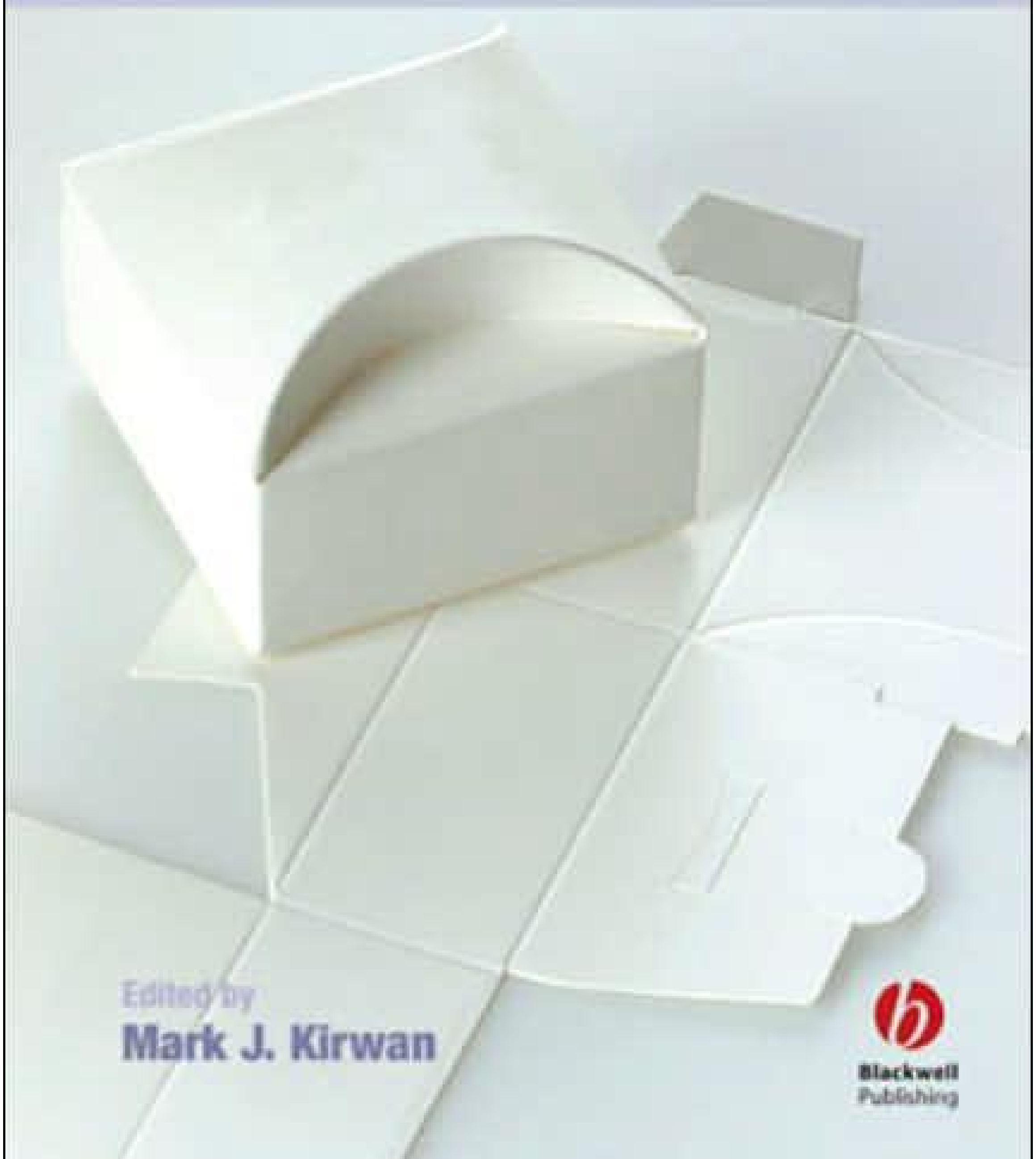
PAPER AND PAPERBOARD
PACKAGING TECHNOLOGY



Edited by
Mark J. Kirwan

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London, UK

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Paper and Paperboard Packaging Technology

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Preface

This book discusses all the main types of packaging based on paper and paperboard. It considers the raw materials and manufacture of paper and paperboard, and the basic properties and features on which packaging made from these materials depends for its appearance and performance. The manufacture of twelve types of paper- and paperboard-based packaging is described, together with their end-use applications and the packaging machinery involved. The importance of pack design is stressed, including how these materials offer packaging designers opportunities for imaginative and innovative design solutions.

Authors have been drawn from major manufacturers of paper- and paperboard-based packaging in the UK, France and the USA. The editor has spent his career in technical roles in the manufacture, printing, conversion and use of packaging.

Packaging represents the largest usage of paper and paperboard and therefore both influences and is influenced by the worldwide paper industry. Paper is based mainly on cellulose fibres derived from wood, which in turn is obtained from forestry. The paper industry is a major user of energy, and is therefore in the forefront of current environmental debates. This book discusses these issues and indicates how the industry stands in relation to the current requirement to be environmentally sound and the need to be sustainable in the long term. Other issues discussed are packaging reduction and the options for waste management.

The book is directed at those joining companies which manufacture packaging grades of paper and paperboard, companies involved in the design, printing and production of packaging, and companies which manufacture inks, coatings, adhesives and packaging machinery. It will be essential reading for students of packaging technology.

The 'packaging chain' comprises:

- Those responsible for sourcing and manufacturing packaging raw materials.
- Printers and manufacturers of packaging, including manufacturers of inks, adhesives, coatings of all kinds and the equipment required for printing and conversion.
- Packers of goods, for example within the food industry, including manufacturers of packaging machinery and those involved in distribution.
- The retail sector, supermarkets, high street shops, etc., together with the service sector, hospitals, catering, education, etc.

The packaging chain creates a large number of supplier/customer interfaces, both between and within companies, which require knowledge and understanding. The papermaker needs to understand the needs of printing, conversion and use. Equally, those involved in printing conversion and use need to understand the technology and logistics of papermaking. Whatever your position within the packaging chain, it is important to be knowledgeable about the technologies both upstream and downstream from your position.

Packaging technologists play a pivotal role in defining packaging needs and cooperating with other specialists to meet those needs in a cost-effective and environmentally sound way. They work with suppliers to keep abreast of innovations in the manufacture of materials and innovations in printing, conversion and use. They are aware of trends in distribution, retailing, point-of-sale/dispensing, consumer use, disposal options and all the societal and environmental issues relevant to packaging in general.

Acknowledgements

My thanks go to the contributing authors and their companies. It is not easy these days to find time for such additional work, and their contributions are much appreciated.

The text has been greatly enhanced by the diagrams kindly provided by a large number of organisations and by the advice and information that I have received from many individuals in packaging companies and organisations.

In particular, I would like to acknowledge the help that I have received from the following:

Iggesund Paperboard, The Institute of Packaging, the Confederation of European Paper Industries (CEPI), Pira International, Pro Carton, British Carton Association, Swedish Forest Industries Federation, PITA, Paper Federation of Great Britain, INCPEN, M-real, Stora Enso, Bobst SA, AMCOR (flexibles for food and healthcare packaging), Billerud Beetham (manufacturer of medical packaging paper, formerly Henry Cooke), Bill Inman (former Technical Manager at Henry Cooke), Alexir Packaging (folding cartons), Papermarc Merton Packaging, Kappa Packaging, Kappa Lokfast, Tetra Pak, Elopak, SIG Combibloc, Rose Forgrove, Marden Edwards, Robert Bosch Packaging Machinery, Rovema Packaging Machines, IMA (tea packaging machinery), Dieinfo, Bernal, Atlas, Michael Pfaff (re. rotary cutting and creasing), Diana Twede (School of Packaging, Michigan State University), Neil Robson (re. packaging issues in relation to the Developing World), National Starch and Chemical (adhesives), Sun Chemical (inks), Paramelt (coating and laminating waxes), Smith Anderson (recycling and packaging products), Interflex Group (wax/paper flexible packaging), John Wiley & Sons (publishers).

This book would not have been attempted without the experience gained in my packaging career, for which I thank former colleagues, especially those with whom I have been in contact recently: Reed Medway Sacks, Bowater Packaging (carton, paper bag and flexible packaging manufacture), Cadbury Schweppes (foods packaging), Glaxo (ethical and proprietary pharmaceuticals packaging), Thames Group (paperboard manufacture) and, in particular, Iggesund Paperboard, who encouraged me to become involved in technical writing.

I would like to thank Richard Slade (Findus and Cadbury Schweppes) for involving me in packaging development from the 1960s onwards; Dennis Hine, who led much of the investigative work on carton performance and packaging machine/packaging materials interactions at PIRA; and Richard Coles who involved me in lecturing on packaging technology at BSc and Institute of Packaging Diploma level at West Hertfordshire College.

I am indebted to Professor Frank Paine, whom I first met as a colleague in Bowater in the 1960s, for his cheerful support and encouragement during the writing, and for reading and commenting constructively on the drafts of the manuscript. He has nearly 60 years of international experience in packaging technology and a substantial involvement in authorship and editing. His practical advice and patience has been much appreciated.

Mark J. Kirwan

1 Paper and paperboard – raw materials, processing and properties

Mark J. Kirwan

1.1 Introduction – quantities, pack types and uses

Paper and paperboard are manufactured worldwide. The world output for the years quoted is shown in Table 1.1. The trend has been upward for many years.

Paper and paperboard are produced in all regions of the world. The proportions produced per region in 2003 are shown in Table 1.2.

Paper and paperboard have many applications. These include newsprint, books, tissues, stationery, photography, money, stamps, general printing, etc. The remainder comprises packaging and many industrial applications, such as plasterboard base and printed impregnated papers for furniture. In 2000, paper and paperboard produced for packaging applications accounted for 47% of total paper and paperboard production (PPI, 2002).

Table 1.1 World production of paper and paperboard

Year	Total tonnage (million tonnes)
1980	171
1985	193
1990	238
1995	276
1998	300
1999	315
2000	324
2001	318
2002	339

Source: PPI, 2002.

Table 1.2 World production % of paper and paperboard by region for 2003

Region	% Production
Europe	30.7
Latin America	4.8
North America	29.6
Africa	1.1
Asia	32.7
Australasia	1.1

Source: PPI, 2002.

As a result of the widespread uses of paper and paperboard, the apparent consumption of paper and paperboard per capita can be used as an economic barometer, i.e. indication, of the standard of economic life. The apparent consumption per capita in the various regions of the world in 2000 is shown in Table 1.3.

Table 1.3 Apparent per capita consumption of all types of paper and paperboard in 2000

Location	Apparent consumption (kg)
North America	303.3
European Union	201.0
Australasia	147.6
Latin America	34.8
Eastern Europe	31.4
Asia	28.2
Africa	6.1

Source: PPI, 2002.

The per capita usage figures provide an interesting contrast between different regions, with 31% of consumption occurring in North America, 27% in Europe and 30% in Asia.

The manufacture of paper and paperboard is therefore of worldwide significance and that significance is increasing. A large proportion of paper and paperboard is used for packaging purposes.

About 28% of the total output is used for corrugated and solid fibreboard and the overall packaging usage is significant. Amongst the membership of CEPI (Confederation of European Paper Industries), 40% of all paper and paperboard output is used in packaging.

Not only is paper and paperboard packaging a significant part of the total paper and paperboard market, it also provides a significant proportion of world packaging consumption. Up to 40% of all *packaging* is based on paper and paperboard, making it the largest packaging material used, by weight. Paper and paperboard packaging is found wherever goods are produced, distributed, marketed and used.

Many of the features of paper and paperboard used for packaging, such as raw material sourcing, principles of manufacture, environmental and waste management issues, are identical to those applying to all the main types of paper and paperboard. It is therefore important to view the packaging applications of paper and paperboard within the context of the worldwide paper and paperboard industry.

According to Robert Opie (2002), paper was used for wrapping reams of printing paper by a papermaker around 1550, the earliest printed paper labels were used to identify bales of cloth in the sixteenth century, printed paper labels for medicines were in use by 1700 and paper labels for bottles of wine exist from the mid-1700s. One of the earliest references to the use of paper for packaging is in a patent taken out by Charles Hildeyerd on 16 February 1665 for ‘The way and art of making blew paper used by sugar-bakers and others’ (Hills, 1988). For an extensive summary of packaging from the 1400s using paper bags, labels, wrappers and cartons, see Davis, 1967.

The use of paper and paperboard packaging accelerated during the latter part of the nineteenth century to meet the developing needs of manufacturing industry. The manufacture of paper had progressed from a laborious manual operation, one sheet at a time, to continuous high-speed production with wood pulp replacing rags as the main raw material. There were also developments in the techniques for printing and converting these materials into packaging containers and components and in mechanising the packaging operation.

Today, examples of the use of paper and paperboard packaging are found in many places, such as supermarkets, traditional street markets, shops and departmental stores, as well as for mail order, fast food, dispensing machines, pharmacies, and in hospital, catering, military, educational, sport and leisure situations.

For example, uses can be found for the packaging of:

- dry food products – e.g. cereals, biscuits, bread and baked products, tea, coffee, sugar, flour, dry food mixes
- frozen foods, chilled foods and ice cream
- liquid foods and beverages – milk, wines, spirits
- chocolate and sugar confectionery
- fast foods
- fresh produce – fruits, vegetables, meat and fish
- personal care and hygiene – perfumes, cosmetics, toiletries
- pharmaceuticals and health care
- sport and leisure
- engineering, electrical and DIY
- agriculture, horticulture and gardening
- military stores.

Papers and paperboards are sheet materials comprising an intertwined network of cellulose fibres. They are printable and have physical properties which enable them to be made into various types of flexible, semi-rigid and rigid packaging.

There are many different types of paper and paperboard. Appearance, strength and many other properties can be varied depending on the type(s) and amount of fibre used, and how the fibres are processed in fibre separation (pulping), fibre treatment and in paper and paperboard manufacture.

In addition to the type of paper or paperboard, the material is also characterised by its weight per unit area and thickness.

The papermaking industry has many specific terms and a good example is the terminology used to describe weight per unit area and thickness.

Weight per unit area may be described as ‘grammage’ because it is measured in grammes per square metre (g/m^2). Other area/weight related terms are ‘basis weight’ and ‘substance’ which are usually based on the weight in pounds of a stated number of sheets of specified dimensions, also known as a ‘ream’, for example 500 sheets of 24 in. × 36 in., which equates to total ream area of 3000 sq ft. Alternative units of measurement used in some parts of the industry would be pounds per 1000 square feet or pounds per 2000 square feet. It is therefore important when discussing weight per unit area, as with all properties, to be clear as to the methods and units of measurement.

Thickness, also described as 'caliper', is measured either in microns (μm), 0.001 mm or in thou. (0.001 in.), also referred to as *points*.

Appearance is characterised by the colour and surface characteristics, such as whether it has a high gloss, satin or matte finish.

Paperboard is thicker than paper and has a higher weight per unit area. Paper over $200\,g\,m^{-2}$ is defined by ISO (International Organization for Standardization) as paperboard, board or cardboard. Some products are, however, known as paperboard even though they are manufactured in grammages less than $200\,g\,m^{-2}$ and, on the other hand, CEPI, the Confederation of European Paper Industries, states, 'paper is usually called board when it is heavier than $220\,g\,m^{-2}$'.

The main types of paper and paperboard-based packaging are:

- bags, wrappings and infusible tissues, for example tea and coffee bags, sachets, pouches, overwraps, sugar and flour bags, carrier bags
- multiwall paper sacks
- folding cartons and rigid boxes
- corrugated and solid fibreboard boxes (transit or shipping cases)
- paper-based tubes, tubs and composite containers
- fibre drums
- liquid packaging
- moulded pulp containers
- labels
- sealing tapes
- cushioning materials
- cap liners (sealing wads) and diaphragms (membranes).

Paper and paperboard-based packaging is widely used because it meets the criteria for successful packing, namely to:

- contain the product
- protect goods from mechanical damage
- preserve products from deterioration
- inform the customer/consumer
- provide visual impact through graphical and structural designs.

These needs are met at all three levels of packaging, namely:

- primary – product in single units at the point of sale or use, for example cartons
- secondary – groups of primary packs packed for storage and distribution, wholesaling and 'cash and carry', for example transit trays and cases
- tertiary – unit loads for distribution in bulk, for example heavy-duty fibreboard packaging.

Paper and paperboard, in many packaging forms, meet these needs because they have appearance and performance properties which enable them to be made into a wide range of packaging structures cost-effectively.

They are printable, varnishable and can be laminated to other materials. They have physical properties which enable them to be made into flexible, semi-rigid and rigid packages by cutting, creasing, folding, forming, winding, gluing, etc.

Paper and paperboard packaging is used over a wide temperature range, from frozen-food storage to the temperatures of boiling water and heating in microwave and conventional ovens.

Whilst it is approved for direct contact with many food products, packaging made solely from paper and paperboard is permeable to water, water vapour, aqueous solutions and emulsions, organic solvents, fatty substances (except grease-resistant papers), gases such as oxygen, carbon dioxide and nitrogen, aggressive chemicals and volatile vapours and aromas. Whilst paper and paperboard can be sealed with several types of adhesive, it is not itself heat sealable.

Paper and paperboard can acquire barrier properties and extended functional performance, such as heat sealability, heat resistance, grease resistance, product release, etc. by coating, lamination and impregnation. Materials used for these purposes in these ways include extrusion coating with polyethylene (PE), polypropylene (PP), polyethylene terephthalate (PET or PETE), ethylene vinyl alcohol (EVOH) and polymethyl pentene (PMP); lamination with plastic films or aluminium foil; and by treatment with wax, silicone or fluorocarbon. Papers can be impregnated with a vapour-phase metal-corrosion inhibitor, mould inhibitor or coated with an insect repellent.

Packaging made solely from paperboard can also provide a wide range of barrier properties by being *overwrapped* with a heat-sealable plastic film, such as polyvinylidene chloride (PVdC) coated oriented polypropylene (OPP or as it is sometimes referred to BOPP).

Several types of paper and paperboard-based packaging may incorporate metal or plastic components, examples being as closures in liquid-packaging cartons and as lids, dispensers and bases in composite cans.

In an age where environmental and waste management issues have a high profile, packaging based on paper and paperboard has important advantages that:

- The main raw material (wood) is based on a naturally renewable resource, the growth of which removes carbon dioxide from the atmosphere, thereby reducing the greenhouse effect.
- When the use of the package is completed, many types of paper and paperboard packaging can be recovered and recycled. They can also be incinerated with energy recovery and if none of these options is possible, they are biodegradable in landfill.

1.2 Choice of raw materials and manufacture of paper and paperboard

1.2.1 Introduction to raw materials and processing

So far we have indicated that paper and paperboard-based packaging provides a well-established choice for meeting the packaging needs of a wide range of products. We have defined paper and paperboard and summarised the reasons why this type of packaging is used. We now need to discuss the underlying reasons why paper and paperboard packaging is able to meet these needs.

This discussion falls into four distinct sections:

- choice and processing of raw materials
- manufacture of paper and paperboard
- additional processes which enhance the appearance and performance of paper and paperboard by coating and lamination
- use of paper and paperboard in the printing, conversion and construction of particular types of packaging.

Cotton, wool and flax are examples of fibres and we know that they can be spun into a thread and that thread can be woven into a sheet of cloth material. Papers and paperboards are also based on fibre, but the sheet is a three-dimensional structure formed by a random intertwining of fibres. The resulting structure, which is known as a *sheet* or *web*, is sometimes described as being 'non-woven'. The fibres are prepared by mixing them with water to form a very dilute suspension, which is poured on to a moving wire mesh. The paper structure is formed as an even layer on the wire mesh, which acts as a sieve. Most of the water is then removed successively by drainage, pressure and heat.

So why does this structure have the strength and toughness which makes it suitable for printing and conversion for use in many applications, including packaging? To answer this question we need to examine the choices which are available in the raw materials used and how they are processed.

According to tradition, paper was first made in China around the year AD 105 using fibres such as cotton and flax. Such fibres are of vegetable origin, based on cellulose, which is a natural polymer, formed in green plants from carbon dioxide and water by the action of sunlight. The process initially results in natural sugars based on a multiple-glucose-type structure comprising carbon, hydrogen and oxygen in long chains of hexagonally linked carbon atoms, to which hydrogen atoms and hydroxyl (OH) groups are attached. This process is known as photosynthesis, oxygen is the by-product and the result is that carbon is removed (fixed) from the atmosphere. Large numbers of cellulose molecules form fibres – the length, shape and thickness of which vary depending on the plant species concerned. Pure cellulose is non-toxic, tasteless and odourless.

The fibres can bond at points of interfibre contact as the fibre structure dries during water removal. It is thought that bonds are formed between hydrogen (H) and hydroxyl (OH) units in adjacent cellulose molecules causing a consolidation of the three-dimensional sheet structure. The degree of bonding, which prevents the sheet from fragmenting, depends on a number of factors which can be controlled by the choice and treatment of the fibre prior to forming the sheet.

The resulting non-woven structure which we know as paper ultimately depends on a three-dimensional intertwined fibre network and the degree of interfibre bonding. Its thickness, weight per unit area and strength can be controlled, and in this context paperboard is a uniform thicker paper-based sheet. It is flat, printable, creasable, foldable, gluable and can be made into many two and three dimensional shapes. These features make paper and paperboard ideal wrapping and packaging materials.

Over the centuries, different cellulose-based raw materials, particularly rags incorporating cotton, flax and hemp, were used to make paper, providing good examples of recycling. During the nineteenth century the demand for paper and paperboard increased, as wider education for the increasing population created a rising demand for written material. This in turn led to the search for alternative sources of fibre. Esparto grass was widely used but eventually processes for the separation of the fibres from wood became technically and commercially successful and from that time (1880 onwards) wood has become the main source of fibre. The process of fibre separation is known as pulping.

Today there are choices in:

- source of fibre
- method of fibre separation (pulping)
- whether the fibre is whitened (bleached) or not
- preparation of the fibre (stock) prior to use on the paper or paperboard machine.

1.2.2 Sources of fibre

Basically, the choice is between *virgin*, or primary, fibre derived from logs of wood and *recovered*, or secondary, fibre derived from waste paper and paperboard. About 55% of the fibre used in 2001 was virgin fibre and the rest, 45%, from recovered paper. It must be appreciated at the outset that:

- fibres from all sources, virgin and recovered, are not universally interchangeable with respect to the paper and paperboard products which can be made from them
- some fibres by nature of their use are not recoverable and some that are recovered are not suitable for recycling on grounds of hygiene and contamination
- fibres cannot be recycled indefinitely.

The properties of virgin fibre depend on the species of tree from which the fibre is derived. The flexibility, shape and dimensional features of the fibres influence their ability to form a uniform interlaced network. Some specialised paper products incorporate other cellulose fibres such as cotton and hemp and there is some use of synthetic fibre.

The paper or paperboard maker has a choice between trees which have relatively *long* fibres, such as spruce, fir and pine (*coniferous species*), which provide strength, toughness and structure, and *shorter* fibres, such as those from birch, eucalyptus, poplar (aspen), acacia and chestnut (*deciduous species*), which give high bulk (low density), closeness of texture and smoothness of surface.

The longer, wood-derived, fibres used by the paper and paperboard industry are around 3–4 mm in length and the short fibres are 1–1.5 mm. The fibre tends to be ribbon shaped, about 30 microns across and therefore visible to the naked eye.

The terms ‘long’ and ‘short’ are relative to the lengths of fibres from wood as, by contrast, cotton and hemp fibres may be as long as 20–30 mm.

1.2.3 Fibre separation from wood (pulping)

In trees, the cellulose fibres are cemented together by a hard, brittle material known as lignin, another complex polymer, which forms up to 30% of the tree. The separation of fibre from wood is known as pulping. The process may be based on either mechanical or chemical methods.

