glass containers" refers to the correct choice of shape and dimensions in accordance with production possibilities.

An object that is technically incorrect in shape may reveal a number of inadequacies when used. Before placing his orders the customer should therefore consult the experts of the glass manufacturers on form and dimension. The most favourable shape for glass containers is that of the cylinder. It is the most suitable form for the production process and the more one deviates from this basic shape the less efficient it becomes for production. Table 9 lists optimal data (width, length, thickness etc.) and ratios of various sized glass containers produced at fully automatic plants.

The choice of dimensions for glass containers is also influenced by production technology. The containers are shaped in cast iron moulds while they are still in a plastic condition. When leaving the mould, the glass must be sufficiently hardened by the mould, which has absorbed a portion of the heat, so that dimensional discrepancies will not occur. The specified dimensions must be set to ensure that the volume and neck are suitable for upright sealing and to limit dimensional discrepancies. Table 10 lists the admissible tolerances.

TABLE 9. GLASS CONTAINERS PRODUCED AT FULLY AUTOMATIC PLANTS – OPTIMAL DIMENSIONS AND RATIOS

Container size	*Diameter or width (mm)*	*Height (mm)*	*Ratio height : diameter or width*	*Mean wall thickness (mm)*		*Variations in wall thickness (mm)*	*Ratio diameter of body : diameter of neck*	*Minimum curvature of radius (mm)*	*Maximum weight (g)*
				light containers	*heavy containers*				
Small	19–50	25–75	3 : 1	1.5	2.5	± 25	3 : 1	3	85
Medium	50–100	75–150	3.5 : 1	2	3	± 25	4.5 : 1	6	450
Large	100–165	150–300	3 : 1	3	4.5	± 25	6 : 1	9	1.600

TABLE 10. GLASS CONTAINERS ADMISSIBLE TOLERANCES

Height	*Tolerances*	*Diameter*	*Tolerances*	*Permissible degree of ovalness (greater axis minus smaller axis)*
25 75	± 1.5	25 75	± 0.75	0.02
	± 1.5	75 150	± 1.20	0.02
	± 1.5	150 225	± 1.50	0.0175
	± 1.5	225 300	± 2.00	0.0175
	± 3.0	300 500	± 3.00	0.0175

In addition to complying with the admissible dimension tolerances, glass containers must be free of internal stresses in order to sustain sudden changes of temperature within given limits. A temperature difference of 45°C is adopted as the limit. Glass containers used for carbonated beverages have to sustain pressures from 4 to 20 atmospheres.

Efficient quality control helps to minimize the breakage of the glass containers during usage. As glass containers are subject to rough handling and transportation they must be resistant to mechanical shocks. Taking these features into account, quality control of glass containers must include the following:

(a) Visual inspection (elimination of glass containers with cracks, break-offs and similar defects);
(b) Dimensional checking;
(c) Thermal-shock testing;
(d) Mechanical-shock testing;
(e) Pressure testing;
(f) Checking of colour.

The labelling and sealing of containers must also be considered. The label provides information on the kind, quantity and quality of the contents. Paper labels are printed in multi-colour and glued onto the containers after filling. "Ceramic labels" are ceramic paints baked on glass, the paint being applied by means of a silk screen. As these labels last as long as the containers, they are normally used for returnable containers. Such a label is three to five times more expensive than a paper label. Costs are recovered if the container is used more than five times.

Glass containers are widely used in the food-processing industry and are employed for packaging natural and artificial juices, beverages, beer, wine, milk, cream, yogurt, kefir and processed fruits and vegetables. Containers differ greatly in capacity; table 11 lists the most common sizes.

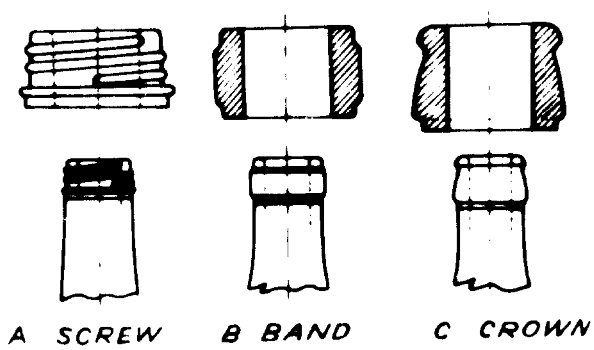
Glass containers are also produced in a variety of shapes. There is a tendency towards low-neck containers to obtain maximum content capacities at relatively low height to facilitate transportation and storage.

TABLE 11. GLASS CONTAINER CAPACITIES ACCORDING TO PACKAGED PRODUCT

Product	*Litre capacity*
Natural juice	0.25
Artificial juice	0.2
Beer	0.33. 0.5
Wine	0.7, 1, 2
Milk	0.5, 1
Fruit and vegetables	0.25, 0.58, 0.8
Spirit	0.2, 0.5, 1
Vegetable oil	0.5, 1
Vinegar	0.5, 1

Closures for glass containers

The closure of glass containers is another problem to be dealt with. Three main types of closure have been adopted, namely closure by cork plug, by crown cap and by screw cap. Each type of closure requires a special kind of bottle neck (figure 32). Figure 33 shows drawings of crown and screw caps (twice their actual size).



A: Bottle neck threaded for screw cap
B: Bottle neck of band type
C: Bottle neck for crown cap

Figure 32. Bottle necks and caps

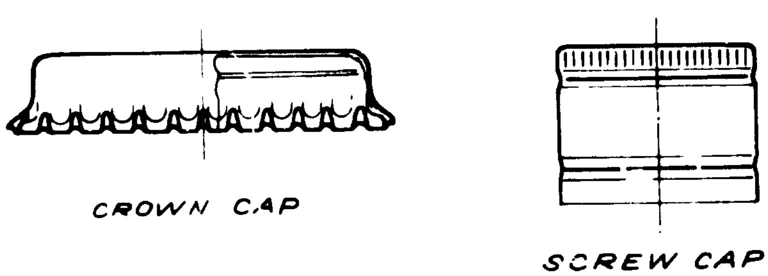


Figure 33. Crown and screw caps

A bottle neck strengthened by a band in order to achieve higher mechanical resistance is called a band bottle neck or simply a band. For this kind of neck, cork plugs and various plastic plugs are used.

The crown cap derives its name from its resemblance to a crown. It covers and closes the bottle neck and is used for carbonated beverages, such as beer and mineral water. The cap is made from tin and aluminium sheets, whereas the gasket may be made of cork or of rubber.

The threaded bottle neck has a thread onto which a metal or plastic cap is wound. A screw cap made of aluminium is shown in figure 33 which was threaded by a special capping machine for "caps with rim". The lower part of the cap is passed over a rim on the neck; when unscrewed, it separates from the rest of the cap along the perforation. The gasket is made either of cork or rubber.

Glass jars can be sealed in various ways, but three types of cap Omnia, Pano and Twist-off and the corresponding jar necks are commonly used today. The Omnia cap is made of aluminium, 0.15 mm thick and lacquered with golden lacquer. For this type of cap a special shape of jar neck is required (figure 34).

The Pano cap is also made of aluminium strips it is, however, less suitable for glass with high tolerances. The Twist-off cap, made of tin sheet, is a very successful hybrid of the threaded and bayonet types of cap.

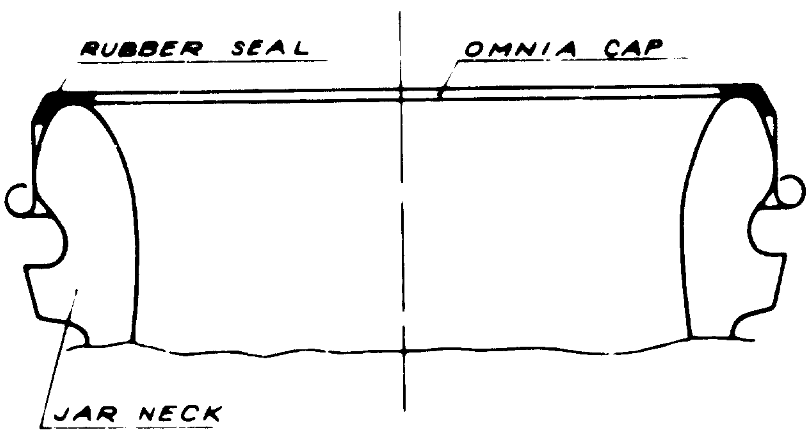


Figure 34. Omnia cap and corresponding jar neck

Cellophane

Cellophane is a transparent foil of regenerated cellulose without fibres and pores. Its relative density is 1.45. Next to paper, it is the oldest kind of wrapping material and holds priority among all packaging foils despite the rapid development of plastic material. Cellophane is highly permeable to steam and when immerged in water it can absorb moisture up to 100 per cent of its own net weight. When dry, it is impervious to gases; in a wet state it is pervious to gas in varying degrees. It is also impervious to fats and oils and insoluble to organic solvents. Cellophane does not have the same