Mechanical pulping applies mechanical force to wood in a crushing or grinding action which generates heat and softens the lignin thereby separating the individual fibres. As it does not remove lignin, the yield of pulp from wood is very high. The presence of lignin on the surface and within the fibres makes them hard and stiff. They are also described as being dimensionally more stable. This is related to the fact that cellulose fibre absorbs moisture from the atmosphere when the relative humidity is high and loses moisture when the relative humidity is low. This is accompanied by dimensional changes and these are reduced if the fibre is coated with a material such as lignin. The degree of interfibre bonding is not high. Sheets made from mechanically separated fibre have a ‘high bulk’ or low density, i.e. a relatively low weight per unit area for a given thickness. This, as will be discussed later, has technical and commercial implications. Figure 1.1 illustrates the production of mechanically separated pulp.

Wood in chip form may be heated prior to pulping in which case the pulp is known as thermomechanical pulp (TMP) and when this is accompanied by a limited chemical treatment to remove some of the lignin, it is called chemi-thermomechanical

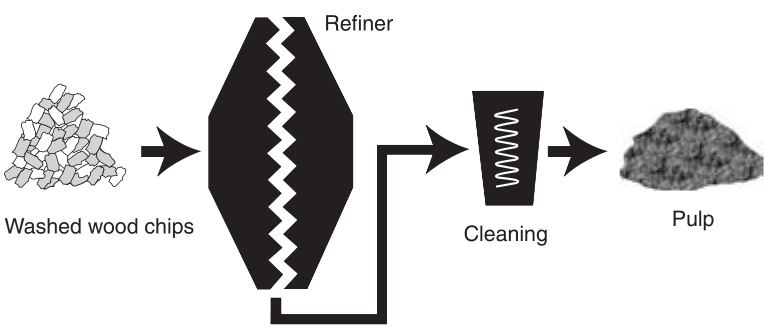

Figure 1.1 Production of mechanically separated pulp (courtesy of Pro Carton).

pulp (CTMP). Mechanical pulp retains the colour of the original wood and CTMP is lighter in colour.

Chemical pulping uses chemicals to separate the fibre by dissolving the non-cellulose and non-fibrous components of the wood (Fig. 1.2). There are two main processes characterised by the names of the types of chemicals used. The Sulphate process, also known as the Kraft process, is most widely used today because it can process all the main types of wood, and the chemicals can be recovered and re-used. The other process is known as the sulphite process. In both processes, the non-cellulose and non-fibrous material extracted from the wood is used as the main energy source in the pulp mill and in what are referred to as 'integrated' mills which manufacture both pulp and paper/paperboard.

Chemically separated pulp comprises 65% of virgin fibre production. It has a lower yield than the mechanically separated pulp due to the fact that the non-cellulose constituents of the wood have been removed. This results in a higher degree of interfibre bonding. Furthermore, the average fibre length of wood from the same species is longer than for mechanically separated fibre. It is also more flexible. These factors result in a stronger and more flexible sheet. The colour is brown.

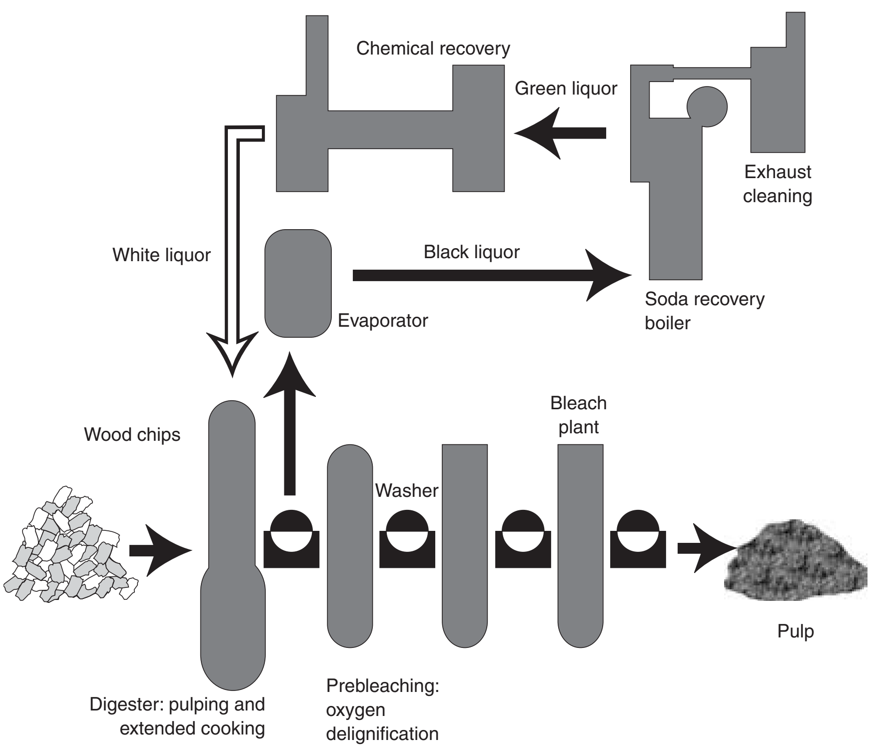

Figure 1.2 Production of chemically separated and bleached pulp (courtesy of Pro Carton).

1.2.4 Whitening (bleaching)

Chemically separated pulp can be whitened or bleached by processes which remove residual lignin and traces of any other wood-based material. Bleached pulp is white in colour even though individual cellulose fibres are colourless and translucent. Chemically separated and bleached fibre is pure cellulose and this has particular relevance in packaging products where there is a need to prevent materials originating from the packaging affecting the flavour, odour or aroma of the product. Examples of such sensitive products are chocolate, butter, tea and tobacco.

Bleaching has been subject to criticism on environmental grounds. This was due to chloro-organic by-products in the effluent from mills where chlorine gas was used to treat the pulp. The criticism is no longer valid, as today the main bleaching process is elemental chlorine free (ECF) which uses oxygen, hydrogen peroxide and chlorine dioxide. The by-products of this process are simple and harmless. Another process called totally chlorine free (TCF) is based on oxygen and hydrogen peroxide.

Bleached cellulose fibre has high light stability, i.e. there is little tendency for fading or yellowing in sunlight.

1.2.5 Recovered fibre

Waste paper and paperboard are also collected, sorted and repulped by mechanical agitation in water (Fig. 1.3). There are many different qualities of repulped fibre depending on the nature of the original fibre, how it was processed and how the paper or paperboard product was converted and used. Each time paper or paperboard is repulped, the average fibre length and the degree of interfibre bonding is reduced. This, together with the fact that some types of paper and

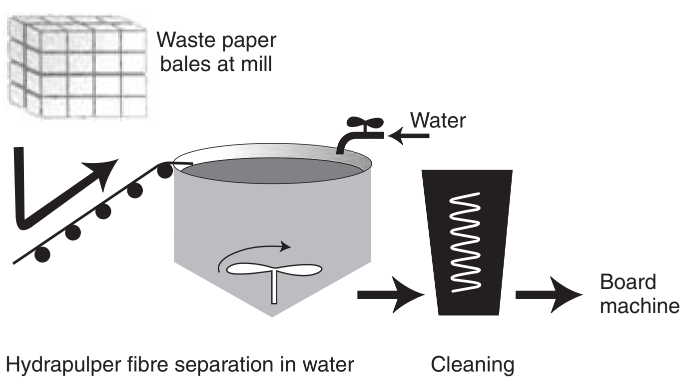

Figure 1.3 Production of pulp from recovered paper/paperboard (recycling) (courtesy of Pro Carton).

paperboard cannot be recovered by nature of their use, means that new fibre, primary or virgin fibre, made directly from wood must be introduced into the market on a regular basis to maintain *quantity* and *quality*.

There are many classifications, based on type and source, of recovered paper and paperboard which reflect their value for re-use. Classifications range from ‘White shavings’ (highly priced), newspapers (medium priced) to ‘mixed recovered paper and board’ (lowest priced). Generally, where recovered paper and paperboard which is printed is used in the manufacture of packaging grades, it is not de-inked as part of the process. Industry-agreed classification lists have been developed in Europe, where there are 57 defined grades, the United States and Japan.

Some paper and paperboard products are either made exclusively from recycled pulp or contain a high proportion of recycled fibre. Others are made exclusively from either chemical pulp or a mixture of chemical and mechanical pulp.

1.2.6 Other raw materials

In addition to fibre, which provides around 88% of the raw material for paper and paperboard, there are a number of non-fibre additives. These comprise:

- mineral pigment for surface coating
- fillers and internal sizing additives
- additives for strength
- surface sizing additives
- chemicals used to assist the process of paper manufacture.

They all assist in one way or another in improving either the appearance or performance of the product or the productivity of the process.

Coating the paper or paperboard involves the application of mineral pigment to one or both surfaces with one or more layers. Coatings control surface appearance, smoothness, gloss, whiteness and printability. Coatings comprise: a pigment, which could be either china clay, calcium carbonate (chalk) or titanium dioxide; an adhesive or binder, which ensures that the particles adhere together and to the surface being coated; and water (the vehicle), which facilitates the application and smoothing of the wet coating. Additional components could be optical brightening agents (OBA), also known as fluorescent whitening agents (FWA), dyes and processing aids such as anti-foaming agents.

Fillers are white inorganic materials added to the stock to improve the printability of the surface and also the opacity, brightness and smoothness of uncoated papers. They fill in voids in the fibre structure and increase light scattering. In general, fillers are not widely used in the manufacture of packaging grades of paper and paperboard.

Mineral pigment for coating and as fillers account for 9% of the raw materials used by the paper industry.

Internal sizing is the technique whereby the surface of cellulose fibres which are naturally absorbent to water are treated to render them water repellent. Traditionally, this has been carried out by what is known as alum sizing. The material used comprises a rosin size derived from pine tree gum which, after treatment to make it water soluble, is added together with aluminium sulphate at the stock-preparation stage – hence the name ‘alum’. The aluminium sulphate reacts with rosin to produce a modified resin which is deposited onto the fibre surface. The process has been progressively developed using both rosin and chemically unrelated synthetic resins.

Urea and melamine formaldehyde can be added to ensure that a high proportion of the dry strength of paper is retained when it is saturated with water, as would be necessary for multiwall paper sacks which may be exposed to rain or carriers for cans or bottles of beer in the wet environment of a brewery. Starch is used to increase strength by increasing interfibre bonding within the sheet and interply bonding in the case of multi-ply paperboard.

Starch is also applied as a *surface size* in the drying section of a paper or paperboard machine to one or both surfaces. The purpose is to increase the strength of the sheet and in particular the surface strength which is important during printing. It also helps to bind the surface fibres into the surface thereby preventing fibre shedding, which would lead to poor printing results. It also prepares the surface for mineral pigment coating. Other additives used for performance include wax (resistance to moisture, permeation of taint and odour, heat sealability and gloss), acrylic resins (moderate moisture resistance) and fluorocarbons (grease resistance).

Chemicals are used to assist the process of manufacture. Examples are anti-foaming agents, flocculating agents to improve drainage during the forming of the wet sheet, biocides to restrict microbiological activity in the mill and pitch-control chemicals which prevent pitch (wood resins) from being deposited on the paper machine where it can build up and break away causing machine web breaks and subsequent problems with particles (fragments) in printing.

1.2.7 Processing of fibre at the paper mill

Preparing fibres for paper manufacture is known as ‘stock preparation’. The properties of fibres can be modified by processing and the use of additives at the stock-preparation stage prior to paper or paperboard manufacture. In this way, the papermaker can in theory start with, for example, a suspension of bleached chemically separated and bleached fibre in water and by the use of different treatments produce modified pulps which can be used to make papers as different as blotting paper, bag paper or greaseproof paper.

The surface structure of the fibre can be modified in a controlled way by mechanical treatment in water. This was originally carried out in a beater. Beating is a *batch* process in which the pulp suspension is drawn between moving and stationary bars.

The moving bars are mounted on the surface of a beater roll which rotates at a fixed, adjustable distance above a bedplate, which also carries bars. The motion of the beater roll draws the suspension between the bars causing fibrillation of the fibre surface and swelling of the fibre. The suspension is thrown over the backfall and around the midfeather to the front of the roll for further treatment (see Figure 1.4). Unless the grade of paper being produced requires beating in this way, for example greaseproof paper, where the pulp is highly beaten to an almost gelatinous consistency (Fig 1.5) this treatment is carried out as a continuous, *in-line*, process through a refiner. Refiners also have stationary and moving bars. They are mounted either conically or on parallel discs (Grant *et al.*, 1978).

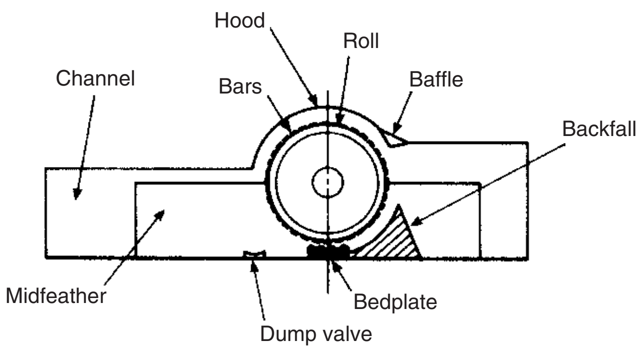

Figure 1.4 Beater (courtesy of PITA).

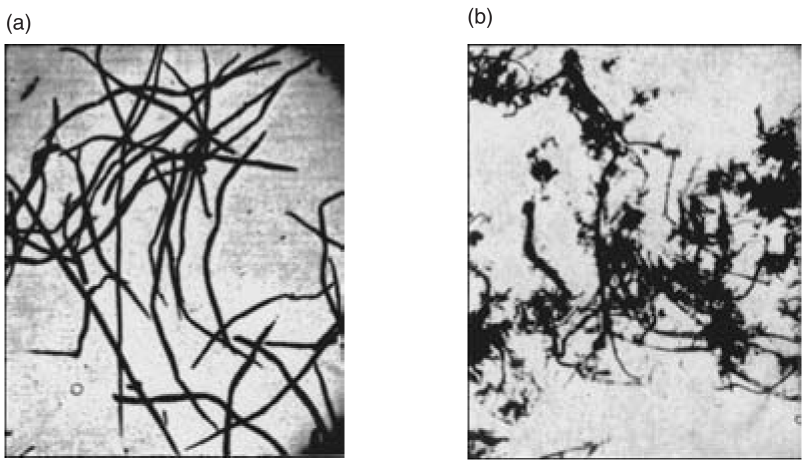

Figure 1.5 Fibres before beating (a) and after being well beaten (b) for greaseproof paper manufacture (courtesy of PITA).

1.2.8 Manufacture on the paper or paperboard machine

The basic principles of papermaking today are the same as they have always been:

- prepare a dilute suspension of fibres in water
- form a sheet from an intertwined network of fibres
- remove most of the water progressively by drainage, pressure and evaporation (drying).

Traditionally, forming was achieved manually, by dipping a finely woven flat wire mesh set in a wooden frame, called a mould, into a vat of fibres suspended in water and allowing excess suspension to flow over a separate wooden frame, or deckle, fitted around the edge of the mould. Water was drained through the wire mesh. The deckle was removed when the layer of fibres had consolidated. This resulted in a sheet where the fibres were randomly and evenly distributed (Fig. 1.6).

The mould was then inverted and the sheet transferred to a wetted felt blanket (couched) (Fig. 1.7). The wet sheet was covered by another felt. This was repeated several times to build up a pile of alternate layers of wet sheets and felts. The pile, or post, was then subjected to pressure in a hydraulic press which squeezed water from the sheet. The sheets were then strong enough to be handled and separated from the felts.

Further pressing without felts removed more water and the sheets were then dried in air. Sheets intended for printing would then be tub-sized by dipping them in a solution of gelatine and dried in air (Fig. 1.8).

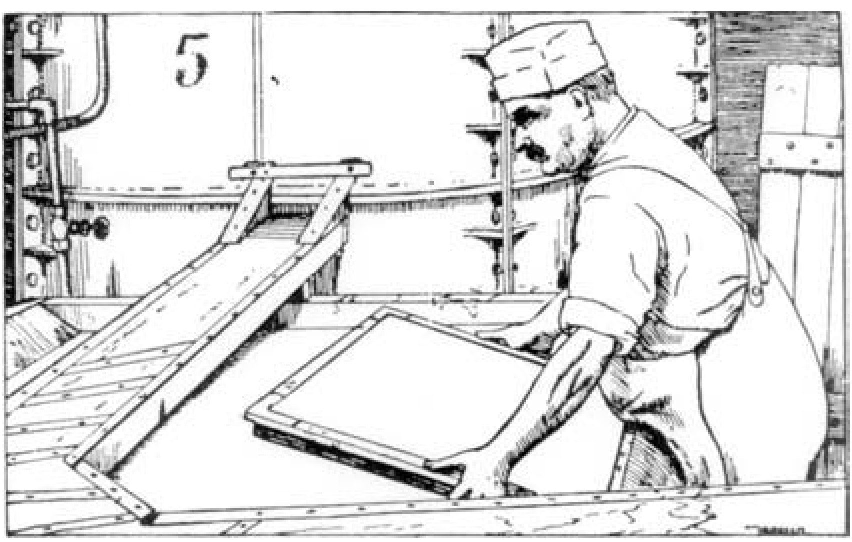

Figure 1.6 Vatman hand forming paper sheet using mould (courtesy of PITA).

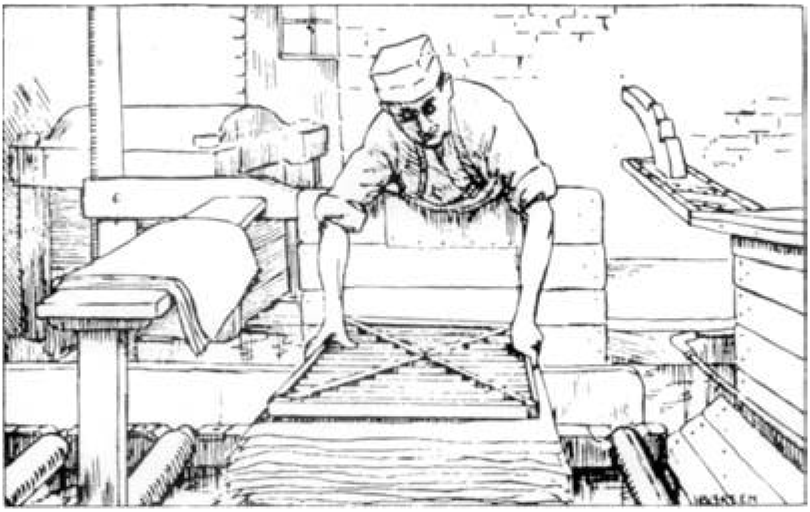

Figure 1.7 Coucher removing wet sheet from mould (courtesy of PITA).

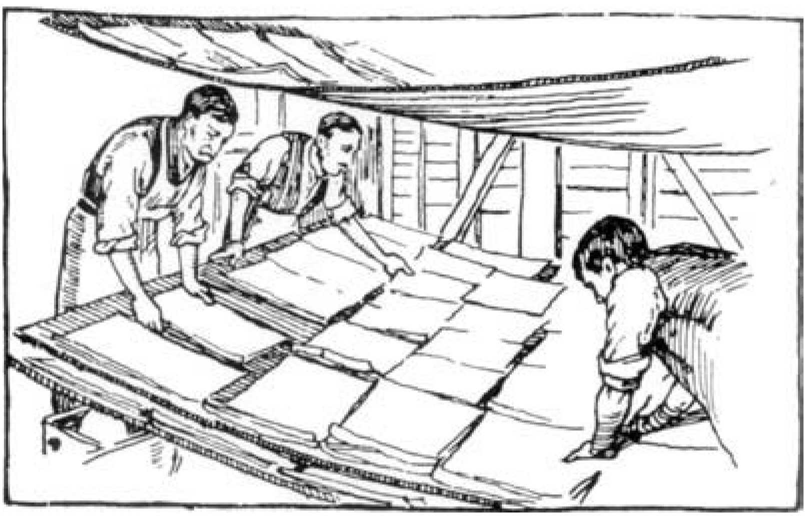

Figure 1.8 Loft-drying hand-made paper (courtesy of PITA).

The Industrial Revolution facilitated progress from laborious manual operations, one sheet at a time, to today's continuous high-speed production, using computerised process control.

Whilst the principles of sheet forming, pressing and drying are common to all paper and paperboard, the way in which it is carried out depends on the specific requirements and the most cost-effective method available.

Since the early 1800s, pulp has been mechanically applied to a wire mesh on a paper or paperboard machine. Mechanical forming (Fig. 1.9) induces a degree of directionality in the way the fibres are arranged in the sheet. As the fibres are relatively long in relation to their width they tend to line up, as the sheet is formed, in the direction of motion along the machine. This direction is known as the machine direction (MD) and whilst fibres line up in all directions the least number of fibres will line up in the direction at right angles to the MD and this is known as the cross direction (CD).

The techniques used prior to and during forming are very important for the performance of the product. Strength properties and other features show variations characterised by these two directions of property measurement. The significance of this feature for the printing, conversion and use of paper and paperboard packaging varies depending on the application, and users should be aware of the implications in specific situations. Examples are discussed in the chapters on the various types of packaging.

It is important that the weight per unit area and the distribution of fibre orientation are functionally adequate and consistent, both within makings and from making to making, for the intended use.

There are two main methods of forming. Wire forming, where the pulp suspension in water, with a consistency of around 2% fibre and 98% water, flows from a headbox out of a narrow horizontal slot, known as the slice, onto a moving wire, was originated by Nicolas Robert in France, 1793. The initial method required further development by others, particularly Bryan Donkin, before the first continuous paper machine, financed by the Fourdrinier brothers, was installed at Frogmore Mill, Herts, England in 1803. The name 'Fourdrinier' has been adopted to describe this method of forming (Fig. 1.10).

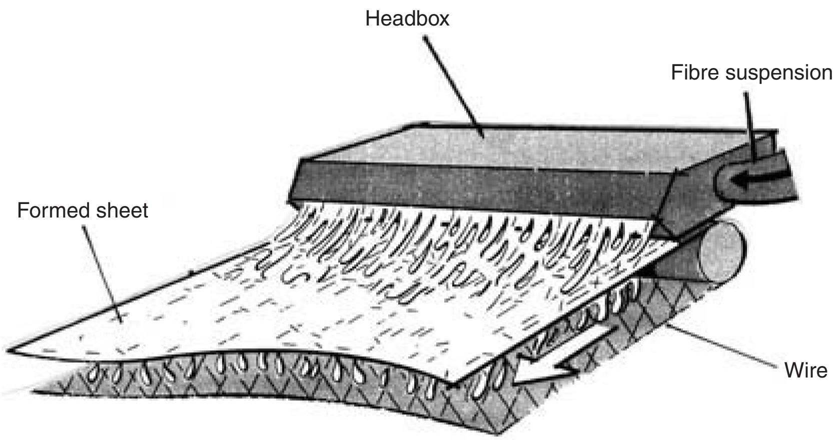

Figure 1.9 Simplified diagram of the forming process (Fourdrinier) (courtesy of Iggesund Paperboard).

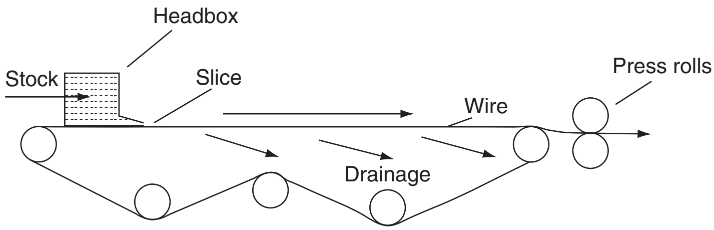

Figure 1.10 Sheet forming on moving wire – Fourdrinier process.

The wire mesh, which is usually a plastic mesh today, may have a transverse 'shake' from side to side to assist a more random orientation of fibre. Water is drained from the underside of the wire using several techniques, including vacuum. The wet sheet is removed from the wire when it can support its own weight. This section of the machine is called the wet end and the wire, which is a continuous band, carries on around to receive more pulp in water suspension.

An alternative method of mechanical forming using a wire-covered cylinder was also being developed at the same time. The patent which led to a successful process was taken out by John Dickinson in 1809 and he was making paper in quantity at Apsley and Nash mills also in Herts, England by 1812. In this process, the wire-covered cylinder revolves in a vat of pulp which forms a sheet on the surface of the cylinder as a result of the maintenance of a differential pressure between the outside and inside of the cylinder. Figure 1.11 shows a 'uniflow' vat where the pulp suspension flows through the vat in the same direction as the wire mould is rotating. This arrangement results in good sheet formation whereas if the pulp suspension flows in the opposite direction, in what is known as a contraflow vat, higher weights of pulp are formed on the mould.

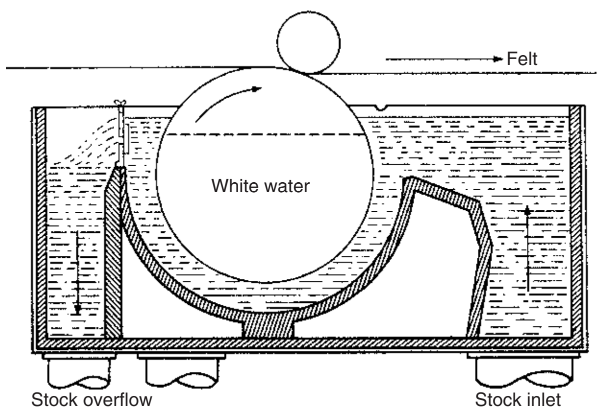

Figure 1.11 Uniflow vat cylinder mould forming (courtesy of PITA).

Multi-web, or *multi-ply*, sheet forming can be achieved by using several wires or several vats. A modification of the wire forming method is the Inverform process where a second and subsequent headboxes add additional layers of pulp. As each layer is added a top wire contacts the additional layer and drains water upwards as a result of the mechanical design which is assisted with vacuum. This resulted in a significant increase in productivity without loss of quality.

Multilayering enables the manufacturer to make heavier weight per unit area products and use different pulps in the various layers to achieve specific functional needs cost-effectively. Multilayering in the case of thicker grades of paperboard also facilitates weight control and good creasing properties.

Following the forming, the next stage occurs in the press section. More water is removed by pressing the sheet, sandwiched between supporting blankets or felts, often accompanied by vacuum induced suction. This reduces moisture content to around 60–65%. Thereafter the sheet is dried in contact with steam-heated steel cylinders.

Some products are made on machines with a large diameter machine glazing or 'Yankee' cylinder. The sheet is applied to the cylinder whilst the moisture content is still high enough for the sheet to adhere to the polished, hot surface. This process not only dries the sheet but also promotes a polished or glazed smooth surface. An important aspect of this for some products is that a smooth surface is achieved without loss of thickness – a feature which preserves stiffness, as will be discussed later.

Surface sizing can be applied to one or both surfaces during drying. Starch may be used to improve strength and prevent any tendency for fibre shedding during printing. Grease-resistant additives may also be applied in this way. A wax size may be applied as an emulsion in water, and with the heat from the drying cylinders the wax impregnates the paper or paperboard. However, the majority of wax treatments are applied as secondary conversion processes, i.e. off-machine.

Calendering is a process which is used to enhance smoothness and finish and to control thickness by passing the dry sheet between cylinders. Calendering can be applied in several ways depending on the product and the surface finish required. Cylinders may be heated or chilled and in some cases water is applied to the surface of the material. At its simplest, calendering comprises two steel rolls though more could be used – paperboard for instance would only require light calendering to control thickness without compressing the material excessively, which would reduce stiffness, as will be discussed later. There are paper machines with up to seven rolls where steel and composite rolls are used alternatively to provide smoother and glossier finishes. An off-machine 'supercalender' produces a much smoother and glossier finish. In the case of glassine, as many as 14 rolls are used in supercalendering.

White-pigmented mineral-based coatings are applied, to one or both sides of the sheet and smoothed and dried, to improve appearance in respect of colour, smoothness, printing and varnishing. The method of coating has been adopted to describe the types of coating such as blade (Fig. 1.12), air knife and roll bar. One, two or three coating layers may be applied, depending on the needs of the product.

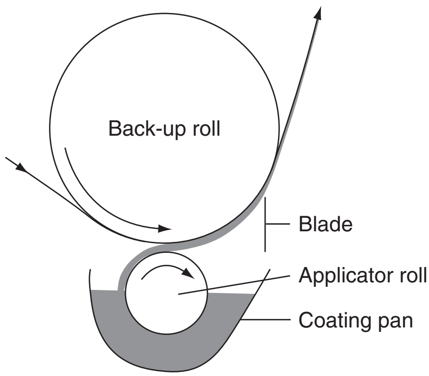

Figure 1.12 Blade coating (courtesy of PITA).

The coating process described produces a surface with a matt finish. A more light-reflective gloss finish can be achieved by brushing and/or friction glazing.

A specific type of mineral pigment coating is known as cast coating which is applied off-machine as a separate process. This is a reel-to-reel process in which the coating mix is applied to the paper or paperboard surface, smoothed, and whilst still wet is cast against the surface of a highly polished heated cylinder. When dry, the coated surface peels away from the cylinder leaving a coating on the paper or paperboard with a very smooth high gloss finish.

Paper and paperboard machines vary in width from around 1 m to as much as 10 m. The size is geared to output and output is geared to market size. The output limiting factors for a given width are the amount of pulp used per unit area and the linear speed – both of which relate to the amount of water which has to be removed by a combination of drainage, vacuum, pressing and drying. Principle features of paper/paperboard manufacture by wire forming are shown in Figure 1.13.

1.2.9 Finishing

This is the name given to the processes which are carried out after the paper and paperboard have left the papermaking machine. There are a number of options depending on customer requirements. Large reels ex-machine are slit to narrower widths and smaller diameters. Reels may be slit, sheeted, counted, palletised, wrapped and labelled. The product is normally wrapped in moisture resistant material such as PE, film and stretch or shrink wrapped.

Papers and paperboards produced in the way described may be given secondary treatments by way of coating, lamination and impregnation with other materials to achieve specific functional properties. These are known as 'conversion' processes. They are carried after the paper and paperboard have left the mill either by specialist converters, such as laminators or plastic extrusion coaters, or they may be integrated

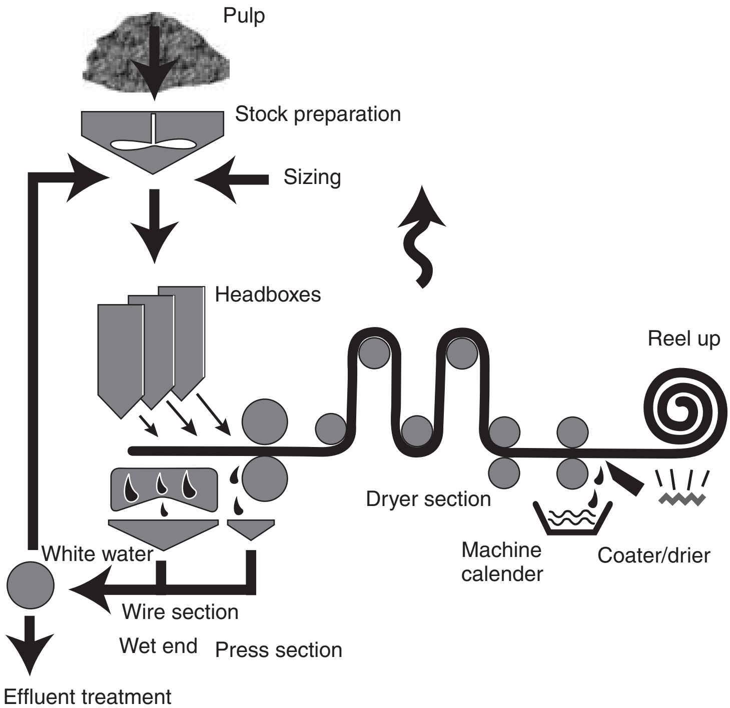

Figure 1.13 Principal features of paper/paperboard manufacture by wire forming – the number of headboxes will vary depending on the product and the machine design (courtesy of Pro Carton).

within the plants making packaging materials and containers. These processes are discussed in the packaging-specific chapters of this book.

We have now identified the nature of paper and paperboard, the raw materials and the processing which can be undertaken to make a wide range of papers and paperboards. We now need to review the various paper and paperboard products which are used to manufacture packaging materials and containers.

1.3 Packaging papers and paperboards

1.3.1 Introduction

A wide range of papers and paperboards is commercially available to meet market needs based on the choice of fibre (bleached or unbleached, chemically or mechanically separated, virgin or recovered fibre), the treatment and additives used at the stock-preparation stage.

We have noted that paper and paperboard-based products can be made in a wide range of grammages and thicknesses. The surface finish (appearance) can be varied mechanically. Additives introduced at the stock-preparation stage provide special properties. Coatings applied to either one or both surfaces, smoothed and dried, offer a variety of appearance and performance features which are enhanced by subsequent printing and conversion thereby resulting in various types of packaging material. To illustrate these features of paper and paperboard, some product examples are described below.

1.3.2 Tissues

These are lightweight papers with grammages from 12 to 30 g m^{-2}. The lightest tissues for tea and coffee bags which require a strong porous sheet are based on long fibres such as those derived from Manila hemp. The Constanta-type bag with the lowest grammage is folded and stapled. Heat-sealed tea and coffee bags require the inclusion of a heat-sealing fibre, such as polypropylene. Single-portion tea bags have grammages in the range 12–17 g m^{-2} but larger bags would require higher grammages.

Neutral pH grades with low chloride and sulphate residues are laminated to aluminium foil. These grades are also used as wrappings to wrap silverware, jewellery and clothing, etc. (Packaging tissues should not be confused with absorbent tissues used for hygienic purposes, which are made on a different type of paper machine using different types of pulp.)

1.3.3 Greaseproof

The hydration (refining) of fibres at the stock-preparation stage, already described, is taken much further than normal. Hydration can also be carried out as a batch process in a beater. The fibres are treated (hydrated) so that they become almost gelatinous. Grammage range is 30–70 g m^{-2}.

1.3.4 Glassine

This is a supercalendered greaseproof paper. The calendering produces a very dense sheet with a high (smooth and glossy) finish. It is non-porous, greaseproof and can be laminated to paperboard. It may be plasticised with glycerine. It may be embossed, PE coated, aluminium foil laminated, metallised or release-treated with silicone to facilitate product release. It is produced in plain and coloured versions, for example chocolate brown. Grammage range is 30–80 g m^{-2}.

1.3.5 Vegetable parchment

Bleached chemical pulp is made into paper conventionally and then passed through a bath of sulphuric acid, which produces partial hydrolysis of the cellulose surface of the fibres. Some of the surface cellulose is gelatinised and redeposited between the surface fibres forming an impervious layer closing the pores in the paper structure. The process is stopped by chemical neutralisation and the web is thoroughly washed in water. This paper has high grease resistance and wet strength. It can be used in the deep freeze and in both conventional and microwave ovens. It can be silicone treated for product release. Grammage range is 30–230 $g\,m^{-2}$.

1.3.6 Label paper

These may be coated MG (machine glazed) or MF (machine finished – calendered) kraft papers (100% sulphate chemical pulp) in the grammage range 70–90 $g\,m^{-2}$. The paper may be coated on-machine or cast coated for the highest gloss in an off-machine or secondary process.

The term ‘finish’ in the paper industry refers to the surface appearance. This may be:

- machine finish (MF) – smooth but not glazed
- water finish (WF) – where one or both sides are dampened and smoothed to be smoother and glossier than MF
- machine glazed (MG) – with high gloss on one side only
- supercalendered (SC) – which is dampened and polished off-machine to produce a high gloss on both sides.

1.3.7 Bag papers

‘Imitation kraft’ is a term on which there is no universally agreed definition, it can be either a blend of kraft with recycled fibre or 100% recycled. It is usually dyed brown. It has many uses for wrapping and for bags where it may have an MG and a ribbed finish. Thinner grades may be used for lamination with aluminium foil and PE for use on form, fill, seal machines. For sugar or flour bags, coated or uncoated bleached kraft in the range 90–100 $g\,m^{-2}$ is used.

1.3.8 Sack kraft

Usually this is unbleached kraft (90–100% sulphate chemical) pulp, though there is some use of bleached kraft. The grammage range is 70–100 $g\,m^{-2}$.

Paper used in wet conditions needs to retain considerable strength, at least 30%, when saturated with water. To achieve wet strength resins such as urea formaldehyde and melamine formaldehyde are added to the stock. These chemicals cross link during drying and are deposited on the surface of the cellulose fibres making them more resistant to water absorption.

Microcreping, as achieved for example by the Clupak process, builds an almost invisible crimp into paper during drying enabling paper to stretch up to 7% in the MD compared to a more normal 2%. When used in paper sacks, this feature improves the ability of the paper to withstand dynamic stresses, which occurs when sacks are dropped.

1.3.9 Impregnated papers

Papers are made for subsequent impregnation off-machine. Such treatment can, for example, be with wax, vapour phase inhibitor for metal packaging and mould inhibitors for soap wrapping. (Mills have ceased to impregnate these products on-maching for technical and commercial reasons.)

1.3.10 Laminating papers

Coated and uncoated papers based on both kraft (sulphate) and sulphite pulps can be laminated to aluminium foil and extrusion coated with PE. The heavier weights can be PE laminated to plastic films and wax or glue laminated to unlined chipboard. The grammage range is 40–80 $g\,m^{-2}$.

1.3.11 Solid bleached board (SBB)

This board (Fig. 1.14) is made exclusively from bleached chemical pulp. It usually has a mineral pigment coated top surface and some grades are also coated on the back. The term ‘solid bleached sulphate’ (SBS), derived from the method of pulp production, is sometimes used to describe this product.

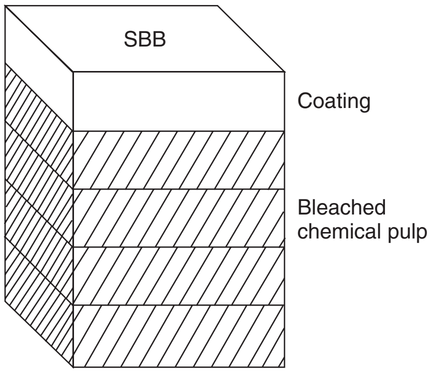

Figure 1.14 Solid bleached board (courtesy of Iggesund Paperboard).

This paperboard has an excellent surface and printing characteristics. It gives wide scope for innovative structural designs and can be embossed, cut, creased, folded and glued with ease. This is a pure cellulose primary (virgin) paperboard with consistent purity for food product safety, making it the best choice for the packaging of aroma and flavour sensitive products. Examples of use include chocolate packaging, frozen, chilled and reheatable products, tea, coffee, liquid packaging and non-foods such as cigarettes, cosmetics and pharmaceuticals.

1.3.12 Solid unbleached board (SUB)

This board (Fig. 1.15) is made exclusively from unbleached chemical pulp. The base board is brown in colour. This product is also known as solid unbleached sulphate. To achieve a white surface, it can be coated with a white mineral pigment coating, sometimes in combination with a layer of bleached white fibres under the coating.

SUB is used where there is a high strength requirement in terms of puncture and tear resistance and/or good wet strength is required such as for bottle or can multipacks and as a base for liquid packaging.

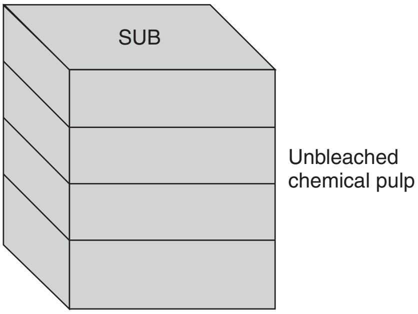

Figure 1.15 Solid unbleached board (courtesy of Iggesund Paperboard).

1.3.13 Folding boxboard (FBB)

This board (Fig. 1.16) comprises middle layers of mechanical pulp sandwiched between layers of bleached chemical pulp. The top layer of bleached chemical pulp is usually coated with a white mineral pigment coating. The back is cream (manila) in colour. This is because the back layer of bleached chemical pulp is translucent allowing the colour of the middle layers to show through. However, if the mechanical pulp in the middle layers is given a mild chemical treatment, it becomes lighter in colour and this makes the reverse side colour lighter in shade. The back layer may, however, be thicker or coated with a white mineral pigment

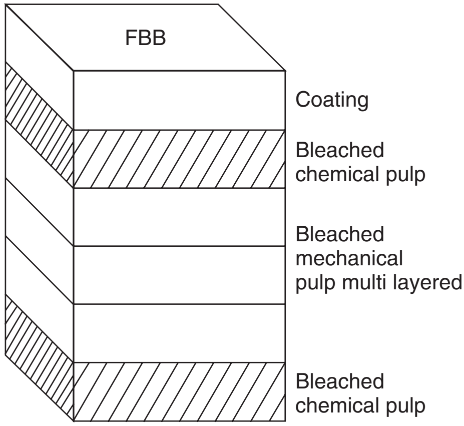

Figure 1.16 Folding boxboard (courtesy of Iggesund Paperboard).

coating, thus becoming a white back folding box board. The combination of inner layers of mechanical pulp and outer layers of bleached chemical pulp creates a paperboard with high stiffness.

Fully coated grades have a smooth surface and excellent printing characteristics. This paperboard is a primary (virgin fibre) product with consistent purity for food product safety and suitable for the packing of aroma and flavour sensitive products. It is used for packing confectionery, frozen, chilled and dry foods, healthcare products, cigarettes, cosmetics, toys, games and photographic products.

1.3.14 White lined chipboard (WLC)

WLC (Fig. 1.17) comprises middle plies of recycled pulp recovered from mixed papers or carton waste. The middle layers are grey in colour. The top layer, or liner of bleached chemical pulp is usually white mineral pigment coated. The second layer, or under liner may also comprise bleached chemical pulp or mechanical pulp. This product is also known as newsboard or chipboard, though the latter name is more likely to be associated with unlined grades, i.e. no white, or other colour, liner.

The reverse side outer layer usually comprises specially selected recycled pulp and is grey in colour. The external appearance may be white by the use of bleached chemical pulp and, possibly, a white mineral pigment coating (white PE has also been used).

There are additional grades of unlined chipboard and grades with specially coloured (dyed) liner plies. (WLC with a blue inner liner was used for the packing of cube sugar.)

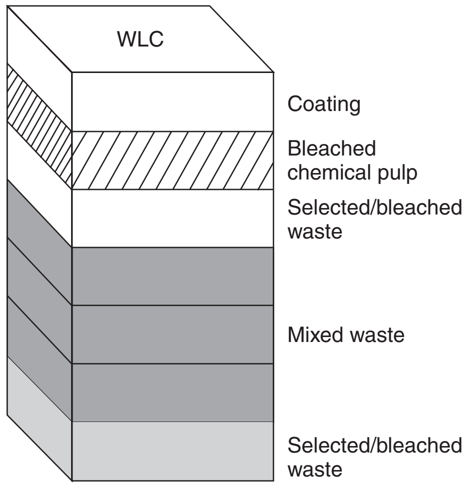

Figure 1.17 White lined chipboard (courtesy of Iggesund Paperboard).

The overall content of WLC varies from about 80–100% recovered fibre depending on the choice of fibre used in the various layers. WLC is widely used for dry foods, frozen and chilled foods, toys, games, household products and DIY.

1.4 Packaging requirements

Packaging protects and identifies the product for customers/consumers. When we think about packaging requirements, we may initially think of the needs of the customer who is the purchaser of a branded product in a supermarket (supplier). However, the purchaser is not always the consumer or user of the product and closer investigation also brings the realisation that there is a wide range of important needs which must be met at several supplier/customer interfaces in a chain which links:

- supply of raw materials, i.e. pulp, coatings, etc.
- manufacture of packaging material, i.e. papermaker
- manufacture of the pack or package components, i.e. printer, laminator, converter
- packing/filling the product, i.e. food manufacturer
- storage and distribution, i.e. regional depot, wholesaler or ‘cash and carry’
- point of sale, provision or dispensing to customer, i.e. retailer, pharmacy, etc.

At every stage, there are functional requirements which must be met. These requirements must be identified and built into the specification of the pack and the materials used to construct the pack. The specification for a primary consumer-use pack must also be compatible with the specification of the secondary distribution pack and the tertiary palletisation or other form of unit load.

Packaging requirements can be identified with respect to:

- *protection, preservation and containment* of the product to meet the needs of the packaging operation and the proposed distribution and use within the required shelf life
- *efficient production* of the packaging material, the pack in printing and converting, in packing, handling, distribution and storage, taking account of all associated hazards
- *promotion* requirements of visual impact, display and information throughout the packaging, sale and use of the product.

Checklists can be used to carry out these tasks logically to ensure that all important potential needs are examined.

Whilst the overall needs are defined by marketing and those responsible for the product itself, these needs have to be interpreted by packaging technologists and packaging buyers in both end-user and retailer, and by production, purchasing and technical departments in printers, converters and manufacturers of the packaging.

The next step is to match these requirements with the knowledge about the ability of the proposed material, and the package which can be manufactured from that material, in order to achieve the requirements effectively. This implies making *choices*. A technologist, using this term in a general sense, assists this process using his/her knowledge about materials and the packages which can be made from these materials, methods of packing and the general logistical environment within which the business concerned operates. Ultimately, packaging must meet the needs of society in a sustainable way by:

- minimising product waste
- improving the quality of life
- protecting the environment
- managing packaging waste through recovery and recycling.

All these requirements have technical implications and in order to meet the requirements at every stage in the manufacture and use of the packaging, paper and paperboard must be carefully selected on the basis of their properties and other relevant features.

We will now examine those physical properties and other features of paper and paperboard with technical implications which relate to their performance in printing, conversion and use.

1.5 Technical requirements of paper and paperboard for packaging

1.5.1 Requirements of appearance and performance

The properties of paper and paperboard correlating with the needs of printing, its conversion into packages and their use in packing, distribution, storage, product protection and consumer use can be identified and measured.

All paper and paperboard properties depend on the ingredients used, for example type and amount of fibre and other materials, together with the manufacturing processes. These properties of the paper and paperboard are related to the visual appearance and technical performance of packaging incorporating such materials:

- appearance that relates to colour, visual impression and the needs of any processes, such as printing, which have a major impact on the appearance of the packaging
- performance that relates to strength, product/consumer protection and the efficiency of all the production operations involved in making and using the packaging.

1.5.2 Appearance properties

1.5.2.1 Colour

Colour is a perceived sensation of the human eye and brain, which depends on the viewing light source and the ability of the illuminated surface to absorb, reflect and scatter that illumination. The lighting conditions under which the colour of paper and paperboard is viewed have been standardised so that different observers can make judgements about colour. Colour measurement has been standardised so that specifications can be defined.

The colour of paper and paperboard is usually white or brown depending on whether the fibre is bleached or unbleached (brown). The outer surface, and sometimes the reverse side, may be pigment coated. Coating is usually white though other colours are possible. Other colours are also possible in uncoated products through the use of dyes added at the stock-preparation stage. Recycled mixed fibres which are not de-inked have a grey colour commonly seen on the reverse side of WLC.

Colour is assessed by eye under specified conditions of lighting. It is measured using reflected light from a standard light source in a reflectance spectrophotometer and calculating the colour values (CIE co-ordinates).