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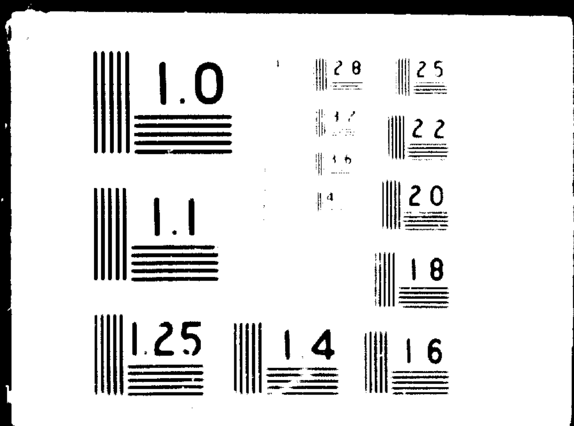

tensile strength as plastics and is non-resistant to strong acids and alkalis. It can be easily printed by aniline colours or the copper printing method. As it is flammable, it cannot be heat-sealed. By subsequent lacquering cellophane becomes heat-sealable and steamproof, and by combining cellophane and plastic foils, water absorption is diminished and the degree of perviousness to gases greatly lowered.

Plastics

The rapid development in the production and the application of plastics during the last decades is also reflected in their use as packaging materials. The food-processing, the pharmaceutical and the cosmetic industries are the main users of plastics for commercial packaging.

Like no other material, plastics have a number of positive properties which can be adjusted to special needs by suitable choice and combination of raw materials. Thus, packages made of plastics can be as light in weight as those made of paper and at the same time transparent, gas- and moisture-proof like those made of glass. Some plastic materials are even impermeable to gases and odours. They are not attacked by insects and are resistant to many chemicals and to atmospheric influences. Plastics have smooth surfaces which can be decorated by printing. Their mechanical properties can be varied to such extents that they can be sealed hermetically to protect the contents from dust, water and so on. Some plastics remain unaffected by temperatures of from −60° to +200°C.

The following plastic materials are frequently used for the manufacturing of packages and containers: cellulose acetate (acetyl cellulose), rubber hydrochloride (e.g. Pliofilm), polyvinyl chloride (e.g. Saran, Cryovac), polyethylene, polyesters (e.g. Mylar), other polyvinyl compounds and polyamides (e.g. Rilsan).

Acetyl cellulose has a good dimensional stability. It is transparent, durable, resistant to petrol, fat and oils and impermeable to gases and vapours. It is more expensive than cellophane. Acetyl-cellulose film is used for windows of carton packs and for packaging products that perish if sealed hermetically. Transparent commercial packages for many products are made out of thicker acetyl-cellulose boards. Its use-temperature ranges from −50° to +150°C.

Rubber hydrochloride is transparent and resistant to fats but not very resistant to moisture. Its relative density is 1.11. It is not very durable under extreme temperatures and under the influence of light. Per unit of weight it is more expensive than cellophane, but, owing to its greater strength, thinner films can be produced. However, above 90°C it loses some of its strength. It is increasingly used for packaging fresh meat, especially beef, as it preserves the colour of meat better than cellophane.

Among plastic materials *polyvinyl chloride* has the highest degree of impermeability to water and gases, as well as resistance to chemicals, strength, toughness and elasticity, even at low temperatures. Polyvinyl chloride is completely transparent. Its relative density is 1.68. It cannot be processed on normal packaging machines; consequently it is only used in cases where the aforementioned exceptional properties are of great importance (e.g. packaging of salted meat products, poultry, cheese). In such cases the bags must be vacuumized before they are hermetically sealed. Goods packaged in this way are, for a certain period, immersed in water heated up to 95°C. When the bags are lifted from the water, the packaging material shrinks 30 per cent so that it fully bonds the packaged goods and becomes almost invisible. Polyvinyl chloride softens at 130°C and melts at 140°C.

Polyvinyl mixtures with a relative density from 1.23 to 1.29 can be produced either from pure (plasticized) polyvinyl chloride (PVC) or formed by the co-polymerization of vinyl chloride, vinyl acetate and other artificial resins. Through this, a wide range of materials with various properties (ranging from hard and shiny to soft and elastic) can be obtained. Polyvinyl films have a good dimensional stability, are almost impenetrable by odours and water vapour, and are impermeable to gases and resistant to fats, oils and inorganic chemicals. They can be printed easily and firmly heat-sealed. Polyvinyl resins are soluble in some of the organic solvents. They are slow-burning and lose their toughness at low temperatures. They are used frequently for lining paper, boards and aluminium foils.