Natural daylight, or a simulated equivalent, is used as the source for viewing. The Commission International de l'Eclairage (CIE) is recognised as the scientific authority with respect to colour in the paper, printing and packaging industries. The CIE colour co-ordinates (Fig. 1.18), L*, a* and b*, are used to express whiteness and colour using a standard D65 light source which simulates natural daylight.

Positive figures for a* indicate redness, negative figures greenness; positive b* indicates yellowness, negative figures blueness; and L* is the percentage for luminance (intensity of light) on a scale where black is zero and pure white 100%. (A top of the range specification for a white paperboard coated surface would be around a* +2, b* −5 and an L of 97.)

There are many different examples of whiteness, or hue, found in packaging papers and paperboards. It is relatively easy to develop a specific whiteness/hue when using a mineral-based coating and the perceived colour can be modified

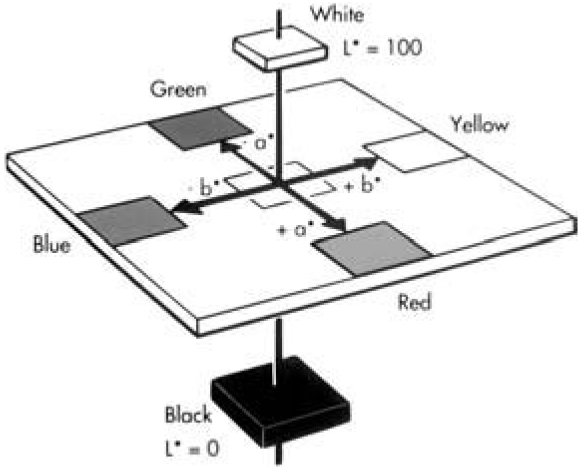

Figure 1.18 CIELAB colour co-ordinates (courtesy of Iggesund Paperboard).

with additional components such as dyes and optical brightening agents, also known as fluorescent whitening agents. However, the base sheet colour, which depends on its composition, influences the colour of a pigment-coated surface. In packaging today, a whiteness with a bluish hue is preferred for retail packaging as this is felt to give the best appearance for food products, suggesting freshness, hygiene and high quality under shop (retail) lighting.

Brightness is often mentioned in the same context as colour but it is *not* comparable. Brightness is the percentage of light reflected from the surface at a wavelength of 457 nm. The human eye perceives a range of wavelengths from under 400 to over 700 nm. Normally brightness is only measured on pulp. As it measures reflectance at one wavelength of blue light, it is of little value to a printer or end-user of packaging. Many packaging grades of paper and paperboard are brown as they do not incorporate bleached fibre.

1.5.2.2 Surface smoothness

Surface smoothness is an important aesthetic feature and is also functionally important with respect to printing and varnishing. With some print processes, a rough paper would not faithfully reproduce the printing image as a result of 'dot skip' where ink has not been transferred from the plate, for example in the gravure printing process, to the surface being printed.

Surface smoothness is measured as surface roughness by air leak methods (Fig. 1.19) – the rougher the surface, the greater the rate of air leakage, at a specified air pressure, from under a cylindrical knife edge placed on the surface. Hence, the rougher the surface, the higher the value. As papers and paperboards are compressible, the pressure exerted by the knife edge is specified. By measuring roughness at two specified knife edge pressures, an indication of compressibility

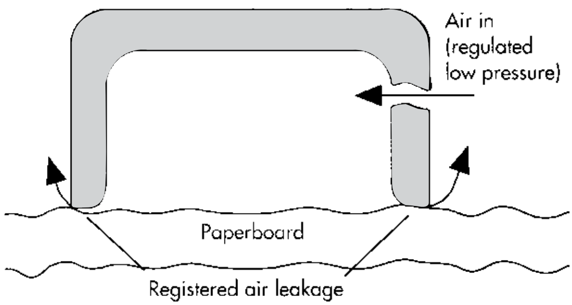

Figure 1.19 Surface roughness – measuring principle (courtesy of Iggesund Paperboard).

is also achieved. (Compressibility is also important in printing.) The most common methods are based on the Parker PrintSurf (PPS), Bendtsen and Sheffield instruments.

1.5.2.3 Surface structure

Surface structure is assessed visually by observing the surface under low-angle illumination (Fig. 1.20) which highlights any irregularities in the surface. The appearance varies depending on the direction, i.e. MD or CD, of observation and illumination. The surface structure is usually not fully apparent until the surface is varnished or laminated with either a transparent film or aluminium foil.

1.5.2.4 Gloss

Gloss is defined as the percentage of light reflected from the surface at the same angle as the angle of incidence. For better discrimination, the gloss of paper and paperboard is measured at an angle of 75° (Fig. 1.21) and printed and varnished surfaces are measured at 60°. Glossy surfaces are usually achieved either with mineral pigment coated surfaces which have been calendered, brush burnished, friction glazed or cast coated.

With uncoated papers, gloss is achieved by drying the paper or paperboard on an MG cylinder with a polished surface, as, for example, with MG bleached or unbleached

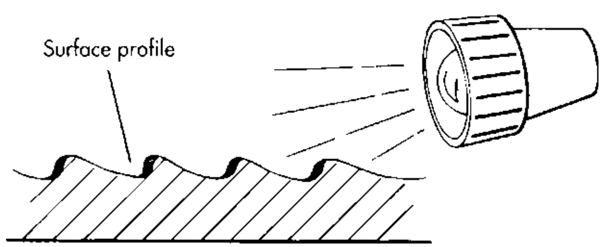

Figure 1.20 Low-angle illumination to examine surface irregularities (courtesy of Iggesund Paperboard).

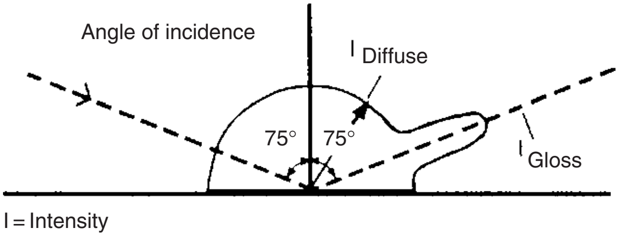

Figure 1.21 Principle of gloss measurement for paper and paperboard (courtesy of Iggesund Paperboard).

kraft papers. The high gloss of a glassine is developed on a supercalender, where it is passed through several nips, i.e. the gaps between alternate hard metal and soft rolls made from compressed fibrous material.

1.5.2.5 Opacity

Opacity relates to the capacity of a sheet to obscure print on an underlying sheet or on the reverse of the sheet itself. This is required in a packaging context where paper is used as an overwrap on top of a printed surface. Opacity is measured by comparing light reflectance, using a spectrophotometer, from the surface of a single sheet over a black background with the reflectance from a pile of 100 sheets.

1.5.2.6 Printability and varnishability

Packaging is usually printed to provide information, illustrations and to enhance visual display. Print may be varnished to give improved gloss and to protect print. The colour of the surface and the print design, text, solid colour and half-tone illustrations, and whether the print is varnished, all have a major impact on the appearance.

There is a wide range of print design in packaging as evidenced by the needs of, for example, multiwall paper sacks for cement, sugar bags, labels for beer bottles, cartons for breakfast cereals and the packaging used for brand leaders in chocolate assortments or expensive cosmetics. These examples will also be different compared with the printing on transit or shipping cases, used in distribution, or the labels on hazardous chemicals packaging.

Several printing processes are used commercially today. They are discussed in the package-specific chapters which follow. These processes include offset lithography, flexography, letterpress, gravure, silkscreen and digital printing. They vary in several important characteristics. They chiefly relate to the ink and varnish formulations, the techniques by which they are applied to the paper or paperboard substrate and the processes by which they dry and become permanent and durable.

Despite the variability, there are common features relating to printability which apply to all papers and paperboards. They comprise surface smoothness, surface structure, gloss level, opacity, surface strength, ink and varnish absorption, drying, rub resistance together with edge and surface cleanliness. In specific cases, surface pH and surface tension or wettability are also relevant.

Print colour can be measured using a spectrophotometer or with a densitometer. It can also be compared visually, under standardised lighting, with pre-set colour standards to ensure that colours remain within acceptable light, standard and dark limits.

1.5.2.7 Surface strength

Adequate surface strength is necessary to ensure good appearance in printing and after embossing. The offset lithographic printing process uses tacky inks and it places a high requirement for surface strength at the point of separation between the ink left on the sheet and the ink left on the offset rubber blanket. The IGT pick and printability test simulates this process by increasing tack on a printed strip of paper or paperboard to the point of failure, which is either a surface pick or blister. Measurement of the point of failure against a specification which is known to be satisfactory provides a means of predicting a satisfactory result.

Embossing is a means of producing a defined design feature, pattern or text in the surface of paper and paperboard in relief. Surface strength in the fibre, interfibre bonding and, where present, the coating are necessary to achieve the required result depending on the depth, sharpness of detail and area of the surface which is distorted.

An alternative approach to the measurement of surface strength is to apply a number of wax sticks which are tack graded to the surface. Tack grading relates to their ability, when molten, to stick to a flat surface. The result, Dennison Wax Number, is the highest number wax which does not disrupt the surface, when removed in the specified manner. High wax numbers indicate high surface strength. This test is only suitable for uncoated surfaces since when a coating is present the melted wax fuses with the binder in the coating giving an unrealistic result. For uncoated surfaces, this test is relevant for both printing and adhesion.

With adhesion, it is necessary for an adhesive to pull fibre at a reasonable level of surface strength – if, however, the strength is too high it could cause poor adhesion in practice. This is relevant to adhesion with water-based adhesives, hot melts and to the adhesion of heat-sealed blister packs on heat seal-varnished printed paperboard cards.

1.5.2.8 Ink and varnish absorption and drying

Inks comprise a vehicle, usually an oil, organic solvent or water, a pigment, or dye in some cases, to give colour, and a resin which binds the pigment to the substrate. A varnish is similar without the addition of colour. The vehicle, which depends on the ink and the printing process, is necessary to transfer the ink from the ink duct or reservoir via the plate to the substrate. Once printed the vehicle has to be removed by evaporation, absorption or by being changed chemically to a solid state, so that the ink dries by oxidation or cross linking as a result of ultraviolet

(UV) or electron beam (EB) curing. Inks which are not fully dry as they leave the printing press, such as conventional oil-based litho and letterpress inks, must at least 'set', by a degree of adsorbency, to an extent where they do not set off against the reverse side of adjacent sheets as they are stacked off the press.

As with most paper and paperboard properties, the key to satisfactory performance is uniformity. Lack of uniformity can lead to set-off, mottle and strike through. Tests based on the absorption of a standard ink or ink vehicle or solvent are used to check uniformity and achievement of a satisfactory specification.

Additionally, in the conventional offset lithographic process, the second colour printed in-line is transferred to a substrate which has been wetted. Under certain circumstances this can result in print mottle and hence a test has been devised to check ink repellency on a water-dampened surface.

1.5.2.9 Surface pH

For oil-based inks which dry by oxidation a surface pH of around 6–8 is preferred. A surface pH of 5 or less is unsatisfactory as it can lead to poor ink drying with some types of ink, for example oil-based litho inks. The test is carried out by measuring the pH of a drop of distilled water using a pH electrode. This range is also important for papers or paperboards which are printed with metal pigments such as bronze and those required for laminating with aluminium foil.

1.5.2.10 Surface tension

This property is important in the printing and adhesion of non-absorbent surfaces such as plastic extrusion coated papers and paperboards. These plastic surfaces require treatment to prevent inks from reticulating. This is done by surface oxidation using an electric corona discharge or a gas flame. The effect of the treatment can be measured by checking the surface tension using Dynes measuring pens. It should be noted that the effect of such treatment reduces with the passage of time.

1.5.2.11 Rub resistance

It is unacceptable for packages to be scuffed, smudged or marked in any way as a result of post-printing handling, transportation or use. Wet rub resistance is also necessary where packaging materials become wet as the result of contact with water or condensation, as is common with food packaging for products which are frozen or chilled. Good rub resistance is achieved by a combination of the paper or paperboard surface properties, the printing or varnishing process and the formulation of the print and varnish. Rub resistance can be measured against pre-set standards using standard test methods (Fig. 1.22).

1.5.2.12 Surface cleanliness

A major consideration in printing is that the surface of paper and paperboard which is to be printed should be free from particles and surface dust.

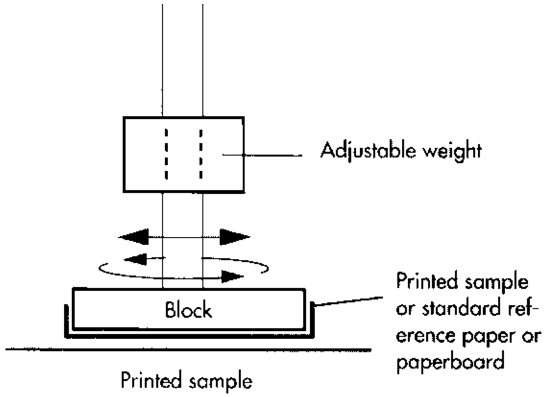

Figure 1.22 Print rub testing (courtesy of Iggesund Paperboard).

Problems can be caused by loose fibres, fragments of fibres, clumps of fibres, shives (non-fibrous particles in pulp) and coating particles (see Figure 10.17). They can originate in the finishing processes of slitting and sheeting, and together with additional particles which can originate in paper and paperboard manufacture, they can cause print impression problems.

These problems are typically spots (hickies) in solid print, loss of screen definition in half-tone illustrations, ink spots in non-printing areas, etc. These problems also lead to poor efficiency in the printing operation and waste.

There are no officially recognised methods for assessing sheet cleanliness though methods have been developed to measure loose edge debris; and surface debris can be investigated by rolling a soft polyurethane roll over the surface and inspecting and counting particles, using magnification, from a fixed area.

Whenever a problem of this nature occurs, the printer should find the particles causing the problem and identify them under magnification. Having made a correct identification, action can then be taken to eliminate or minimise the effect of the problem. It should be noted that problems of this nature may not have originated in the material. They can also arise on, or in the vicinity of, the press or as a result of problems with the inks. Hence, a correct diagnosis is essential.

1.5.3 Performance properties

1.5.3.1 Introduction

Adequate performance to enable a paper or paperboard material to meet the needs of packaging manufacture and use is essential. The material must provide strength for whatever structural shape is necessary for the packaging, be it a tea bag, a label, folding carton or shipping container. Strength is necessary in printing and constructing the packaging, both in packaging manufacture, also known as conversion, and in the packaging operation, whether this is carried out manually or by machinery. Strength is also necessary for the physical protection of the goods in distribution and storage, at the point of sale and in consumer use.

Research has identified the specific features of strength and other performance needs, and tests which simulate these features have been developed so that specifications can be established. Specifications fulfil two important functions. Firstly, they provide the basic parameters for manufacture whereby paper and paperboard products are defined. Secondly, by regular testing during manufacture against the specification the manufacturer has an accurate view of the degree of uniformity within a making and of consistency between makings. Many tests can now be carried out on-line during manufacture and by linking testing with computer technology, a high frequency of such testing is possible. It is also possible to provide feedback within the system to automatically maintain parameters such as moisture content, thickness and grammage within the target range. This approach is being applied to other parameters – e.g. colour, gloss and stiffness.

In testing strength and other related performance properties, account is taken of the hygroscopic nature of the cellulose fibre. The fibre absorbs moisture when exposed to high humidity and loses moisture when exposed to low humidity. Paper and paperboard will vary in moisture content depending on the relative humidity (RH) of the atmosphere to which it is exposed.

As strength properties in particular vary with moisture content, it is necessary for specifications and test procedures to be based on samples conditioned at, and therefore in equilibrium with, a fixed temperature and relative humidity. This is set in laboratories at 50% RH and 23°C. It is therefore necessary to correlate specification values with the actual conditions prevailing during manufacture on the machine such that when subsequently tested after conditioning that the paper and paperboard conforms with the specification.

The specific type and value of the various performance properties required will depend on the needs of the packaging concerned. Both the thinnest tissue and the thickest paperboard will have specific requirements and the actual properties may be the same properties such as tensile strength, elongation (% stretch), tear, creasing and folding, wet strength, etc. The underlying principles and how they are achieved for each type of paper and paperboard have much in common. This is because paper and paperboard are sheet materials formed from an interlaced network of cellulose fibres. Differences in the type and value of the strength and other performance properties depend on the amount, type of fibre and processing, whether the paper or paperboard is multilayered, together with any other ingredients, coatings or laminations which provide additional properties.

The difference between MD and CD has already been noted. Strength properties and other features show variations which are characterised by these two directions. The value of many of the test-method measurements of properties will vary depending on the direction of measurement.

1.5.3.2 Basis weight (substance or grammage)

The amount of fibre in paper and paperboard is measured by weight per unit area. In the laboratory, this is done by weighing an area of material which has been cut accurately. Basis weight is expressed in a number of ways – typically the units are grammes per square metre or pounds per 1000, 2000 or 3000 square feet. For a given paper or paperboard product, most of the strength-related properties increase with increasing basis weight.

This also has commercial implications as for a specific paper or paperboard the higher the basis weight the lower the number of packs from a given weight of packaging material. Higher basis weight means more fibre per unit area, and more fibre requires the removal of more water and lower output on the paper or paperboard machine.

1.5.3.3 Thickness (caliper)

Thickness is measured in either microns (0.001 mm or 1×10^{-6} m) or points (1 point is 0.001 in. or one thousandth of an inch). Paper, and paperboard, is a fibrous structure, it is compressible and therefore thickness is measured with a dead weight micrometer which applies a fixed weight over a fixed area. For specific papers and paperboards, thickness increases with basis weight and hence for a given grade, several strength properties increase with increasing thickness. However, as will be seen when stiffness is discussed, thickness can be more relevant than basis weight.

1.5.3.4 Moisture content

Moisture content is measured as a percentage of the dry weight. Many strength properties change with changes in moisture content.

The cellulose fibres in paper and paperboard will expand by absorbing moisture in high RH and shrink by losing moisture in low RH conditions. The dimensions of fibres change more in their CD by swelling or contracting than they do in their length. As more of the fibres tend to line up in the direction of motion through the paper machine, any change in dimension across the fibres results in a greater cumulative change in the CD of the sheet. Hence dimensional stability is more critical in the CD compared with the MD. (This can be used to determine the MD and CD of a sheet by moistening one face of a square sample where one side is parallel to an edge of the sheet. The fibres quickly swell and the moistened face expands in the CD, tending to form a cylinder, the axis of which is in the MD.)

Every paper and paperboard product will seek to achieve moisture content equilibrium with the relative humidity of the ambient conditions in which it finds itself. This is known as hygrosensitivity. It is possible to construct curves showing how this changes over a range of relative humidities. Paper and paperboard have one set of equilibrium moisture contents when the RH is rising and a different set when the RH is decreasing. This is known as the hysteresis effect (Fig. 1.23) where results are affected by previous storage conditions.

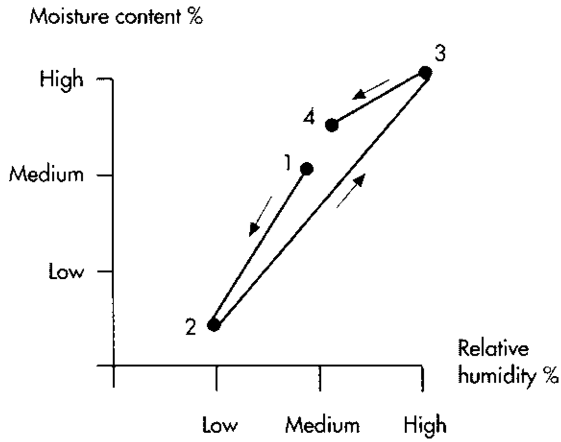

Figure 1.23 Moisture hysteresis (courtesy of Iggesund Paperboard).

The implication of this is that the moisture content achieved in manufacture is critically important for what subsequently happens to the material in printing, conversion and use. There are therefore two aims in manufacture with respect to moisture. First, to set a moisture content specification range which matches the equilibrium moisture content of that material over the average range of RH likely to be encountered by the product in the course of its use. The recommended percentage of RH in which paper and paperboard are printed, converted and used on packaging lines is 45–60%. Secondly, and the papermakers have many techniques at their disposal to achieve this, to maintain a uniform moisture content within this range during manufacture.

The hygroscopic nature of cellulose fibre, however, also implies that the material must be adequately protected in distribution and storage. If optimum efficiency in printing, conversion and use is to be achieved, the following elements of good manufacturing practice must be observed:

- use moisture resistant wrappings in transit and storage
- follow mill recommendations with respect to storage
- establish temperature equilibrium in the material before unwrapping
- provide protection after each process.

Critical situations can exist when paper or paperboard is brought from a cold to a warm environment. Users should never remove moisture resistant wrappings from paper and paperboard until the material has achieved temperature equilibrium with the room where it is to be used on, for example a printing press or a packaging machine. A paperboard with a cold surface, for example after being unloaded from a lorry in winter, can cool a tacky ink, causing the tack to increase to such an extent that a severe print blister occurs during printing.

Additionally, the cold edges of a stack cool the adjacent air when moved from a cold store to a warm production area and this can lead to the condensation of moisture on the edges. This moisture cannot be seen but it can be absorbed, causing curl and hence difficulty in feeding the material on a printing press or a packaging machine (Fig. 1.24). Equally, if unwrapped material is left exposed to high temperature or low humidity, it can dry out, also causing distortion.

In practice, papers and paperboards are manufactured in ways which are intended to minimise such dimensional changes (hygrosensitivity). The following of mill-recommended practices in the wrapping, storage and use of paper and paperboard by printers, converters and users is also important in order to achieve the best efficiencies in printing, conversion and use.

1.5.3.5 Tensile strength

The strength, or force, required to rupture a strip of the material is known as the tensile strength. The material shows elastic behaviour up to a certain point. This means that the force, or stress, applied to the strip is proportional to the deformation or elongation caused by the applied force. This is known as Hooke's Law and is expressed as:

$$\text{Stress (applied force)} = \text{Constant} \times \text{Strain (dimensional change)}$$

This constant is known as the Modulus of Elasticity (E) or Young's Modulus.

Up to a certain point, paper and paperboard show elastic properties (Fig. 1.25). This means that if the force is removed the sample will regain its original shape – however, above the elastic limit this no longer applies as the material is increasingly deformed until it ruptures.

Specifications are based on test methods with fixed strip widths and rates of loading – the tensile being recorded as force per unit width. Tensile strength is higher in the MD compared with the CD.

The tensile value at the point of rupture will vary with the rate of applying the load. When the load is steadily increased the measurement is referred to as a static tensile and when the load is applied suddenly over a very short time interval, the measurement is referred to as a dynamic tensile.

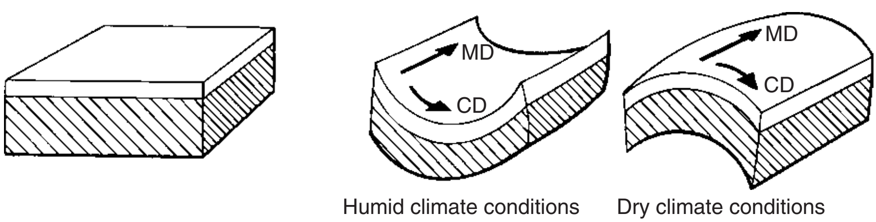

Figure 1.24 Humidity changes affect paper and paperboard flatness (courtesy of Iggesund Paperboard).

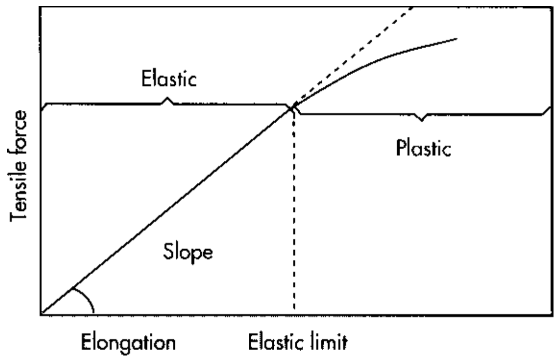

Figure 1.25 Stress/strain relationship showing elastic and plastic properties (courtesy of Iggesund Paperboard).

The latter, defined as tensile energy absorption (TEA) is important in understanding the paper properties which relate to the drop-test performance of a multiwall paper sack. This test is a measure of the work done, i.e. force × distance, to rupture the sample and it combines the features of tensile strength and percentage stretch.

1.5.3.6 Stretch or elongation

This is the maximum elongation of a strip in a tensile test at rupture and is a measure of elasticity expressed as a percentage increase compared with the original length between the clamping jaws. CD elongation is higher than MD elongation.

1.5.3.7 Tearing resistance

Tearing resistance (Fig. 1.26) is the measured force required to promulgate a tear in the sheet from an initiated cut. In most situations, the need is to prevent damage by tearing. In some cases as, for instance, with a tear strip to facilitate opening

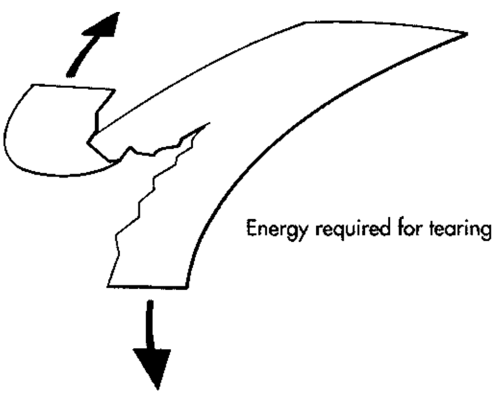

Figure 1.26 Principle of tearing resistance (courtesy of Iggesund Paperboard).

a pack and gaining access to the contents, the requirement is for the material to tear cleanly.

1.5.3.8 Burst resistance

To test for burst resistance, the sheet is clamped over a circular area and subjected to increasing pressure until it ruptures (Fig. 1.27). It is a simple test to perform but its relevance to strength in practice is complicated. High values, however, indicate toughness. As noted in Section 1.2.6, urea and melamine formaldehyde resins can be added at the stock-preparation stage to enable the paper to retain a significant proportion of its dry strength if it becomes wet during subsequent usage. The extent of wet strength is calculated by comparing the dry burst strength with the burst strength after the sample has been wetted in a specified way. The percentage of wet burst to dry burst expresses the extent of strength retention when wet.

1.5.3.9 Stiffness

This property has major significance in printing, conversion and use. Stiffness is defined as the resistance to bending caused by an externally applied force. Stiffness is measured by applying a force (F) to the free end of a fixed size piece of the material, length (l), which is clamped at the other end, and deflecting the free end through a fixed distance or angle (δ). This is known as the 2-point method (Fig. 1.28). It is used to measure bending stiffness (Lorentzen and Wettres, 5°), bending resistance (Lorentzen and Wettres, 15°) and bending moment (Taber, 15°).

The MD stiffness value is higher than the CD value and sometimes this is expressed as the stiffness ratio, i.e. MD stiffness/CD stiffness. This difference is the result of the differing fibre alignment arising as a result of the method of manufacture. Stiffness is also related to other important features, such as box compression, creasability, foldability and overall toughness. An important consideration

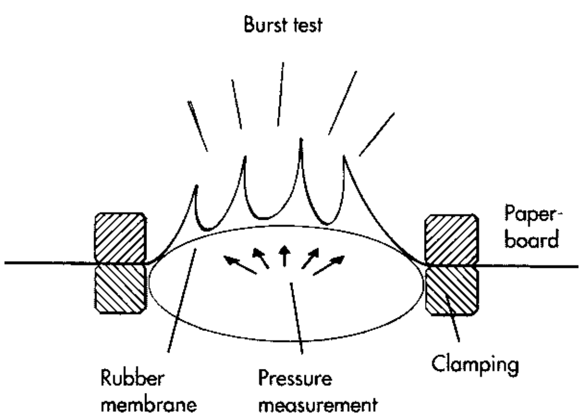

Figure 1.27 Principle of burst resistance (courtesy of Iggesund Paperboard).

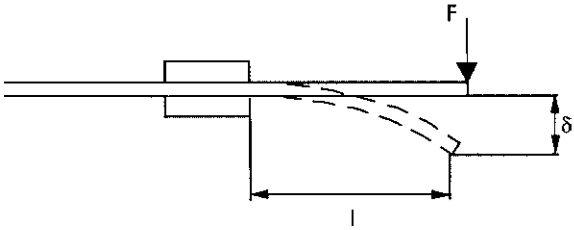

Figure 1.28 Loading principle for the measurement of bending moment by the 2-point method (courtesy of Iggesund Paperboard).

regarding stiffness is that it is related to the Modulus of Elasticity (E) and thickness (t) (caliper) as follows:

$$\text{Stiffness} = \text{Constant (material specific)} \times E \times t^3$$

The cubic relationship is valid for homogeneous materials providing that the elastic limit is not exceeded. For paper and paperboard, the indice is lower than 3.0 but is still significant. For some types of paperboard the indice is around 2.5–2.6. Thus it is valid to claim that stiffness is highly dependent on thickness as is shown by doubling the thickness and noting that the stiffness increases by a factor of just over five.

1.5.3.10 Compression strength

When we discuss compression in the context of packaging needs, we usually mean the effect of externally applied loads in the storage, distribution and use of packed products in packaging, such as cartons, cases and drums.

We can study the effect on compression of different aspects of pack design, different types and thicknesses of paper and paperboard and different climatic conditions. We recognise the difference between static loads applied over long periods, as with palletised loads in storage, and the dynamic loads associated with high forces applied for very short periods as in dropping and with transport induced shocks. So we carry out compression tests on the packs at different rates of loading.

Research has shown that the inherent paper and paperboard properties involved in box compression are stiffness, as already discussed, and what is known as the short-span compression strength.

When an unsupported sample of paper or paperboard is compressed by applying a force to opposite edges in the same plane as the sample, the material will, not unexpectedly, bend. This does not give a measure of compression strength (Fig. 1.29). If, however, the sample height in the direction of the applied force is reduced below the average fibre length, say to 0.7 mm, the force is applied to the fibre network in such a way that the network itself is compressed causing the fibres

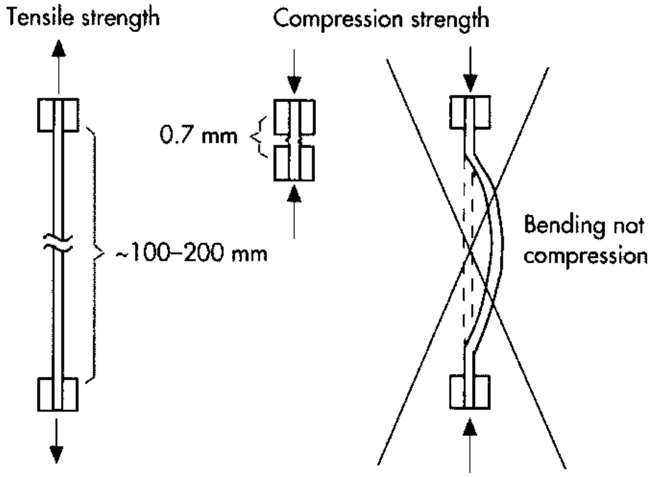

Figure 1.29 Compression strength testing – note the difference in sample length compared with the tensile test (courtesy of Iggesund Paperboard).

to move in relation to each other. In this situation, interfibre bonding and the type(s) and quantity of fibre become important to the result which we call the 'short-span compression strength'. It is this inherent characteristic of the sheet, in the direction of measurement, MD or CD, together with stiffness, which relates to box compression strength.

1.5.3.11 Creasability and foldability

Paper and paperboard are frequently folded in the construction of pack shapes such as many designs of bags and sachets, cartons and corrugated and solid fibreboard cases. The thinner materials are folded mechanically through 180° and the resulting folds are rolled to give permanence. The thicker materials for cartons and cases require a crease to be made in the material prior to folding.

The material to be creased is supported on a thin sheet of material known as the make-ready, or counter die, which itself is adhered to a flat steel plate. Grooves are cut in the make-ready to match the position of the creasing rules in the die. When the die is closed, creases are pressed into the surface creating a groove in the surface of the carton and a bulge on the reverse side. Crease forming in this way subjects the material to several forms of stress which are indicated in Figure 10.29.

When the crease is folded, the top layers of fibre on the outside of the resulting fold are extended and therefore require an adequate tensile strength and stretch. The internal layers are compressed causing a localised delamination (Figures 10.30–10.32). The reverse side bulge in turn develops as a bead as folding continues to the desired angle and thus behaves like a hinge (Fig. 1.30). It is important that the bulge itself does not rupture or become distorted. Hence the layer of fibre on the reverse side also requires good strength properties.

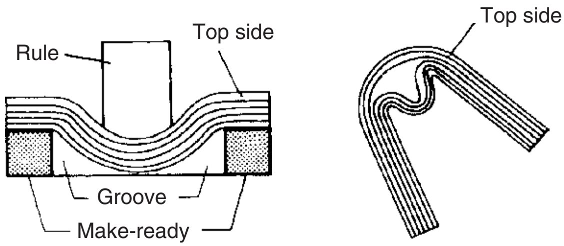

Figure 1.30 Crease forming and folding (courtesy of British Carton Association).

In addition to good strength properties in the material, the geometry of the creasing operation – i.e. the width of the creasing rule, width and depth of the make-ready groove and the penetration of the creasing rule into the surface of the material – is most important. In addition to the visual inspection of creases and folds, it is also possible to measure resistance to folding and spring-back force – features which can be controlled by the creasing geometry.

The subsequent performance of carton creases folded during gluing is time dependent. This is important where side seam–glued cartons are stored before use on a cartonning machine. This feature can be measured as 'carton opening force'. The conditions of such intermediate storage in terms of humidity, temperature, tightness or looseness of packing and the stacking of the cases in which the cartons are stored are also important factors which can affect efficiency in packaging operations.

1.5.3.12 Ply bond (interlayer) strength

Ply bond strength (Fig. 1.31) is important for multilayered paper and paperboard products. It relates to the delamination of the material when subjected to forces which cause delamination. Using either the TAPPI (Technical Association for the Pulp, Paper and Converting Industry) or the Scott method, the delaminating force is measured with the help of metal plates which are attached to the paperboard by means of double sided self-adhesive tape.

If delamination strength is too low, adhesive bonds may fail too easily and if too high, the internal delamination necessary for good creasing will not occur.

1.5.3.13 Flatness and dimensional stability

Flatness is important in the sheet of paper or paperboard for its efficiency both in printing and conversion and subsequently at the packing stage. Examples of the type of problems which can occur are misfeeds which cause stoppages and mis-register, of colour to colour and print to profile. The flatness required is built into the material during paper or paperboard manufacturing. Variations in forming, tension, drying and moisture content can cause wave, curl, twists and baggy patches (Fig. 1.32).

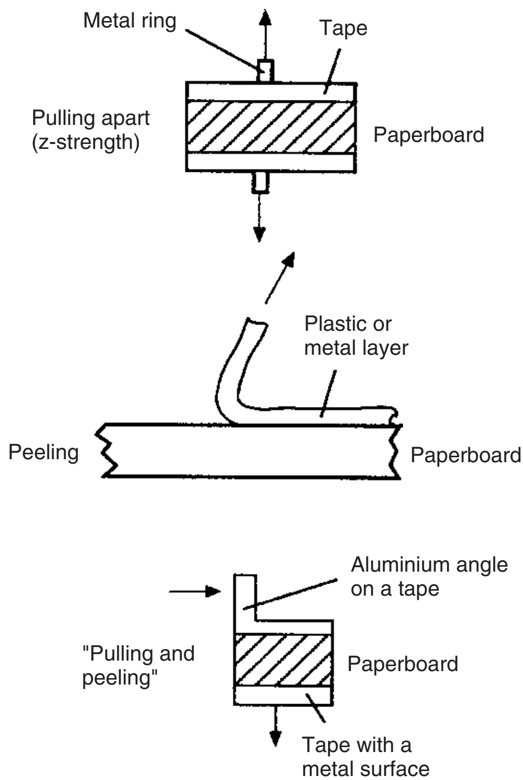

Figure 1.31 Principles of testing interlaminar strength (courtesy of Iggesund Paperboard).

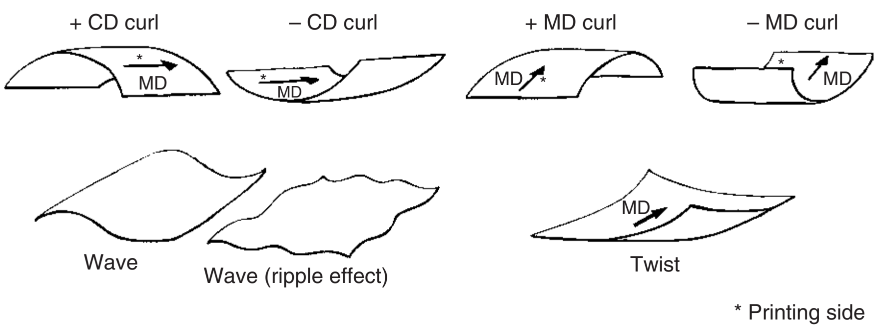

Figure 1.32 Different types of curl, twist and wave (courtesy of Iggesund Paperboard).

As we have discussed in Section 1.5.3.4, the hygroscopic nature of cellulose fibre requires that the material must be adequately protected in distribution, storage and use. There are requirements of good manufacturing practice which must be observed if optimum efficiency in printing, conversion and use is to be achieved. As noted, these are to do with the use of moisture resistant wrappings, achieving temperature equilibrium before unwrapping and rewrapping where paper or paperboard is liable to be affected by storage in either high or low RH conditions. Critical situations can exist when paper or paperboard is brought from a cold to a warm environment and where the RH range is outside 45–60%.

1.5.3.14 Porosity

Uncoated papers and paperboards are permeable to air and the time for a given volume of air to pass through a sheet of defined area can be measured using the Gurley method. This has implications for situations where the material is picked up by a vacuum cup so that it can be moved to another position. This occurs on printing presses, cutting and creasing machines and packaging machines. Variable porosity outside specified limits can lead to more than one sheet or piece of packaging being picked up which, in turn, can jam the machine.

Problems can also occur when coated materials are incorrectly picked up by vacuum cups from the uncoated reverse side surface when air can be drawn in from the adjacent raw edge of the material. This, however, is a problem of either machine setting or an incompatibility between the pack design and the machine setting.

Porosity is an important factor in the speed of filling of fine powders in multiwall paper sacks where it is necessary for air to escape from the inside of the package.

1.5.3.15 Water absorbency

There are occasions when water comes in contact with paper and paperboard materials – this may happen deliberately as when water-based adhesives are used or in an unplanned way as for instance when moisture condenses on the surfaces and cut edges of a carton removed from a frozen-food cabinet at the point of sale.

Water absorbency is dealt with in one of two ways or a combination of both. Firstly, by internally sizing, whereby a water repellent resin (size) is incorporated at the stock or pulp preparation stage just prior to introducing the stock to the paper or paperboard machine. Many types of paper and paperboard are sized as part of normal production but where a higher degree of water hold-out is required, extra hard sizing is added to the stock. In multilayer paperboards this means that each layer, including the middle layers, is hard sized. The resin, which may be either of natural origin (rosin) or synthetic, is deposited on the surface of the cellulose fibres making them water repellent. Secondly, a surface coating can be applied during manufacture either as a surface size or as a separate coating operation, as would be the case with an extrusion coating of PE or where a varnish is applied over print.

The simplest method of measuring the water absorbency of flat surfaces is by the Cobb test method (Fig. 1.33) which measures the weight of water absorbed in a given time over a given area. Usually the time interval is either 1 or 3 min. A note of caution must be stated that whilst this seems an obvious and suitable method of testing, it does not always correlate with what happens in practice. This is mainly due to different, usually shorter, time intervals or dwell times where water-based adhesives are held under pressure on packaging machines and where

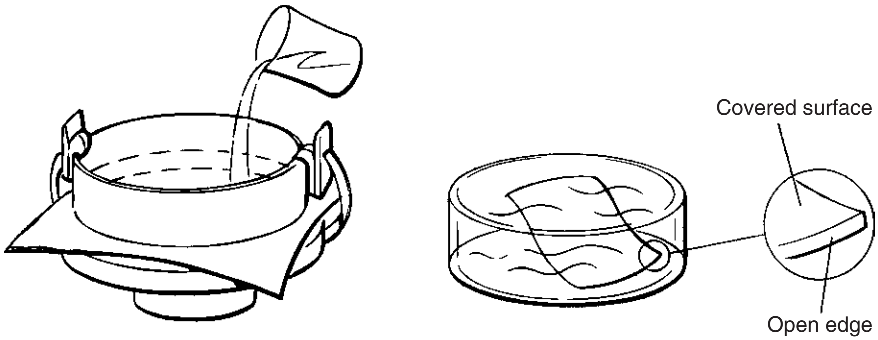

Figure 1.33 Cobb and wicking tests (courtesy of Iggesund Paperboard).

tack develops as a result of some of the water being adsorbed. However, in many cases it is an indication of functional performance.

Water can also enter through the exposed cut edges of packaging. This can also be retarded by hard sizing. The flat surfaces of samples for this test are sealed with waterproof plastic adhesive tape prior to weighing the sample and immersing it in water for the stipulated time.

1.5.3.16 Gluability/Adhesion/Sealing

The principles of adhesion and gluability apply in many situations where materials incorporating paper and paperboard are joined together. This occurs, for instance, when side seams are required for bags, cartons and cases and when packs are closed after filling. It is also relevant to lamination with adhesives, the manufacture and use of labels, plastic-extrusion coating and heat sealing.

The adhesives (glues), are usually either water-based with a bonding material solids content of 50–60%, where the water acts as a carrier, or wax/polymer blends which are 100% solid and applied hot in the molten state. In heat sealing, the plastic incorporated in or on the surface of the material acts as the adhesive.

Adhesion is characterised by three stages:

- open time for the adhesive to remain functional after being applied to one surface and before the joint is made
- setting time during which it is necessary to keep the joint under pressure
- drying time is the time necessary to develop a permanent bond.

Adhesives are chosen to suit the surfaces being joined, the constraints of the operation in respect of open, setting and drying times and any special functional needs of the pack and its use, for example wet strength, direct food contact approval, etc.

A good glue bond, where at least one of the surfaces is paper or paperboard, must show fibre tear at a satisfactory strength when peeled open. Where the adhesive is applied to the surface, it must ‘wet’ or flow out evenly over the area of application.

Some paper and paperboards are extrusion coated with plastics such as PE on one or two sides. Packs incorporating such materials may be sealed by heat sealing either by sealing plastic to paper, as an overlap seal, or plastic to plastic. The plastic is softened and becomes tacky/molten under heat and pressure and then cools and resolidifies forming a strong seal. A strong heat seal also requires good fibre tear in the paper or paperboard material.

Heat-sealable tea-bag tissue incorporates a heat-sealing medium such as PP in the form of a fibre dispersed within the very thin sheet. With multilayer thicker materials, such as paperboard, the fibre tear must rupture the internal layers when the seal is peeled open.

1.5.3.17 Taint and odour neutrality

Some products are sensitive to changes in their taste, flavour or aroma. Examples are fat-containing food products, such as butter, vegetable fats and chocolate. Other flavour and aroma sensitive products are tea and coffee and a range of tobacco products. Changes can occur by loss of flavour through the packaging, the ingress of unwanted flavours from the external environment and by the transfer of flavours originating in the packaging. The first two potential causes are prevented by augmenting the paper and paperboard with additional barrier materials, such as aluminium foil, a metallised coating on plastic film, PVdC coated oriented polypropylene film, etc. Whilst all packaging associated with flavour and aroma sensitive products has to meet critical requirements, here we are concerned with aspects which potentially can apply to paper and paperboard packaging.

The best approach is to ensure that when odour and taint critical packaging is required, the raw materials are chosen carefully. The range of paper and paperboard materials is wide and depending on the needs of the product, many papers and paperboards can be ruled out initially from what is known, doubtful or potentially variable about their constituents.

For the most critical products virgin fibre is necessary. The best results are achieved with chemically separated and bleached virgin pulp. For some critical products paperboard with a mixture of this material and mechanically separated virgin pulp has also been approved and is used widely. The concern with these materials is not the pure cellulose fibre, which is inert and odourless, but other residual wood originating compounds which may not be fully removed by bleaching and which are either not removed, or only partially removed, in the case of mechanical pulp. The pulp can contain residual fatty acids from the wood and these compounds are oxidised over time producing odiferous aldehydes.

Another potential source of odour and taint can be residual compounds originating from the chemicals which are used for the mineral coating – not so much the mineral compounds themselves but the synthetic binders (adhesives) which bind the particles together and to the base sheet of fibre.

Paper and paperboard-based packaging for use with products which have critical odour and taint-free requirements can be checked by panels of selected people using sensory methods based on smelling and tasting. Where odour or taint is detected, the compounds responsible can be identified by gas chromatography and mass spectrometry. The concentration of compounds can be measured by gas chromatography, see Section 10.8. Many other potential sources for odour and taint arise as the result of printing, varnishing and other conversion processes.

1.5.3.18 Product safety

The basic requirement of packaging is that it should ensure the quality of the packed product however that is defined. In some cases, this leads to the need for assurances regarding the safety of food in direct contact, or close proximity, to specific packaging materials. It also leads to a similar need with respect to the packaging used for toys.

These needs are defined in regulations. In the United States, the regulations are given in the 'Code of Federal Regulations, Food and Drugs Administration (FDA)'. In Europe, the most widely quoted are those formulated by the 'Bundesgesundheitsamt (BGA)' and in Holland there are the 'Warenwet' regulations. For toy packaging, the regulations are embodied in EN71 Part 3 (migration of certain elements).

Users of packaging can show diligence in ensuring that regulations are met by requiring evidence from suppliers, which approved laboratories have checked that the materials concerned meet the appropriate regulations.

1.6 Specifications and quality standards

Having examined the appearance and performance properties of paper and paperboard packaging materials, it is clear that considerable efforts have been made to relate them to packaging needs. Test procedures which measure these properties and relate them to market needs have been developed and used in specifications.

Specifications are needed for a variety of reasons – communication of exact needs, quality assessment, resolving disputes, compatibility of competing quotations and as a basis for improvement.

The paper and paperboard market is international with pulp, paper and packaging traded on a worldwide basis. Hence there has been a need for harmonisation of test methodology. Test methods are developed locally and between suppliers and customers on a one-to-one basis. These may become national standards such as British Standards (BS), German Standards, DIN and TAPPI in North America. In recent years, International Standards have been developed through the ISO.

Tolerances which are realistic are an important requirement of specifications. Over time, the needs and expectations of customers increase – equally the abilities and achievements of suppliers have to respond to market needs. On-line computer control has, in many cases, augmented laboratory testing, which of its nature is historical. This development which is progressive and ongoing results in less variability within makings and between makings, and less variability leads to higher productivity.

Equally important is the requirement that quality management systems overall must be seen to be effective. Many manufacturers now have their quality systems independently and regularly assessed under the ISO 9000 series of Quality Standards. Supplier audits are also undertaken.

1.7 Conversion factors for substance (basis weight) and thickness measurements

It will already have been noted, e.g. in sections 1.5.3.2 and 1.5.3.3 respectively, that different conventions are used in different parts of the world for the measurement of basis weight and thickness.