Polyethylene, a synthetic highly molecular paraffin, has a milky white colour and a greasy touch like paraffin. It is flexible even at low temperatures, resistant to acids (including hydrofluoric and trichlor-acetic acid), alkalis and inorganic chemicals. Polyethylene is also insoluble in all solvents (at normal temperature), almost resistant to moisture and can be processed without addition of plasticizers. Its resistance to fats and oils is relatively low. Because of the low production costs, polyethylene is used for the mass production of foils, bags, containers, bottles and other commercial containers for the food-processing, the pharmaceutical and the cosmetic industries. Polyethylene is also used for plugs and caps for packaging containers made of other materials. It is increasingly employed for the making of transportation packs. Polypropylene has similar properties to polyethylene. From both of these materials films are made with orientation molecules that reduce the dimensions under the action of heat. Their use-temperature ranges from −50° to +80°C.

The *polyester foil* obtained from ethylene glycol and terephthalic acid, is, to a certain extent, used for packaging containers because of its exceptional toughness, gasproofness and resistance to acids, alkalis, fats and solvents. It melts at 250°C and the mechanical properties are preserved even at temperatures as low as −30°C. The relative density of polyester foil is 1.38 to 1.39. Owing to its high melting point, it is necessary either to add benzyl alcohol when sealing it or to cover the foil with a layer of material having a lower melting point. Polyester foil is rather expensive, but because of its outstanding mechanical properties it is used for packing heavy machinery parts with sharp edges and also for packs which are subject to unusual mechanical loads during transportation in storehouses or during their shelf-life.

Polyamide films maintain their mechanical properties up to a temperature of 110°C; consequently, sterilized and pasteurized products can be filled into polyamide packages. Their relative density is 1.14 to 1.15. Polyamide films have a good water-vapour transmission and are used in the packaging of processed meat and fish.

Often two or more layers of similar or different materials are rolled together in a combined film to achieve the required properties and characteristics. Other typical combinations are: acetyl cellulose with rubber hydrochloride; textiles, polyethylene, kraft paper and polyvinyl mixtures with cellophane; and cellophane with rubber hydrochloride. Through the first combination transparency, stability, resistance to moisture and easy heat-sealing are achieved; the second renders a very strong and water-vapour-resistant material (which is often used for military purposes).

Wood

Wood is among the oldest materials used for packaging containers; the wooden case was the first type of modern transportation container for ready-made goods and for raw materials. In the initial stages of modern transport, quality wood was available in sufficient quantity and at low price. Along with excessive exploitation of forests and the growing demand for packaging containers, the price of wood increased and other materials became competitive to it. This is especially true of corrugated board which, due to its low weight, helps to lower transport costs. However, even in the technically developed countries wooden packaging containers still play an important role due to their mechanical properties.

The properties of wooden packaging containers depend to a great extent on the kind of wood used. The most important property is resistance to bending and blows. Wood is also one of the few packaging materials that can be nailed. Wood of conifers and soft wood of deciduous trees have less mechanical resistance than the hard wood of deciduous trees. For instance, soft wood holds nails less well than hard wood; among soft and hard woods, however, there are certain types that tend to splinter when nailed.

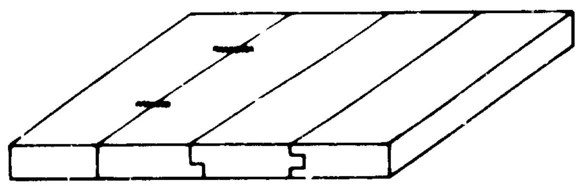

Figure 35. Method of interconnecting planks for wooden cases

Sawn, chopped and peeled wood is used in the manufacturing of packaging containers. Planks and battens (mostly soft wood) are the end products of the sawing process. In this process an average of only 65 per cent of the trunk is utilized. In keeping with the tendency to increase the utilization of material and to use hard wood of deciduous trees for packaging containers, chopping and peeling are applied.