It is, however, possible to convert from measurements in one convention to another as follows:

Substance (basis weight) measured in lb/1000 sq.ft = 4.882g/m^2, (grammage)

Substance (basis weight) measured in lb/3000 sq.ft = 1.627g/m^2, (grammage)

Thickness measured in ‘thou’, (thousandths of an inch) = 25.4 micron, (thousandths of a mm)

A thousandth of an inch is also known as a ‘point’ and, in the case of plastic film thicknesses, as a ‘mil’. The SI symbol for a micron, or micrometre is ‘µm’.

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2 Environmental and waste management issues

Mark J. Kirwan

2.1 Introduction

Anything *environmental* commands attention. We now know more about the effects of human activity on the environment at local, regional and global level. Society is concerned, as never before, about environmental issues. Since the 1960s, through education and the media generally, the general public has become aware of the issues. We have seen the rise of the 'green' movement in the form of non-governmental organisations (NGOs). The overall result has led to government involvement at local, national and international level. There are regulations which require the measuring and regular monitoring of critical factors which can affect the environment.

There is a concern about the quality of life today, and in both the medium and the long term. These concerns have been summarised as follows (Tickell, 1996):

- population growth causing pressure on *resources*
- deterioration of land quality
- pollution of rivers, lakes and seas
- limited freshwater availability
- changes in the chemistry of the atmosphere – acidification, ozone depletion and climate change attributed to the 'greenhouse effect'
- losses of species or reduction in biodiversity.

The key components relating to world population are life expectancy, which is increasing, and birth rate, which is declining. The birth rate per 1000 is declining but because of the numbers of people overall, the population as a whole increases. Nevertheless, the figures for 2050 have been revised downwards in recent years as the overall rate of population growth reduces (Table 2.1). The fact, however, remains that more people will use more resources.

In addition to global and regional issues, there can be local environmental issues which affect communities, such as the siting of a waste incinerator or a wind 'farm', which are examples of the NIMBY ('not in my backyard') approach. There is also concern about the effects of our activities on indigenous people and forest-based communities.

Industry is a primary user of resources and creates additional environmental impact through its manufacturing processes and the products it produces. The effect of heightened environmental concern has caused industry to balance the need to be technically efficient and profitable against the environmental needs of society which are driven by people's perceptions, resulting in a legal framework within which industry must operate.

Table 2.1 World population 1950–2050 (median projection)

Year	Population (billion)
1950	2.5
1960	3.0
1970	3.7
1980	4.4
1990	5.3
2000	6.1
2010	6.8
2020	7.5
2030	8.1
2040	8.6
2050	8.9

Source: Population Division of the Department of Economic and Social Affairs of the United Nations Secretariat (UN, 2003).

Paper and paperboard packaging is subject to two aspects of environmental concern. First, as an important part of the paper industry, it is subject to concerns which apply to the paper industry as a whole. Secondly, it is subject to the concerns which apply to all packaging.

In summary, these concerns comprise:

- pressure on resources due to the increasing demand for paper and paperboard
- wood, the main raw material, is sourced from forestry
- environmental impact caused by the use of energy and freshwater
- pollution in manufacture, particularly in fibre separation (pulping) and bleaching
- packaging is perceived as wasteful in itself and, when discarded, after its protective function has been completed, as a waste management problem.

The increasing demand for paper-based products arises from the increase in population worldwide together with increases in per capita consumption associated with rising standards of living. The disparities in consumption shown in Table 1.3 highlight the potential for increases in per capita consumption of paper-based products.

Whilst there are environmental issues concerning forests, energy, water, impact of industrial activity and waste management that are specific to paper and paper-based packaging, such matters have also to be viewed in the context of agendas driven by world realities. The issues of climate change (global warming), dependence on fossil fuels (the 'oil economy'), competition for scarce resources such as freshwater, and what to do about 'waste', all set agendas with environmental implications for society.

We are aware of the limitations of the planet Earth. We recognise 'the global village' where actions in one location or sphere of activity can have regional and worldwide implications. We used to see environmental issues in terms of a range of single issues, such as the concentration of a waste emission which when reduced was seen as a problem solved. Now we appreciate that we must consider whole systems where any change may have wider implications. Hence, there is a need for holistic solutions.

We are asked if specific products, processes or practices are 'environmentally friendly'. These are difficult questions because everything we do, cause to be done or merely observe has an environmental effect, and assessing the extent of that effect involves a value judgement. Widespread and indiscriminate use of the precautionary principle is not an option.

The guiding principle for society, when evaluating our approach to meeting the demands of today and in the future, is to ensure that we operate in an environmentally 'sustainable' way.

2.2 Sustainable development

In 1987, the World Commission on Environment and Development, also known as 'The Bruntland Commission', issued a report entitled 'Our Common Future'. This discussed, internationally, the concept and the need for sustainable development. The report defined this as 'development which meets the needs of the present without compromising the ability of future generations to meet their own needs'.

At Rio in 1992, the governments of various nations agreed that sustainability had economic, environmental and social aspects which were equally important and interdependent (United Nations Conference on Environment and Development).

This theme has been taken forward in a number of major areas including forestry with significant coordinating leadership from FAO (United Nations Food and Agricultural Organization):

> Nations must manage their forests in a sustainable way so that present generations can enjoy the benefits of the planet's forest resources while preserving them to meet the needs of future generations. (FAO, 2003)

Several leading paper companies are featured in the Dow Jones Sustainability Indexes (DJSI) (www.sustainability-index.com). These indices are based on criteria from companies which are evaluated in terms of quality of management and strategy, together with performance, in dealing with opportunities and risks deriving from economic, environmental and social developments. Such developments can be quantified and used to identify and select leading companies for investment purposes. In several annual reports, the DJSI has outperformed the market in general, indicating that sustainability priorities enhance performance overall for the companies concerned.

The position today, and for the future, is that paper and paperboard:

- should not be a polluter in manufacturing, use and disposal
- should not be a drain on irreplaceable resources.

More, of course, can be said about both these points, but they are the bottom line – the key messages irrespective of what may have applied in the past when our knowledge, measurement techniques and understanding of environmental impact were much less sophisticated than is the case today.

We should also be confident of the main benefit of paper and paperboard packaging in that they protect far greater resources, in terms of the goods protected, than are consumed in the manufacture and use of the packaging. This benefit is achieved during the packing, storage, distribution, sale and consumption of food and other manufactured goods.

Effective packaging, in which paper and paperboard-based packaging is a major component, has revolutionised the safe distribution of all products, particularly food, in the advanced industrial societies and to a lesser extent so far in the developing world. It is acknowledged that packaging *reduces* waste.

Ample evidence exists of large-scale losses occurring during post-harvest and distribution operations in developing countries. The subject was first addressed at the World Food Conference in 1974. In 1977, the FAO carried out a study of post-harvest crop losses in developing countries. This produced evidence of post-harvest waste. Post-harvest losses were also presented at the 1996 World Food Summit. The results have been summarised by Neil Robson (Robson, 1997), and the conclusion drawn that 'the world's packaging professionals have a major task ahead if they are to convince governments and opinion leaders of the vital role which packaging should play in reducing food wastes'.

It is therefore important that paper and paperboard-based packaging continues to be available and this has to be achieved in a sustainable manner. Sustainability for paper-based packaging concerns the availability and use of the resources needed to meet increasing demand and the minimisation of the environmental impact of manufacturing, use and disposal. In summary, it concerns forestry, manufacture of paper and paperboard, printing, conversion, packaging, distribution, consumer use and the ultimate disposal of paper and paperboard-based packaging. These subjects will now be discussed in terms of 'sustainability'.

2.3 Forestry

Forests cover around 30% of the earth's land area and are one of the essential support systems which sustain life on Earth as we know it – the other essential systems concern air, water, soil and energy.

Forests are important as they:

- reverse the 'greenhouse effect'
- stabilise climate and water levels
- promote biodiversity by providing a habitat for a wide range of animals, birds, plants and insects
- prevent soil erosion and protect watercourses
- store solar energy.

The greenhouse effect occurs when radiant energy from the sun is unable to escape from the earth's atmosphere because of the build-up of gases, such as CO_2. These are believed to prevent the heat from escaping – acting, in effect, like glass in a greenhouse – and so cause the temperature to rise. This is known as 'global warming', which is considered to be a cause of climate change.

Carbon dioxide is the most common greenhouse gas. It is released when fossil fuels like coal, oil and natural gas are burnt to produce energy in the form of heat and electricity and when used in internal combustion engines. The world's use of fossil fuels releases about five billion tonnes of carbon into the atmosphere per annum. The proportion of CO_2 in the atmosphere is increasing by about 5% a decade and this is thought to be the main cause of global warming.

Trees grow by absorbing CO_2 and releasing oxygen. As trees grow, therefore, they remove carbon from the atmosphere and so help to reverse the 'greenhouse effect'. This is known as 'fixing' carbon and the forest acts as a 'carbon sink' or reservoir.

Growing trees process CO_2 from the atmosphere by photosynthesis (Fig. 2.1). In this process, trees, in common with all green-leafed plants, using energy supplied by the sun, convert CO_2 and water into simple sugars and oxygen. The sugars are polymerised naturally and ultimately result in the formation of cellulose fibres.

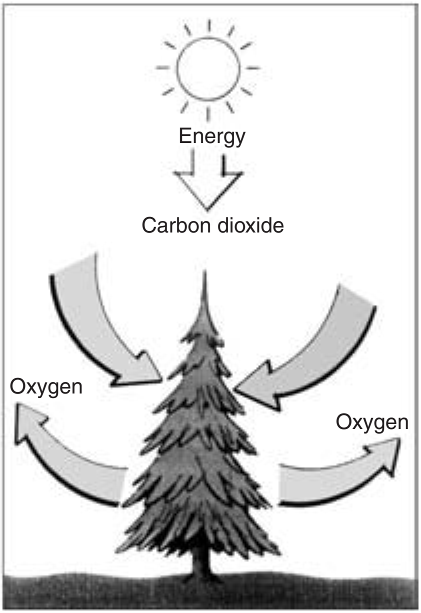


Figure 2.1 Trees grow by the combination of carbon dioxide and water, using energy from the sun. This process, which emits oxygen, is known as photosynthesis. (Reproduced, with permission, from Iggesund Paperboard.)

A mature forest, however, also contains dead trees and other vegetation. As this organic material decays, it actually gives off CO_2. Also, growing trees emit oxygen and decaying trees absorb oxygen. Hence, where the biomass (collective term for trees and other vegetation) stays approximately constant in a mature forest, the emission and absorption rates for oxygen and CO_2 remain in balance, and it is incorrect to refer to such mature forests as being 'the lungs of the world'. In expanding forests, on the other hand, where there is an annual incremental net addition of new wood volume, CO_2 is effectively removed from the atmosphere.

With respect to carbon 'fixing', area alone does not reflect the complete picture. Location, climate, age of trees, soil, rainfall, competing species, proportion of dead and decaying trees and other biomass, etc. are all important factors. Large land masses and vegetation, or lack of it, including large areas of forest, are known to be the major determinants of climate. Other factors are solar energy, temperature, humidity, precipitation, condensation, atmospheric pressure and wind, which all interact dynamically.

Forests prevent soil erosion and protect watercourses from silting – the destruction of forests has resulted in humanitarian disasters through landslides and flooding. Forests are important for the maintenance of the traditional form of life of forest-based communities in the developing world. It is self-evident that forests provide a habitat for many species, viz. animals, birds, trees, other types of plants and insects, etc. It is also a fact that species evolve and some become extinct. Biodiversity has entered the environmental debate with respect to the extent that human interference in forestry is causing species to be lost by extinction. Some exceedingly high losses have been *predicted*. However, the UN *Global Biodiversity Assessment* (UNEP, 1995) states that 'the rate at which species are likely to become extinct in the near future is very uncertain', taking note of 'the discrepancy between field knowledge and predictions'.

The importance of forests as a store of solar energy is less controversial, if not fully appreciated. About 80% of the wood felled in the developing world is used as fuel (Remrod, 1991).

In the industrialised countries, around 20% of the wood felled is used for fuel. In the European Union (EU), about 1% of the energy used is derived from wood though the proportion is likely to increase as the EU seeks to replace fossil-fuel energy with energy from renewable sources, which include wood.

Forests, particularly in the industrialised countries, are also important in providing an environment for leisure and for the commercial viability of small communities working in forest-based activities.

Forests are therefore important for many reasons. FAO defines four types of forest by ecological zone as follows:

- Boreal (33% area) – these are forests in the northern parts of the Northern Hemisphere, i.e. northern parts of Canada, Scandinavia and the Russian Federation, including Siberia. The alternative name 'taiga' is used for the boreal area of Russia. These forests are predominantly coniferous, i.e. with pine, spruce, larch and fir, with a proportion of deciduous birch and poplar. Some analyses refer to these forests as temperate coniferous.

- Temperate (11% area) – these forests are mainly in North America and Europe; they contain mixed coniferous and deciduous species.
- Sub-tropical (9% area) – also referred to as warm temperate. An important area for this type of forest is the south-east of the United States of America.
- Tropical (47% area) – there are three types of tropical forest. The rain forest is given the most publicity in areas such as the Amazon basin, Congo basin and South-east Asia. However, the area loss in the arid dry forests and savannah forests of South America, Africa and India are a greater cause for concern, where the use of wood for fuel and unsuitable agricultural practices can lead to desertification. The trees are predominantly deciduous (FAO, 2001, p. xxii).

Tropical and sub-tropical forests comprise 56% of the world's forests, and temperate and boreal forests account for 44%.

Figure 2.2 shows six categories of forest area which give a general indication of where forests are located. FAO has defined the various types of forest area based on tree size and concentration.

The main source for coordinating global statistics for forestry is FAO, and reference should be made to its website for comprehensive details. They issue a 'Forest Resources Assessment' every 10 years. In the report of 2000, it is stated that total forest area is 3.9 billion hectares, roughly 30% of the global land area. (It is thought that between one half and two thirds of the land area was covered by forest, thousands of years ago.)

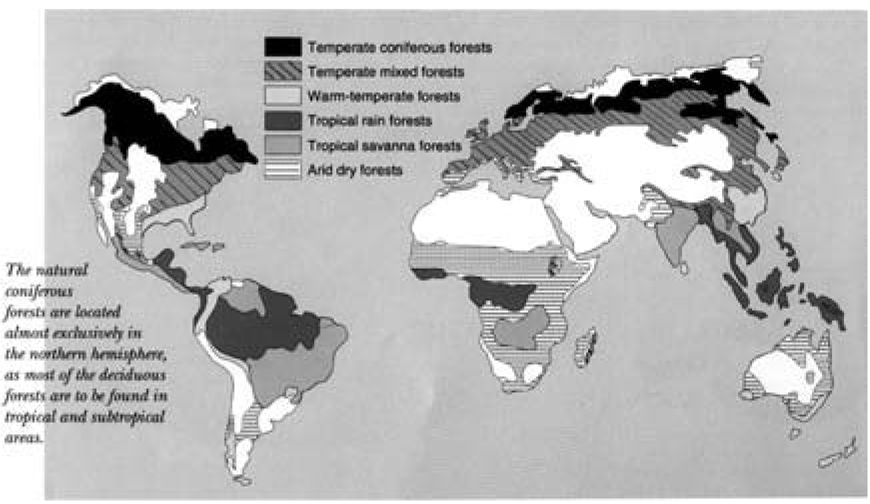


Figure 2.2 Forest locations. (Reproduced, with permission, from the Swedish Forest Industries Federation.)

Deforestation in the developing world has been driven by the demand for agricultural land, though FAO states that the direct link between population growth and the conversion of forests to agriculture was less valid in the 1990s than hitherto.

In the 1990s, the global forest area was diminishing in area by a net 9.4 million hectares pa (per annum). FAO (2001, p. xxiii) states, 'The estimated net loss of forest area for the 10 year period of the 1990s as a whole was 94 mha – an area the size of Venezuela.'

There was, however, a contrast in the change in area between forests in industrialised countries and those in developing countries. Forest area was *increased* by 5.5 million hectares pa in the former and was *decreased* by 14.6 million hectares pa in the latter. Most of the area lost is in Africa (56% approx.) and South America (39% approx.).

The fact that forest area is diminishing is a cause of concern. It is also a fact that forests are the main source of raw material for paper and paperboard. It has become a popular, but totally inaccurate, perception that these two facts are *connected* and that the paper industry is, somehow, responsible for the loss of forest area, particularly the rain forests.

Most of the wood used by the paper industry is sourced from industrial countries where, as FAO states, there has been an *increase* in forest area of 54 million hectares in the period 1990–1999. (This new forest area is slightly less than the area of France.)

In addition to the increase in the area of forest in the industrialised countries, another important positive factor is the difference between annual net incremental growth and the volume of wood harvested. In the third report of the European Environmental Agency (EEA, 2003), it was stated that the volume of new wood growth (annual increment) *exceeded* the volume of wood felled (harvested) in Europe, including the Nordic area, by 40%. *Facts and Figures 2001* published by the American Forestry and Paper Association (AF&PA, 2001) stated that the most recent US data showed that growth *exceeded* harvesting by 47%.

The fact that there are large differences between the volume of wood harvested and the incremental growth is an indication of the value of these forests as 'carbon sinks'.

There are other differences between the forests in industrialised and developing countries. In the former, roughly 71% of trees are coniferous and 29% deciduous whilst in the latter, approximately 94% are deciduous (Remrod, 1991). Most of the deciduous trees in the natural forests of the developing countries are unsuitable for pulpwood.

Forest plantations make up only about 5% of all forests in the FAO survey, the rest is natural forest. Plantations are defined as being forests which are *established* by seeding or planting. An increasing use of plantations as carbon sinks was reported by FAO (2001, p. 23).

Plantation forestry was increased at an annual rate of 4.5 million hectares pa during the 1990s. Of these, 3 million hectares pa were considered successful. By 2000, Asia had 62% of the world's plantation cover. They provided 35% of industrial wood (roundwood), mainly for pulp and sawn timber. In tropical areas, eucalyptus and acacia are the most common species; and in temperate and boreal zones, pine and spruce are predominant. An important advantage of plantations in the tropical zone is that they provide income and, hence, relieve pressure to remove timber from natural forests (FAO, 2001, p. 28).

Many of the forests in the industrial countries are managed. The general aim of sustainable forest management is to 'reduce the differences between virgin forest and cultivated forests' (Holmen, 2002, p. 10).

Forest management is carried out in many ways depending on local factors, such as the nature of the soil, climate, height above sea level, etc. The specific aims are to:

- ensure replacement of harvested trees
- provide habitats for animals, plants and insects
- promote biodiversity
- protect watercourses
- preserve landscape
- maintain rural employment
- create leisure facilities.

Forest management today meets commercial, social and environmental needs. Forests, to an increasing extent, can be independently certified for environmental performance in relation to approved objectives. Certification of timber products can ensure a transparent chain of custody so that the eventual customer knows the source of the wood and has authentic confirmation of the certification.

Apart from the use of wood as fuel, it is used industrially for building (e.g. housing, sheds, fencing, etc.), wood products (e.g. tools, ornaments, transport, furniture, etc.), and as pulpwood for the paper industry (Fig. 2.3). The pulp industry has been criticised for harvesting wood by clear felling though today this is practised in a more environmentally supportive manner. An illustration of this is the provision of 'corridors' of forest cover which allows animal movement. Another example of better management is where a statistical analysis is made of the various species being felled and regeneration by seeding is carried out so that the original proportions of the various species in the forest are maintained. Natural seeding and thinning lead to a wide range in the ages of trees, in a managed forest.

Pulp is also made from trees which have been thinned in managed forests, thereby allowing other trees to grow to maturity for other purposes. There are plantation forests which are not suitable for thinning where, owing to location, prevailing winds and soil depth, thinning would result in the loss of the remaining trees. It is hoped that after several rotations, the depth of soil will build up to the point where the trees will be more deeply rooted and thinning will become possible. Pulping can also use the tops and branches of large trees felled for building-timber as well as sawmill waste, both materials which otherwise have no commercial use. In this way, the paper industry contributes to the overall commercial viability of managed forestry.

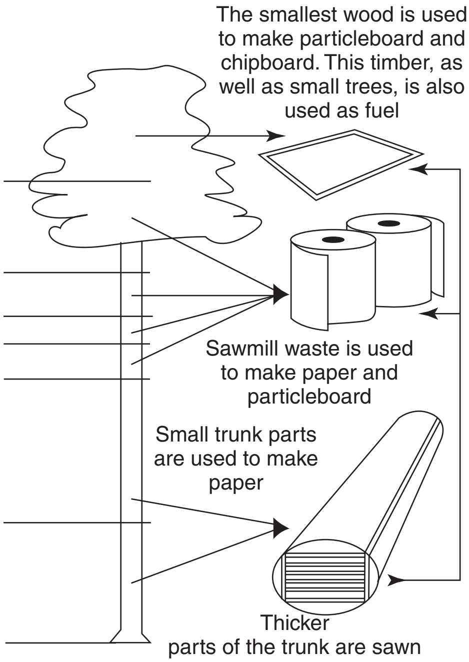


Figure 2.3 How the tree is used. (Reproduced, with permission, from Iggesund Paperboard.)

The answer to the question as to whether the paper industry is responsible for forest depletion in the rain forests, and elsewhere, is a resounding negative. Only 9% of the pulpwood is sourced in the tropical zone and this is derived from sustainable plantations. The pulp which is produced in the tropical zones, for example in Brazil and Indonesia, is derived from plantation wood.

Pulpwood is mainly produced in the industrialised countries of the temperate, boreal and warm-temperate zones, and in these areas forest cover is increasing and there is a significant annual increment in which new growth exceeds the amount harvested.

It can be said that because of the demand for paper, investments in forestry have occurred. The paper industry is in the business of using, rather than saving, trees and thereby saving forests! Yet as recently as 1998 an NGO, Worldwatch Institute (WI), claimed that ‘the dramatically increased demand for paper and other wood products is turning local forest destruction into a global disaster’. The author still meets, and reads about, people who think that using paper ‘destroys’ rainforests.

Another way of looking at the situation is to calculate the area of forest needed to produce, *in new growth per annum*, the volume of wood used for paper and other wood products. This is relatively simple because FAO has worked out the total annual volume of wood used for paper and other wood products as well as the area of the global forest. Using the average growth rate per hectare it is possible to calculate the area of forest needed to produce that volume of wood. Growth rates vary considerably depending on factors such as climate, soil and tree species. A range was published in the EEA Dobris Assessment (1995), giving average growth rates in European countries.

The range included Norway at 2.7 m^3/ha, Finland at 3.5 m^3/ha, Sweden at 4.1 m^3/ha, UK at 5.0 m^3/ha, France at 5.3 m^3/ha and Ireland at 8.8 m^3/ha. On the basis that the Nordic area of Sweden and Finland are significant producers, the area required would be derived from the *growth* of roughly 10% of the global forest area. In practice, many forest areas would have higher growth rates than the Nordic rate and the true area would probably lie between 5 and 10% of the global forest area.

The conclusion to be drawn is that the area of forest necessary is a small proportion of the global forest and, as we are looking at annual incremental growth, no forest depletion is involved.

Many pulp and paper companies worldwide have forest interests and their policy is to manage these forests in sustainable, environmentally sound ways. It is in their best interests to protect their investments and secure their main raw material with sustainable forest management.

Under the guidance of FAO and national governmental woodland supervision, sustainable forestry is progressing on a worldwide basis. There are issues which are being addressed to alleviate the problems of forest loss in the developing world, but the position from the point of view of the paper industry is of a naturally sustainable future.

2.4 Environmental impact of manufacture and use of paper and paperboard

2.4.1 Issues giving rise to environmental concern

Issues giving rise to environmental concern are:

- extraction of wood from forests
- fibre separation by chemical and mechanical pulping processes
- bleaching
- paper and paperboard manufacture
- printing, conversion and packaging
- logistics – storage, distribution and sale of packed goods.

Environmental impact arises through the use of resources:

- energy
- water
- chemicals.

Environmental impact also arises as a result of:

- emissions to air, water and the generation of solid waste during extraction, manufacture and distribution
- packaging waste.

2.4.2 Energy

Energy is used in fibre separation, bleaching and in paper, paperboard and packaging manufacture and use. Energy comprises roughly 25% of the cost of manufacturing paper and paperboard.

The energy source and the amount used depend on the manufacturing process, printing, conversion, packaging, distribution and the locations of energy use.

In chemical fibre separation, chemicals are used to separate fibre by dissolving the non-fibrous constituents of wood. The separated non-fibrous material is used as fuel to generate electricity and steam. The wood is therefore the energy source for both pulping and bleaching. In integrated mills, where paper or paperboard is made on the same site as the pulp, the wood by-products also provide energy in the form of electricity and steam for the manufacturing process. This energy source, biomass, is, therefore, renewable and sustainable. In Europe this results in 53%, and in the USA 55%, of paper and board being made using energy derived from biomass (ICFPA, 2002, p. 12).

In mechanical and recovered fibre separation (recycling of paper and paperboard) energy in the form of electricity is used to separate fibres. Mills using mechanical and recycled pulp generate their electricity and steam on-site. Electricity is used to pump suspensions of fibre in water, drive the machinery, remove water by suction and pressing and dry coatings by radiant heat. Steam is used to heat-drying cylinders, and provides other on-site heating needs. The energy source for all these processes is most likely to be fossil fuel. In Europe, today, this usually means natural gas. The proportion of energy based on oil and coal has fallen from 29% in 1990 to 15% in 2000 (ICFPA, 2002, p. 13). The use of peat is less favoured on environmental grounds.

In paper and paperboard mills processing mechanically separated fibre and recovered fibre, and in printing, conversion and packaging, the energy source is electricity. This is usually obtained from external sources and therefore the supply, and sustainability with respect to energy, depends on the way electricity is generated for society as a whole in the locations concerned. In some locations, hydroelectric power dominates (6.6% of global energy); another source is nuclear energy (6% of global energy). In most countries, however, the energy source for most of industry, including paper and paperboard packaging, and society is fossil fuel (80.4% of global energy) (Lomborg, 2002a).

We live in an oil-dominated economy which has kept the price of crude oil under $30 per barrel since the 1880s apart from 1973 to 1985 when Oil and Petroleum Exporting Countries (OPEC) engineered higher prices by restricting output. This has restricted the commercial development of alternative energy sources. It is also the reason why known oil reserves are projected on a relatively short time scale, since exploration is expensive. More oil is constantly being discovered within this time scale and technology is extracting a higher proportion from existing oilfields. Technology allied to a need to reduce cost has ensured that we use energy more efficiently. The energy demand has increased but the price has remained relatively stable and even fallen in real terms.

Nevertheless, in time the earth's resources of fossil fuels on which we currently depend for the greater part of our total energy consumption, such as gas, oil and coal, will be exhausted. However, technology applied to known reserves of oil, gas and coal, together with the discovery of new sources, continues to extend this time scale. Additionally, there are reserves in tar sands and beyond that shale oil. There is currently some production from Canadian tar sands and it would only require a modest rise in the price of oil for a greater production from tar sands to become commercially available, which could double current oil reserves (Lomborg, 2002b).

Shale oil was exploited in Germany in 1595 and the first patent was issued in London in 1696 (Encyclopaedia Britannica, 2001) but whilst the reserves are huge, the technology required to use this material commercially is complicated and hence expensive. It is nevertheless a potential source.

Conventional fossil fuel–reserves data given by Lomborg (2002c) are: at the present rate of energy consumption, oil – 40 years, natural gas – 60 years and coal – 230 years. The use of coal as fuel is less favoured today because of the high cost due to the removal of noxious emissions. Oil and natural gas will eventually be more difficult to find and use and therefore become more expensive at which point other fossil fuel reserves and alternative sources of energy, which today are more expensive than oil, will become commercially attractive alternatives. Renewable energy sources are by definition sustainable, and it is possible that other, environmental, priorities will be applied to the choice of energy source within the time scale for oil to become more expensive.

A more likely scenario therefore is that we will be considering non-fossil alternatives sooner rather than later in order to reduce carbon emissions. The EU has a target of increasing the proportion of energy derived from renewable sources to 12% by 2010.

Currently, the main non-fossil alternatives which are used today are themselves subject to constraints for expansion. For environmental reasons hydroelectric schemes are unlikely to be significantly expanded and the same conclusion, though for different reasons, applies to nuclear energy.

In industrialised countries, only a small proportion of energy is being supplied from other, renewable, sources such as wind, waves, solar, geothermal, landfill gas and biomass which includes wood. In Europe, in 2001, this proportion was slightly less than 6%.

The subject of wood (biomass) as an energy source for society in developed industrial societies is of interest to the paper and paperboard industry as it would then be competing for supplies of wood. It is, however, realistic to encourage the use of wood for energy in a sustainable way. New coppiced, plantation woodland of poplar and willow, where a crop is taken every 3–5 years by cutting trees to ground level, and stimulating regrowth, is a traditional practice which is being revived in a modern way.

Geothermal energy using heat from the interior of the earth can be harnessed where it is readily available. This is the major energy source in Iceland but there are commercial and technical problems in exporting such energy over long distances in the form of electricity to major potential users, such as the UK. Geothermal energy is used in other countries particularly in western areas of the US and in New Zealand – there is even a small operation in the UK which derives heat from an 1800 m deep drilling, (Southampton Geothermal Heating). There are commercial and technical constraints in expanding these resources.

Wind, landfill gas and solar power are being harnessed. A small amount of wave power is harnessed. Lomborg (2002d) argues that the main reason for the poor uptake of renewable energy is commercial, even though the price per kWh for wind-derived energy is ten times cheaper than it was around 1980. It is the fastest developing source of electricity. There are technical challenges, with cost implications, and it competes in an energy market subject to economic, fiscal and political pressures.

Non-fossil sources exploited are from the incineration of municipal waste, which is discussed in Section 6.3.3, and other forms of agricultural waste, such as poultry litter. There are three such power stations operating in the UK, generating 75 MW (UK Biomass, 2003).

Hydrogen from fuel cells would be a good choice of energy source as the main waste product is water, but production, distribution and use require technical development. At a recent conference it was stated that ‘Hydrogen can be produced from a variety of primary energy sources such as natural gas, coal and renewable sources, and can also be produced through a number of technologies including the electrolysis of water or reforming of natural gas’ (Battershell, 2003), i.e. mainly fossil-based. Alcohol from organic sources and methane from landfill are also being used to a limited extent.

In the developing world, traditional energy sources are wood, charcoal and other animal and vegetable wastes, including bagasse from sugar cane processing. These forms of energy provide 25% of the energy needs of developing countries (Lomborg, 2002e).

Summarising:

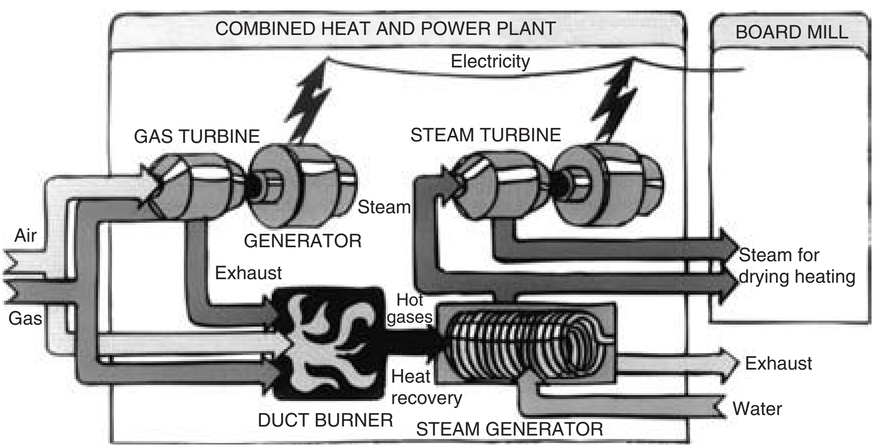
- 50% of the energy used in paper and paperboard manufacture is renewable
- an increasing amount of renewable energy is being used in the general electricity supply, though the impression should not be that this will significantly reduce our current dependence on fossil fuels
- in terms of sustainability, there is no short-term concern for fossil fuel supplies, though the cost will increase as less-accessible sources are exploited.

Another way of looking at energy sustainability in the paper and paperboard industry is to use current energy sources more efficiently.

Paper mills have traditionally produced electricity and steam on-site by heating water to produce high-pressure steam. This is used in turbines to produce electricity and the resulting low-pressure steam is used to heat the steel cylinders which dry the paper and paperboard. The critical requirement is to produce enough steam for drying.

An important way in which the paper industry has contributed to a saving in energy and a reduction of CO_2 emission is by using natural gas in a combined heat and power (CHP) plant (Fig. 2.4). In this process, natural gas is used in a gas turbine to produce electricity. The temperature of the already hot exhaust gases is raised further by heating with additional fuel and used to produce steam which is then passed through a steam turbine to produce more electricity. The exhaust steam is then used to provide heat in the paper or paperboard mill. This is a more efficient use of fuel compared with the traditional boiler and steam turbine approach and more efficient than using electricity from a national grid. CHP generation has several benefits. CHP consumes less fuel for a given energy output and can balance the output of electricity and steam.

The energy saving is of the order of 30–35% compared with conventional boilers (ICFPA, 2002). Moreover, as a consequence, there is a lower gaseous emission



The new combined heat and power plant in Workington gives the paperboard mill much greater energy efficiency, compared with electric power from the public network. The natural gas turbine provides electricity. The temperature of the turbine's exhaust gases is raised further in a gas-fired duct burner. The hot gases from the burner produce steam in a heat exchanger.The steam goes to a steam turbine which generates electricity, and the excess heat is used both for drying the paperboard and for heating.

Figure 2.4 Principle of a combined heat and power (CHP) plant. (Reproduced, with permission, from Iggesund Paperboard.)

(CO_2, SO_2 and NO_x) per unit of electricity and any excess electricity can be supplied to other (local) users, thereby saving the use of less efficiently, remotely produced electricity. The capital cost of CHP is high and commercial effectiveness is dependent on the price obtained for the electricity exported from the mill.

Energy saving is a major area for development as this can have a significant impact on cost and emissions. A published example of this approach is the decision at Holmen (2002) to develop pilot plant to evaluate the production of thermomechanical pulp using a technique with potential energy savings of 20–35%.

In the year 2000, 90% of electricity used in European mills and 88% used in US mills were produced by CHP. Energy consumption per tonne of product in the manufacture of paper and paperboard continues to fall. In the period 1990–2000, the reduction per tonne of product was 15% (ICFPA, 2002, p. 12).

2.4.3 Water

In 1999, European mills consumed, on average, 35 m^3 of water per tonne of paper and paperboard, having achieved a reduction of one third in the previous ten years (CEPI, 2002, p. 30). However, according to CEPI, production of paper and paperboard over the same period increased by 36.5%. Some products consume less than the average consumption and the trend is still downwards with many mills consuming less than 15 m^3 per tonne.

Water is used in mechanical and chemical pulping to separate, bleach, wash, refine and transport primary (virgin) fibres, i.e. fibres made directly from wood. Water is used in recycling to separate, wash, refine and transport recycled (secondary) fibres recovered from waste paper and paperboard. It is used in the de-inking process.

In manufacturing paper and paperboard, water is used to refine, or prepare fibres for use on the paper or paperboard machine. The sheet is then formed from a dilute water suspension of fibres from which water is then removed by vacuum, pressing and drying during which interfibre and, in the case of multi-ply paperboard, interlayer bonding takes place. The role of water in the consolidation and the development of bonding is of fundamental importance in the manufacturing process. Water is used to transport the active ingredients in surface sizing and mineral pigment coating and converted into steam to generate electricity and heat-drying cylinders.

After use, the process water is treated to meet the local regulations and returned to nature, i.e. rivers, lakes or tidal estuaries. As already noted, there is a trend to use less water. Water is recycled and condensate is recovered. There is even a development to close water systems, i.e. to recycle all the process water, in both pulp and paper mills, thereby reducing the demand and the environmental impact of water use. Improved effluent water treatment and the move away from bleaching with elemental chlorine have resulted in a reduction in water usage.

In the printing and conversion of paper and paperboard-based packaging, water is used in many ways:

- as vehicle in liquid inks
- in emulsion-based functional coatings
- in lithographic printing (treatment of non-printing areas of the plate)
- as vehicle in adhesives
- in cooling systems
- in drying systems
- in processing printing plates
- in cleaning systems.

Many reports in recent years have predicted severe shortages of freshwater. *Global Environmental Outlook 2000* from United Nations Environmental Programme states, 'the declining state of the world's freshwater resources, in terms of quality and quantity, may prove to be the dominant issue on the environment and development agenda of the coming century' (UNEP, 2000). This theme is continued in the follow-up report 'Global Environmental Outlook-3' where it is stated that 'more than half the people in the world could be living in severely water-stressed areas by 2032 if market forces drive the globe's economic and social agenda' (UNEP, 2002).

The paper industry is therefore managing water usage with care in respect of the quantity used, proportion recycled and the quality of water returned to nature. The paper industry has reported significant reductions in water consumption and significant improvements in the quality of returned water are continuing.

The use of water in printing, conversion and packaging is much smaller than the amounts used in paper and paperboard manufacture. Users are, however, subject to metering in respect of consumption and controls in respect of effluent (discharges). Overall, it is therefore considered that water management in the manufacture and use of paper and paperboard-based packaging is managed in a sustainable way.

2.4.4 Chemicals

Process chemicals used in the manufacture of paper and paperboard comprise 3% of the raw materials. A further 9% of the overall raw material usage is accounted for by mineral pigments used in surface coatings and fillers (PT, 2003). (Note: fillers, which comprise small particle size white mineral pigment, are used to improve opacity, printability and smoothness.)

Alum used for internal sizing is of natural origin, as is starch used for surface sizing, and promotion of fibre bonding and strength. Chemicals are used to separate (release) fibres in wood. In the case of the sulphate process, most of the chemicals used are recovered and reused in the process. Bleaching chemicals will be discussed in the next section.

This leaves an important group of chemicals which are used to enhance the product, improve the efficiency of the manufacturing process and meet ecotoxicological demands. This group would include coating ingredients, such as binders, speciality sizing agents that impart specific properties, such as grease resistance, optical bleaching agents also known as fluorescent whitening agents, fillers, wet-strength additives, retention aids, defoamers, dyes and anti-fungal and anti-microbial aids which keep the process system clean and efficient.

Waste chemical materials from the applications described are waterborne and are subject to effluent regulations applying in the areas where mills are located. Reference to Environmental Reports from paper mills indicates that process chemicals are carefully chosen and that environmental impact, health and safety are key criteria. From the standpoint of sustainability, it should be noted that some of these chemicals are already derived from sustainable resources, for example starch, alum. Whilst many of the synthetic polymers currently used are based on monomers derived from oil, coal or natural gas, other renewable sources are technically possible.

A wide range of materials is used in printing, conversion and package use:

- resins, vehicles and pigments used in inks
- adhesives for both structural design and lamination – a wide range is used including starch-based, PVA, crosslinking resins and hot melts based on resins and waxes
- plastic extrusion coatings (PE, PP, PET, PMP)
- functional coatings for grease resistance, water repellency, non-slip, release, etc.

All these materials must be suitable for food packaging where they are required to be in contact with, or close proximity to, food. Printers and converters should check the status of all materials with their supplier with respect to the prevailing regulations. In addition, the processes of making printing plates and cylinders also involve the use of chemicals.

2.4.5 Transport

Packaging and packaged goods are, predominantly, transported by road. The movement of logs, pulp, paper and paperboard is by road, rail and by sea. Reference to the Environmental Reports issued by major forest-product companies indicates that they are working on reducing the energy usage and the emission of volatile organic compounds (VOCs) in transportation.

2.4.6 Manufacturing emissions to air, water and solid waste

So far we have discussed the resources necessary for the manufacture of paper and paperboard packaging. Of equal concern from the point of view of environmental impact and sustainability are the emissions and solid wastes which occur during manufacture and the disposal of packaging when its packaging function has been completed.

2.4.6.1 Emissions to air

We have already noted that the combustion of fossil fuel releases CO_2 into the atmosphere and this is considered to be one of the main causes of the 'greenhouse effect' which leads to global warming. Just over 50% of the fibre raw material for the paper and paperboard industry is made from chemically separated fibre where the energy needs are provided by biomass and hence the main emission to air is in the form of CO_2. The balance, made up of recycled fibre and fibre separated mechanically from wood, uses energy which is mainly derived from fossil fuel.

Printers, converters and users of packaging all use electricity and, dependent on the energy sources, can also be assessed for the amount of CO_2 which results from their usage of electricity. Reference has been made to the work companies undertake to reduce the environmental impact of transportation. Reductions in the use of energy in this area are accompanied by reductions in the gaseous emissions associated with the consumption of fossil fuels.

Producing energy from fossil fuels results in the emission of carbon dioxide (CO_2), sulphur dioxide (SO_2) and nitrogen oxides (NO_x). These gases can result in 'acid rain' causing environmental damage to trees and lakes. The amounts which are released of these three gases can be calculated in kg/tonne of product.

The use of natural gas as the preferred fossil fuel and the installation of CHP plants for the production of electricity and steam result in lower emissions. In some locations, mills have access to hydroelectric power which does not produce gaseous emissions.

The separation of pulp by chemical means results in sulphur-based malodorous gases which although present in very small amounts are noticeable in the areas close to the mills because of the sensitivity of the human nose to the odours concerned. Reference to pulp-mill environmental reports indicates that measures to reduce these emissions are ongoing. These acidic and malodorous gases may be burnt in the energy recovery boilers and the flue gases passed through an alkali scrubber. Other possible emissions to air comprise soot (carbon particles) and dust, which can be removed by electrostatic separators.

The printing industry has had to reduce organic discharges to the atmosphere from the drying of solvent-based ink, varnishes and coatings. There is increased usage of water-based inks. An Environmental Report cited the following example from a folding carton–printing facility in that a reduction was made 'in the use of isopropyl alcohol by 40% in litho plate dampening water during litho printing. This was achieved by installing osmosis equipment to treat fresh water and use of safer chemicals to lower the surface tension of the plate dampening solution' (M-real, 2002, p. 26).

2.4.6.2 Emissions to water

Water is collected after use in both pulp mills and paper mills. Some process water is immediately recycled, for example whitewater containing fibre, fillers and dissolved chemicals, from the wet end of the paper machine.

Wastewater is treated to render it suitable for reuse or discharge which is usually directly back to nature or via an urban sewerage system. Mill discharges are subject to external regulation. In Europe, the regulations are operated locally within the guidelines of the EU Integrated Pollution Prevention and Control (IPPC) Directive.

The contents of wastewater depend on the type of mill and the processes operated. The processing could involve chemical or mechanical pulping, bleaching, recycling of recovered fibre, de-inking, paper and paperboard manufacture, mineral-pigment coating, etc. Wastewater can contain fibre, fines (fibrous particles), other solid matters such as particles of bark, fillers and mineral pigments. It could contain colloidal materials such as starch and soluble inorganic salts. Pulp-mill wastewater can contain lignosulphonates, hemi-cellulose, organic high molecular weight soluble fatty acids and degradation products from bleaching.

Wastewater is processed to achieve acceptable standards in respect of its:

- total suspended solids (TSS) – this material would otherwise form deposits in natural waterways
- biological oxygen demand (BOD) – it is necessary to remove material which would compete with other forms of aquatic life, such as fish, for oxygen
- chemical oxygen demand (COD) – slowly decomposing organic material would also compete with other forms of life
- total phosphorus (P) – this is a nutrient and if the concentration (eutrophication) builds up, algae and microscopic forms of life develop which, in turn, prevent oxygen absorption and light penetration into water
- total nitrogen (N) – eutrophication, as with phosphorus
- temperature – the temperature of water emissions to nature must be regulated
- adsorbable organic halogens (AOX) – this measures any organic chlorine present as a result of the bleaching process, though some is naturally present in wood itself.

Adsorbable organic halogens is not a measure of the toxicity of chlorine (halogen) compounds present. This is an important point as the most common chlorine chemical used today is chlorine dioxide where the by-products are simple compounds which are not persistent in the environment and are similar to those which occur in nature.

Particles in suspension are removed by settlement. This can be assisted by coagulation and floatation aeration. BOD reduction can occur naturally in shallow lagoons though this may take some time. If space is limited, aeration can be employed to accelerate the process. The process of BOD reduction is also quicker if ‘activated’ sludge is added (sludge containing bacteria which breaks down the organic material). The treated effluent is subjected to settlement after which some of the sludge is removed for reuse and the excess is removed as solid waste.

Recent developments of this process have occurred which offer improvements and make the process more feasible for operating a closed water system in a pulp mill or paper mill. This process combines biotechnology in a bioreactor aeration tank with membrane filtration. The process is termed the thermophilic membrane bioreactor process (PT, 2001).

Another recent development, in a mill making mechanical pulp, divides the effluent water such that 20% is sent for biological treatment and the rest is evaporated and condensed in a plant which mainly uses waste heat from the chemi-thermomechanical refining process. This recovers 93% of the incoming water, which is returned to the process. Of the remainder, 4% is used in heat and chemical recovery and the balance of 3% is sent to the biological wastewater treatment plant (M-real, 2002, p. 27).

Significant improvements have been made in reducing the levels of the key emissions. The reductions in Europe are shown in Table 2.2.

Regulations should not be based on arbitrary standards for BOD, TSS, etc. Local conditions and environmental impact should be taken into account when setting standards for non-toxic measurements of paper-mill emissions. The levels set must take into account the environmental impact and long-term environmental sustainability, especially in coastal waters and estuaries, due to the dynamic nature of such environments.

A marine biologist who studied a specific estuary environment for 30 years concluded that changes which occur in the disposition and dominance of different species can be wrongly attributed to discharges from a paperboard mill over that period. He found that, for example, a colony of one species could move as the result of a storm disturbing its environment. Without such knowledge, its demise could be associated with the discharge. In another example, a successful colony of one species can attract the attention of a natural predator and disappear as a result. Again, the mill could be blamed for the disappearance. A conclusion of this study was that observations had to be made regularly over a long period – conclusions based on random observations could be misleading (Perkins, 1993).

It is accepted, for example, that the environmental impact of cellulose residues is less critical when discharged into open sea than when it is discharged into with shallow lakes and rivers. In the former, it would not be an environmental benefit to use energy, which in most cases would be derived from fossil fuel with its associated emissions, to aerate using pumps, when the same effects of dilution, dispersion and aeration would be performed in nature through the action of the wind and tides.

Table 2.2 Reductions in mill water emissions 1991–2000

Feature	Reduction 1991–2000 (%)
BOD	70
COD	66
AOX	90

Source: CEPI (2002, p. 30).

2.4.6.3 Solid waste residues in paper industry

Solid waste from pulp mills and paper mills comprises:

- sludges from wastewater treatment
- soda dregs from pulp-mill chemicals recovery
- bark (biofuel or soil conditioner)
- residues from washing and screening pulp in suspension
- waste from mineral pigment coating
- de-inking sludge
- residues from the recycling of recovered paper which can be contaminated with plastics, staples, etc.

CEPI (2002, p. 32) data shows that a reduction in mill waste disposal of around 15% has been achieved over the period 1990–2001. This has mainly been achieved through an increase in the amounts composted and used in land spreading. The main method for disposal of mill residues is by incineration with energy recovery. Bark is used as either fuel or soil conditioner.