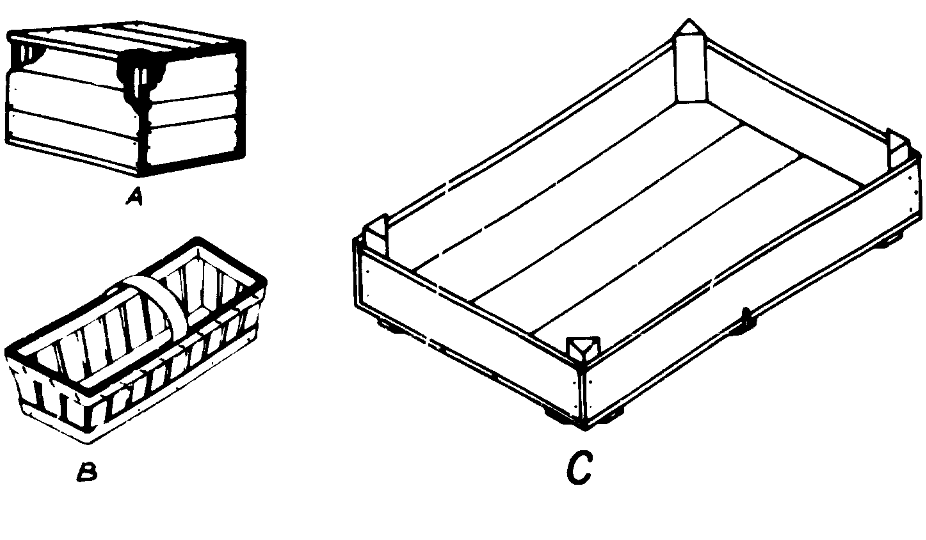

Figure 36. Various types of wooden containers A: Wooden case with interior reinforcement B: Fruit basket made of plywood C: Fruit crate made of laths

Plywood is produced, for example, by gluing together several peeled-off layers of wood (veneer). Plywood is much used in the production of cylindrically shaped wooden barrels and other wooden packaging containers. A method of interconnecting planks for wooden cases is shown in figure 35. Illustrations of various types of wooden containers are given in figure 36.

Textiles

The textile most frequently used for packaging is jute (e.g. for burlap, coarse sackcloth with canvas or ribbon fastening and sacking for packaging of heavy goods). Other materials employed are cotton (especially in the United States) and hemp and flax. Of the materials used in Europe for packaging containers, the textiles represent 4 per cent of total value. In order to increase the protection of packaged goods and to simplify the process of packaging or to give packaging containers a better appearance, textiles are sometimes laminated with other materials. For instance, textiles can be impregnated to make them water-proof and resistant to moulds or to reduce their flammability.

Chapter Six

PACKAGING TECHNIQUES

The packaging process is only one of a number of processes that commodities undergo on their way from production to consumption; it can be effected in various ways, ranging from manual to fully automatic packaging. The level of the procedure depends on the level of the economic development of the relevant country and its financial capacities.

Though packaging machines are not cheap, they are essential for the packaging of food. Machine packaging not only guarantees the highest sanitary level, but ensures the lowest packaging costs per unit of product and avoids dissipation of resources.

Packaging is being carried out in all branches of industry--in the agricultural sector, in wholesale and retail trade, and especially in the food-processing industry that represents a separate field with its wide production programme. An extra large assortment of packaging equipment and machines is required for the packaging of products of the food-processing industry. The modernization and automation of packaging entail the provision of expensive and complex machinery. In choosing equipment for automatic packaging, attention should be paid to the most profitable capacities at the lowest possible investment cost.

Extensive investments are rather rare. It is therefore important to utilize the available financial means for solving the most acute problems. In view of the complex nature of automatic packaging, both in the economic and technical sense, it is necessary to approach this problem systematically to ensure close co-operation among all interested partners. If required, centralized and co-ordinated measures should be taken by boards and business organizations to ensure such co-operation.

Packaging facilities are often located on the periphery of food-processing plants, though they form part of the production programmes of these plants; this should be taken into consideration when production capacities are built and not left for a later date.

Location of packaging facilities

It is difficult in this brief paper to discuss the automation of packaging in all the food-processing industries because of the diverse and complex nature of the problem. In general the packaging can be carried out at the site of production (i.e. within a food-processing plant or an agricultural enterprise), by specialized packaging firms and by the wholesale and retail trade.

Through packaging within a food-processing plant or within an agricultural enterprise, the optimum ratio can be achieved between the fulfilment of the set task and the full utilization of production means. The advantages of packaging within the food industry include:

Low packaging costs;

Optimal solutions of the difficulties of packaging within the enterprise through automation;

Optimal utilization of high-capacity machines;

Limited number of container types;

Improved marketing with commercial firms that have no pre-packaging plants of their own;

Guarantees for quality, quantity and price of the commodities packed.

Packaging by specialized packaging firms is useful as such firms can offer up-to-date services to a large number of small-scale producers. Small-scale food-processing plants and agricultural enterprises with a low output cannot use modern packaging machinery profitably. Specialized packaging firms frequently carry out certain final operations on the products to be packed, i.e. cleaning, sorting, roasting, glazing etc., and thus become involved in food processing. Commodities prepared and packaged by such plants command higher prices and can be more easily marketed.

One of the aims of packaging is to arouse interest in the commodity exhibited and to encourage the customer to buy it. The container itself can inform the customer about quantity, contents, price etc. If the food-processing plant or the agricultural enterprise do not package their products in commercial packages, this job must be done by the wholesale or retail trade. Large-scale commercial establishments have their own up-to-date packaging plants, proper packaging containers and a special style in packing their commodities. In small shops, where the commodity is finally acquired by the customer, the goods are wrapped or packed for practical as well as for advertising reasons.

Packaging machinery

From its beginning after the First World War packaging machinery developed rapidly. The first packaging machines had capacities of 15 packagings per minute, or 25 to 30 packagings per minute for commercial packages. Later machines reached capacities of 45 to 50 packagings per minute and after a number of years capacities reached 60 to 70 packagings per minute. Such machines are still being built today. However, there are also machines with an output of 90 to 120 and 300 packagings per minute. Since the Second World War, the production of packaging machinery has greatly expanded, especially in the Federal Republic of Germany, France, Italy, Switzerland and the United Kingdom. Recently East Germany, Hungary and the Union of Soviet Socialist Republics also took up production in this field.

Two of the questions important for the future development of packaging machinery are: *(a)* Whether to build single- or multi-operation machinery and *(b)* whether preference should be given to high-capacitv or to low-capacity machines.

Machines with very high capacities have a narrow field of application. They can be used only in large plants that can afford high investments and have strong and safe marketing outlets for their mass products. Machines with smaller capacities but designed to carry out a number of operations are of more universal use and are much in demand today, especially in view of the far lower investment required. Such machines are easy to operate and can still be utilized when the production programme and the type of packaging container are changed.

The diversity of machines available is astonishing; there is hardly a commodity that cannot be packaged automatically. Packaging machines can be divided roughly into various groups according to:

(a) Types of packaging material (soft materials such as cellophane and paper, hard materials such as glass and wood);

(b) Special requirements for packaging containers (such as filling and sealing or filling and sealing combined with printing and the production of packaging containers);

(c) Types of product to be packaged (i.e. liquids, pastes, powders, granules, solid confectionery and single piece products);

(d) Filling methods (volumetric filler and weighing machines); and

(e) Supplementary processes (such as group-packing, labelling, coding and dating).

There is also the possibility of combining a number of low-capacity, semi-automatic machines, such as can-filling machines, vibrators, sealers, group-packing machines, in order to arrive at complete aggregates.

The wide range of different types of machines produced necessitates the careful study of individual packaging problems before the purchase of new machines. Maintenance, replacement of machine parts and the training of operators and maintenance workers become more difficult with the increasing number of different types of machines. On the other hand, fewer types of machines limit the choice of packaging containers. The following points should be observed in planning the purchase of packaging machines:

A minimum number of types of machines should be introduced into one country, if possible all of them of the same make.

The purchase of machines should be centralized in order to obtain better purchasing conditions.

The price of packaging containers depends on type and standardization. Standardization provides for a large run for each type of container. The containers must, however, have exact dimensions and the quality of material must be uniform; otherwise they cannot be used by the packaging machinery.

In introducing packaging machines into developing countries, various financial, commercial and technical obstacles have to be overcome. If the import of packaging machines is impossible, packaging procedures can nevertheless be improved by means of relatively simple measures. There are two basic packaging operations: container filling and sealing of packaging containers. Costs can be reduced and a high standard of hygiene achieved through rationalizing individual operations and human labour input. Examples for rationalizing the packaging of granules, liquids and powders are given below.

Granule filler: Figure 37 shows a silo, in which granular products are stored, connected with a simple filling attachment that is operated manually. The filling attachment consists of two interlocking pipes so that the volume of the filling can be changed if required. The filling device operates on a volumetric basis. The pipes are replenished and emptied through two sluices. The packaging container is pulled over the bottom part of the filler and filled by opening the bottom sluice. Thus a rather complex filling operation can easily be mechanized. (If polyethylene bags are used as packaging containers, they can be hot-sealed by means of heated jars.)

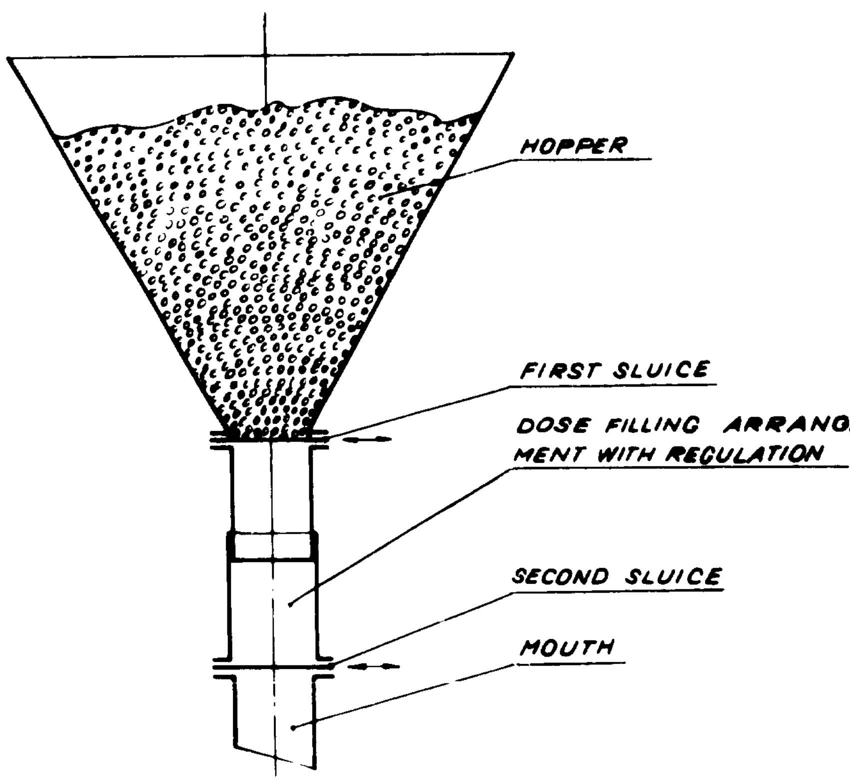

Figure 37. Granule filler

Powder filler: Figure 38 shows a silo (or hopper) for storing powder with the bottom end open. An inclined vibrating conveyor is connected with the hopper. Vibrations are generated by means of an electric magnet. A weighing machine is placed at the end of the vibrating conveyor. The vibrations make the powder fall into a bag on the scale. Once the bag is filled, the scale switches off the activity of the electric magnet, whereupon the conveyor stops the feed of material. This kind of filler operates on a gravimetric basis and ensures exact fills.

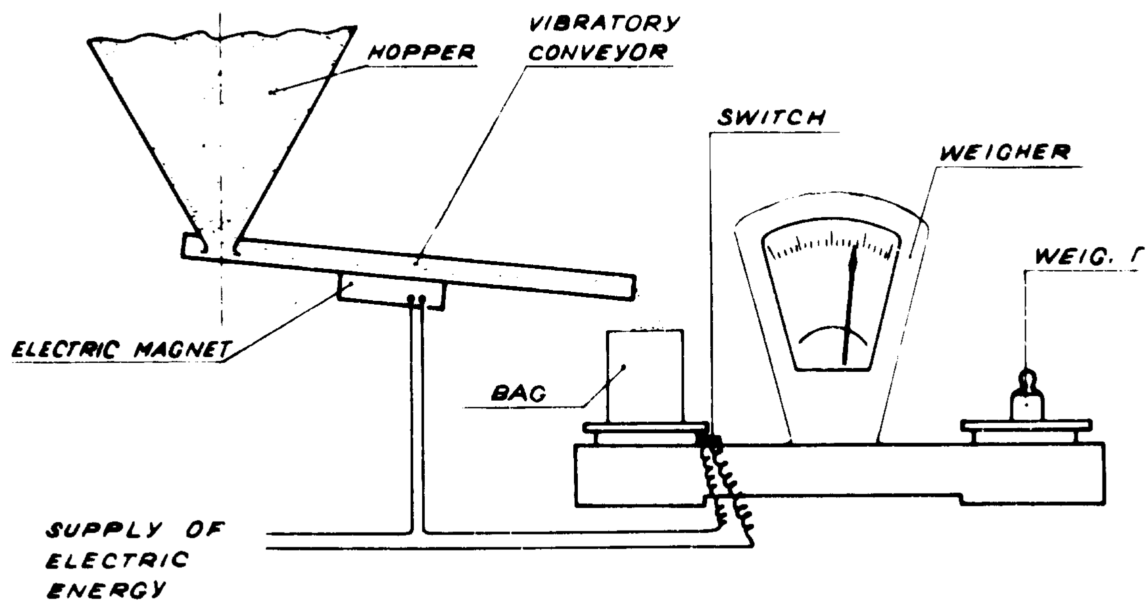

Figure 38. Powder filler

Liquid filler: Liquids to be packed are either stored in a receiver or a drum. For the draw-off, the receiver (or drum) is placed on a higher level. A flexible rubber or plastic hose is connected to the elevated vessel. A valve is then fitted to the end of the hose to regulate the flow. The pipe end is put into the bottle and once the liquid reaches a certain level in the bottle, the valve is closed. The bottle is then sealed with the corresponding cap. The outlay of this system is shown in figure 39 below.

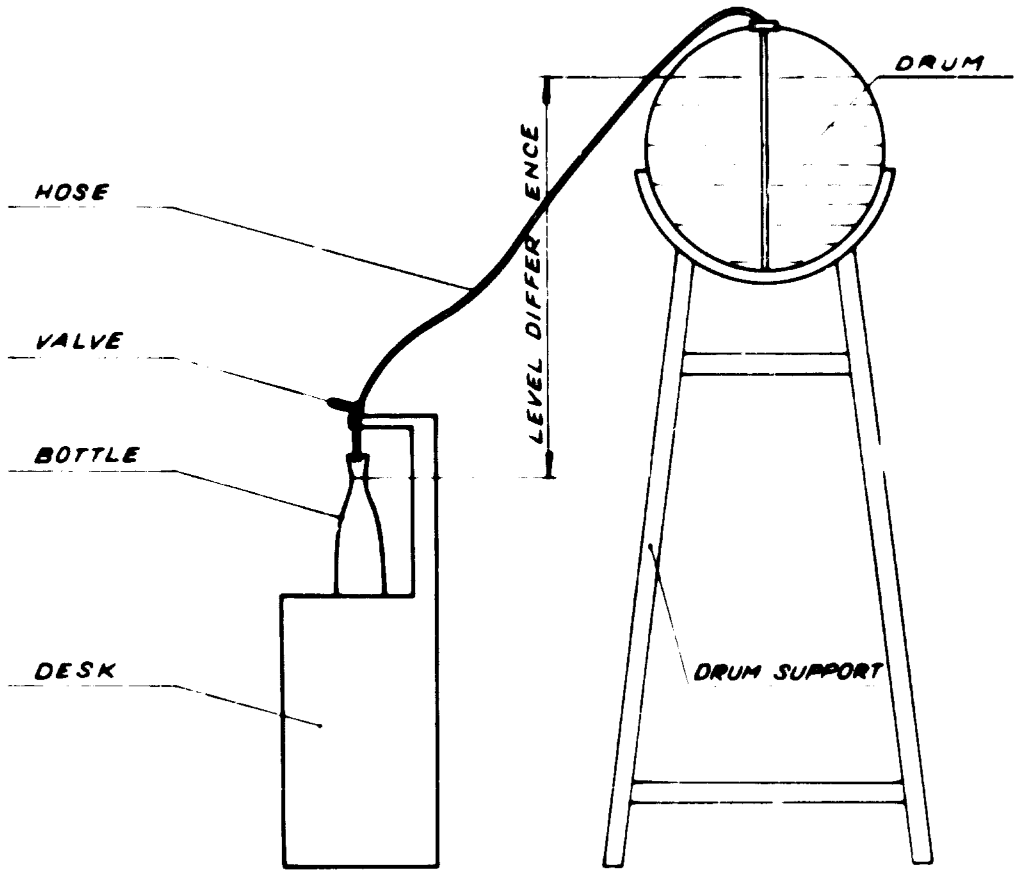

Figure 39. Liquid filler

Cost of packaging

The efficiency of a packaging machine depends on the cost per unit of package. The production cost per package can be calculated by the following formula, in which overheads, depreciation and the costs of raw material, labour and energy are non-variables:

$$C = (C_m + C_e + C_l + O + D)\frac{1}{1 - (N_n/N_e)}$$

C = cost per package

C_m = cost of raw material

C_e = cost of energy

C_l = labour cost

O = corresponding part of overheads

D = corresponding part of depreciation

N_n = number of spoiled packages for a given period

N_e = number of faultless packages within the same period.

The figures for N_n and N_e should be obtained from production records. The ratio between the values N_n and N_e is decisive for the final cost of the product.

Cost calculations based on the above formula are only valid if none of the packaged goods is spoiled by defective packages. In case of spoilage, the corresponding share of the value of these goods has to be added to the cost per unit package.

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