Mills also continue to seek other ways of diverting waste from landfill, for example recovery of pigment-coating waste and its reuse as filler in papermaking (M-real, 2002, p. 26; Stora Enso, 2002a).

2.5 Used packaging in the environment

2.5.1 Introduction

Natural resources provided by the environment are used in many ways but ultimately everything is returned as waste to the environment. Some value has always been extracted from waste by recovery, reuse and recycling but ultimately waste has been disposed of to water, e.g. rivers and tidal estuaries, buried in landfill or burnt (incineration). We are now more aware of the implication of using resources and of the environmental impact of the various forms of waste disposal.

The main areas from which wastes arise are:

- agriculture and horticulture
- mining and quarrying
- construction and demolition
- sewage treatment and dredging
- commerce and manufacturing, i.e. offices and factories
- service sector, for example distribution, retail, hospitals, transport, education, etc.
- municipal solid waste, mainly from households.

Cumulatively, total waste, measured as weight, in the UK is over 400 million tonnes per annum (Mtpa). The used packaging component is around 8.5 Mtpa (2% approx.), of which about 3.4 Mtpa would be paper-based. Similar proportions would be expected in other developed countries, yet the idea exists that waste is synonymous with used packaging!

Whilst used packaging may not be a large proportion of total waste, it is highly visible in places where people live and work. Many aspects of the 'throw-away society' are accepted but society is concerned at the volume of used packaging which accumulates.

In addition to comprising part of domestic waste, used packaging arises in distribution, commerce, manufacturing and catering as well as the packaging disposed of during travel, leisure, education, hospitals and all types of work. This highlights one of the waste management problems associated with packaging – packaging waste arises in relatively small amounts in a large number of locations.

2.5.2 Waste minimisation

The first principal of waste management is that waste should be minimised. This can be applied to paper-based packaging in a number of ways:

- Pack design changes can optimise the amount of material used whilst maintaining strength. Combined plastics/paperboard tubs can optimise protective properties of both materials, whilst at the same time minimising the amounts used.
- Reducing weight per unit area (g/m^2) of material for the same pack design and material ensuring that protection is not compromised. It may be possible to make a net saving by reducing the material in the primary pack by increasing strength in the distribution pack, or vice versa.
- Changing the material specification – some paper and paperboard materials offer the same strength with weight savings of at least 20% when compared with alternatives, for example extensible kraft, corrugated board, use of virgin fibre.

A note of caution here is to make the point that 'higher recovered paper utilisation in a paper substrate is generally equal to greater weight' (CEPI, 2002, p. 29).

2.5.3 Waste management options

2.5.3.1 Recovery

There are several disposal options once the weight of packaging has been minimised, but they all require recovery once the primary function of protecting the product throughout its distribution, point of sale and consumer use has been completed.

Recovery can be achieved in several ways:

- Segregation at the point of disposal, for example in the home, followed by collection or by being taken to a central collecting point, after which the material content of particular waste streams can be recycled.

- Collection in the form of mixed waste which is sent for segregation at a sorting facility after which the material content can be recycled.
- Collection in the form of mixed waste which is sent to a plant which can use the waste in that form, for example an energy-from-waste incinerator or composting plant.

Paper and paperboard packaging presents several disposal options since the basic material is recyclable, combustible and biodegradable.

The reuse of paper and paperboard packaging as a bag, box or other container in its original form is not widely practised. An example would be a rigid solid board case which can be folded flat after the contents, such as folding cartons, have been removed by the packer, so that the case can be returned to the converter for reuse.

2.5.3.2 Recycling

Recycling is defined as reprocessing material in a production process for the original purpose or for another purpose. Another purpose, here, could include organic recycling (composting). Energy recovery is usually excluded in official definitions of recycling.

In general there is a ‘feel-good’ factor about recycling. There is a consensus that it is a good activity to promote. ‘Recycling is one of the most tangible symbols of the commitment to do the right thing’ (Akerman, 1997). Unfortunately, society often uses the word ‘recycling’ when it should use ‘recovery’ or ‘collection’; as already noted, these actions must *precede* recycling. The recovered sorted material is then sent to a reprocessing facility, which for paper and paperboard waste would be a paper or paperboard mill.

Material recycling of paper and paperboard is a major business (Fig. 2.5). Recovered fibre contributes 46% of the fibre used in the paper industry worldwide, currently over 150 Mtpa. It is a significant and essential resource and the proportion is likely to increase, though its use, measured as a percentage of consumption, will ultimately be limited by factors which will be discussed.

The proportions *recovered from consumption* and the proportions of *recovered fibre used in paper and paperboard manufacture* in the US and Europe for 2001 are shown below.

Market	% Recovered	% Recycled in production
US	48.3 (target by 2012 is 55)	37 (AF&PA website)
Europe (EU)	52.1 (target by 2005 is 56)	41.8 (CEPI, 2002, p. 24)

A significant proportion of the recovered fibre in these markets is exported. In 2001, exports were 16 and 6% of the totals recovered for the US and Europe respectively.

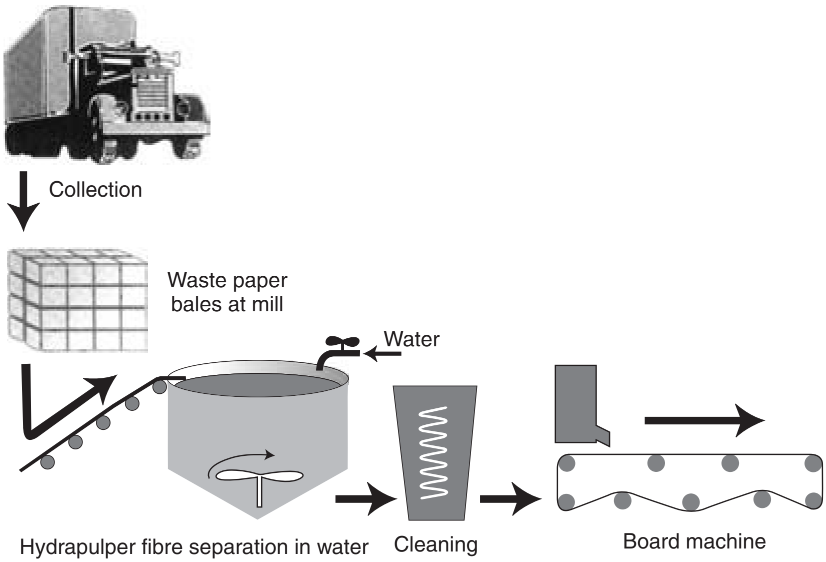


Figure 2.5 Recovery and recycling of waste paper and paperboard. (Reproduced, with permission, from Pro Carton.)

Waste management infrastructures have been operating during the last 100 years. Merchants collect recovered waste paper, which is then made available to paper and paperboard mills.

There are three important facts about paper recycling which should be noted:

- Some fibre by virtue of its use cannot be recovered – food contaminated packaging and tissues used for hygienic purposes, cigarette paper, paper and paperboard materials used in building and materials used in books, maps, documents and archives. Some estimates put the proportion which cannot be recycled, including those products, such as books, which cannot be recycled within a relatively short time scale, as 15–20% and some as high as 30%.
- Cellulose fibres cannot be recycled indefinitely. The fibre loses length and this is a major cause for a relatively high fibre loss, as sludge, during reprocessing. Interfibre bonding potential is also reduced each time it is recycled. The processing of recovered fibre is an important subject for technical development.

  Estimates of the number of cycles a fibre can survive and still be useful suggest that 5–10 cycles are possible depending on the type of paper or paperboard product and the life and usage of that product. The number of cycles is somewhat theoretical because the logistics of the situation show that even at a high recovery rate (50% approx.) from the market only 6% of original fibre survives to the third reuse due to losses in production (20% approx.) and unrecoverable waste (50% per cycle).

- Not all fibres are equal – fibres in waste comprise those which have been chemically and mechanically separated and fibres which have already been recycled through one or more cycles. There are also differences which relate to the tree species from which any particular fibres have been derived, i.e. long and short fibres, and other species-specific features.

  For technical reasons all fibres cannot be satisfactorily used for all paper products. The differences between fibres are taken into account in the way waste paper and paperboard are classified and sold to the mills. In the European (CEPI) classification, there are nine groups of waste which are subdivided into 67 specific types; other parts of the world use similar classifications. Each classification has a price which reflects the quality of the fibre and hence its value to the papermaker. Many people think of waste paper solely as 'waste paper' and not as a whole range of products each with their own characteristics and price/value.

  The highest value waste paper is white, unprinted and woodfree – meaning that it only comprises chemically separated bleached pulp, i.e. no mechanical pulp or recycled pulp. Paperboard waste derived from industrial and commercial premises is usually clean, i.e. no contraries or foreign matter, and easy to collect regularly in reasonable quantities. Post-consumer waste is more difficult to manage. It may be sorted at source, such as newspapers and white-printed waste in the home, or brown corrugated cases at the supermarket. Waste which is mixed has lower value and is more likely to contain contraries, inks, adhesives, other materials laminated to the paper and, in the worst cases of unsorted mixed post-consumer waste, broken glass and other solid contamination. It has been found that as more waste is collected, i.e. recovered, it tends to contain higher proportions of unsorted post-consumer waste. This can reduce the cost of recovery/ collection but lower the value of the waste for material specific recycling.

De-inking is a process whereby ink is removed from recovered printed papers. First, the fibre is dispersed in water and then treated with surfactants which extract the ink particles. The fibre is separated from the ink particles by a cascading, floatation process based on the difference in density between the two materials. Finally, a mild bleaching treatment may be done to increase the brightness of the pulp. This process is not widely used for packaging products though some may contain a proportion of de-inked fibre.

Organic recycling may be described as 'the aerobic (composting) or anaerobic (biomethylisation) treatment under controlled conditions and using micro-organisms, of the biodegradable parts of packaging waste, which produces stabilised organic residues or methane' (UK Packaging (Essential Requirements) Regulations 1998).

Waste paper and paperboard can be organically recycled because cellulose fibre is biodegradable. It can be broken down into natural substances by organisms in the environment and, in particular, by bacteria using microbial enzymes to convert organic material into CO_2, water and humus or compost. Compost is used in agriculture and horticulture as a soil conditioner.

2.5.3.3 *Energy recovery*

In the past, burning or incineration was carried out as a hygienic way of reducing the volume of waste. When emission regulations were brought into force municipal incinerators were closed down and more waste was sent to landfill.

Although the technology to burn waste safely has become available in recent years, the plants require large capital investments. There is also a deep public mistrust of incineration due to lack of knowledge and information.

Paper and paperboard waste retains solar energy because the fibre is originated from the wood. This energy can be recovered in an energy-from-waste (EFW) incinerator. The minimum calorific value of paper and paperboard is 10 mJ/kg and 2 tonnes yield the energy equivalent of approximately 1 tonne oil or 1.5 tonne coal. We cannot, however, discuss the incineration of waste paper and paperboard in isolation from the disposal of mixed municipal waste. It makes no sense to segregate paper and paperboard waste, which is unsuitable for recycling, from mixed solid waste (MSW) and incinerate it in isolation. We must therefore examine the issue of the disposal of MSW by incineration with energy recovery as part of a holistic approach to MSW management.

The benefits of recycling with energy recovery are as follows:

- The main benefit is the recovery of solar energy. A typical EFW facility can recover 35 MW from around 420 000 tonnes of MSW. South East London Combined Heat and Power (SELCHP) collects waste from one million people and provides electricity for 100 000.
- The energy recovered is non-fossil-based – fossil fuel, by contrast, is non-renewable, contributes to the greenhouse effect and produces noxious emissions.
- In cities incineration greatly reduces lorry traffic to out-of-town landfill sites.
- Incineration reduces landfill need by reducing the volume of waste by 90%.
- Diversion of waste from landfill reduces methane production – methane being a much more harmful greenhouse gas than CO_2.
- Recovery of other materials is possible, for example ferrous residues.
- Hygienic benefit – organic waste is reduced to less biologically active material.
- Incineration is to be preferred for highly flammable, volatile, toxic and clinical wastes which should not be landfilled.

When cartonboard and other types of paper-based packaging are incinerated the cellulose component reverts to CO_2 and water vapour. The emission to air should not contain carbon particles, or carbon monoxide, as this would indicate incomplete combustion. The main community concern is, however, more emissions which may arise from other components of mixed waste.

Incineration is now carried out under carefully controlled conditions to minimise potentially harmful conditions and to meet the very tight regulations. This is achieved using high temperatures of, approximately, at least 850 °C and extensive flue-gas cleaning. Processing comprises:

- fine particles of activated carbon absorb dioxins and furans, heavy metals and other organic compounds
- sprays of limewater mixtures neutralise acidic gases such as sulphur dioxide (SO_2) and hydrogen chloride (HCl)
- bag filters remove dust particles down to 10 microns size
- high chimney stack of 100 m.

Emissions are monitored by appropriate authorities. In Europe, a European Directive, 1989, lays down minimum standards; national standards may be tighter.

For a detailed account of independent monitoring in London, consult reference (Onyx, 2000). This report is the result of independent monitoring of air quality in the vicinity of an EFW incinerator. Amongst the conclusions it was stated that the incinerator did not appear to have a significant impact on air quality and that the results were within national and European guidelines.

Incineration is widely practised in countries such as Germany, France, Sweden, Denmark and Switzerland, where environmental issues have a high profile. Many of the incinerators today produce heat for local communities, in addition to electricity.

The UK Government view is that incineration can provide environmental benefits, especially if markets for recycled material are uncertain and if it would significantly reduce transport use. It accepts that as the EU landfill directive is implemented, waste may be diverted from landfill at a rate faster than the markets for recyclate can sustain and hence, alongside a move to a higher level of recycling, a move to a higher level of incineration with energy recovery is necessary over the next 10–15 years in order to develop a more sustainable waste management system ('Less Waste more value', 1998).

It is claimed that incineration with energy recovery is the preferred option compared with recycling when environmental aspects are taken into consideration. This claim is based on the relative analysis of CO_2 emissions (New Scientist, 1997).

An innovation in the use of polyethylene (PE) recovered from liquid-packaging cartons and plastic laminated wrappings has been reported where the PE is gasified after separation and used as a fossil-fuel replacement in a CHP system (Stora Enso, 2002b).

2.5.3.4 Landfill

Disposal to landfill of waste, including paper and paperboard waste, is perceived as the least environmentally sound option. There are several objections:

- waste of agricultural land – this is not the case where waste is disposed of in disused quarries but such sites are not usually located near the source of the waste
- emissions and waste of energy in the use of road or rail transport
- dangers such as contamination of ground water by leaching, scavenging and health hazards

- release of methane which is a much more harmful ‘greenhouse’ gas
- shortage of space in convenient locations.

In many locations, however, it is a low-priced option and the government has to use other means in order to divert waste from landfill. In Europe, a Landfill Directive 99/31/EC has set targets for the reduction of biodegradable waste.

2.6 Life cycle assessment

Life cycle assessment (LCA) is an audit (list or inventory) of the resources used by a product in its manufacture and an assessment of the environmental consequences (impact). LCA can also be applied to a process. The first stage is to define the scope of the study. This sets the boundaries across which material resources and energy pass into the cycle and from which the products and waste emissions to air, water and solid waste leave the cycle. The study can include extraction of raw material, manufacture, transportation, use up to the point of ultimate disposal or recovery – hence the description ‘cradle to grave’ and even ‘cradle to cradle’.

The audit is factual and specific but must be carried out in conformance with ISO (International Organization for Standardisation) standards. The second phase is the assessment of environmental impact. Whilst the criteria used in the audit is objective, assessing effect is more difficult as the threshold level for an effect may be different in one location compared with another for a variety of reasons. An example already noted was the case of receiving waters which can be as different as a shallow river compared with a tidal estuary.

The ISO standards for LCA have been drawn up after international liaison coordinated by Society of Environmental Toxicology and Chemistry (SETAC) and the European Commission.

The following Standards have been issued:

ISO 14040:1997 LCA Principles and framework
ISO 14041:1998 LCA Goal and scope definition and inventory analysis
ISO 14042:2000 LCA Life cycle impact assessment
ISO 14043:2000 LCA Life cycle interpretation
ISO/TS 14048:2000 LCA Data documentation format
ISO/TR 14049:2000 LCA Examples of application of ISO 14041 to goal and scope definition and inventory analysis.

Life cycle assessment is useful in quantitatively highlighting points in a life cycle where environmental impact is high, and for evaluating the effects of life cycle changes, by, for example, substituting one process with an alternative process. A case study indicating several life cycle changes has been published, ‘Towards sustainable development in industry – an example of successful environmental measures within the packaging chain’. It is the result of cooperation between Tetra Pak, Stora Enso and the Swedish Forest Industry Federation. It includes paperboard minimisation and changes in printing, plastic extrusion coating, distribution, recovery and recycling, all of which have reduced environmental impact in the life cycle of a one-litre milk carton (SFI, 2002).

2.7 Conclusion

Basically, we are where we are today with respect to all paper and paperboard issues for reasons other than those based on environmental considerations. Paper recovery and recycling was established at least 100 years ago for sound technical/commercial reasons. In 2002, recovered paper and paperboard provided around 45% of the world's demand for fibre. The amount of fibre recovery and recycling is rising for several reasons:

- fibre demand is rising as the production of paper and paperboard increases
- higher proportions are being recovered for societal and waste management reasons.

Benefits can be stated for each of the three main fibre sources:

1. *Chemically separated fibre* – flexible fibre giving products with high strength; when bleached is chemically pure cellulose, making the fibre odour and taint neutral and the best choice for the packaging of flavour and aroma sensitive products; process chemicals are recovered and reused; and the energy used in manufacture is renewable as it is derived from the non-fibrous components of wood.
2. *Mechanically separated fibre* – stiff fibre giving high bulk, i.e. high thickness for a given weight of fibre (g/m^2), which results in products with high stiffness compared with products incorporating other fibres; high yield from wood; may be given chemical treatment to lighten colour; and is sufficiently odour and taint neutral for the packaging of many flavour and aroma sensitive products.
3. *Recovered fibre* – recovered fibre is functionally adequate and cost effective in many applications. The quality depends on the paper or paperboard from which the fibres were recovered. The use of recovered fibre in making recycled paper and paperboard would rate highly for societal and economic reasons but the environmental benefits are not proven. The main environmental benefit claimed is that recycling in this way 'saves trees' and a general feeling is that because waste is being reused the activity 'must be an environmental benefit'.

Another benefit claimed is that recovered fibre retains the original solar energy and the energy expended in the manufacture and use of the virgin fibre. Further energy is, however, consumed in collecting and delivering fibre to the mills and more energy proportionately is required to make recycled products. There are more fibre losses in paper and paperboard manufacture using recycled fibre, and as equivalent recycled products incorporate a higher weight of fibre, more water, proportionally, must be evaporated during manufacture. As all these energy needs are met by fossil fuel, the associated emissions are also proportionally greater.

These points are made not in order to be controversial but solely to counter the view that somehow it is better for the environment to use recovered fibre. Logistically, we need recovered fibre for recycling. It would be difficult to replace recovered fibre with virgin fibre over a short period, and the economic constraints of the market together with society's waste management needs will ensure an expansion in the recovery and use of waste paper. This is important as sustainability depends on economic and social needs as well as environmental implications.

The respective benefits of the different types, and combinations, of fibre become more specific when particular papers and paperboards are considered for specific applications. All fibres are not universally interchangeable. It is, therefore, not practical to insist on a mandatory minimum level, or declaration, of recovered fibre content.

Industry requires virgin fibres to meet the functional needs of many applications. It also needs virgin fibre to maintain the quality of recovered fibre and the total quantity of fibre required by the industry overall. Virgin fibre is also required to replace ('top up') recycled fibre which is lost in reprocessing. Fibres cannot be recycled indefinitely, and reprocessing reduces fibre length to the point when it eventually accumulates as sludge.

Hence for all practical purposes it is correct to say that virgin and recycled fibres are both necessary.

Sustainability, as we have seen, depends on social and economic aspects as well as environmental criteria. Many commentators have said that the environmental debate has moved on from single issues, such as the virgin/recovered fibre debate, to a more holistic environmental consideration of whole systems, which comprises:

- procurement of raw materials
- using energy to make paper/paperboard
- converting the material into packaging
- meeting regulations at all stages applying to air and water emissions and solid waste
- meet needs of the product to be packed during packing, distribution, point of sale or delivery to customer and use by the ultimate consumer
- end-of-life management of the packaging where the options are for either to reuse, recycle, incinerate with energy recovery or dispose to landfill.

The whole system must be sustainable in environmental, economic and societal terms and should include processes to ensure continuous improvement. The issues discussed provide evidence that this is the approach currently used in the manufacture and use of paper and paperboard based packaging.

The wood supply for the paper industry is sustainable. Independent forest certification is established in many regions including North America and Europe. Over 50% of the energy used in paper and paperboard manufacture is renewable. Mills not having biomass available as part of their process and mills and factories where electricity is imported are in the same situation as society at large as regards the resources used. At the present time, the greater proportion of that energy depends on fossil fuels but the proportion of renewable energy is increasing. The mills have increased their efficiency in energy usage (CHP) and have reduced emissions by switching from coal and oil to natural gas. Reductions have been made in water consumption, and the quality of water returned to nature has been improved. The amounts of paper and paperboard recovered and the proportion of recovered fibre used in the manufacture of paper and paperboard have increased.

By their activities in all these areas and by having independent assessments to internationally accepted environmental and quality management standards, the companies involved in the manufacture and use of paper and paperboard packaging continue to demonstrate their commitment to sustainable development and continuing improvement.

Finally, an important feature of the paper and paperboard industry which underpins its claim to sustainability is the part it plays in the carbon cycle.

The carbon cycle links the atmosphere, the seas and the earth in a fundamental way (Fig. 2.6). All life depends on carbon in one form or another. Paper and paperboard are involved because:

- CO_2 in the atmosphere is absorbed and transformed into cellulose fibre in trees
- trees cumulatively form forests
- forests are essential to climate, biodiversity, etc., they store solar energy and CO_2
- the principle raw material for paper and paperboard is wood
- non-cellulose wood components provide just over 50% of the energy used to manufacture paper and paperboard and this releases CO_2 back into the atmosphere

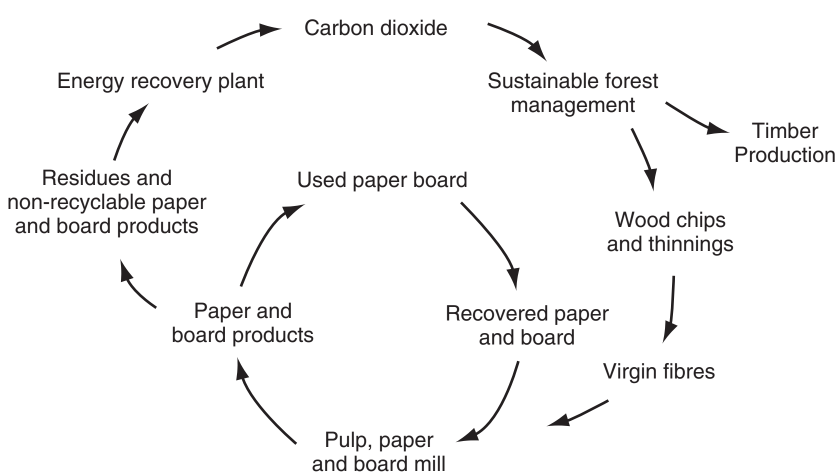


Figure 2.6 The paper and paperboards carbon cycle. (Reproduced, with permission, copyright, Confederation of European Paper Industries.)

- some paper and paperboard in long life usages such as books, together with timber, act as carbon sinks which remove CO_2 from the atmosphere
- when paper and paperboard are incinerated after use with energy recovery and even when it biodegrades in landfill, it releases CO_2 back into the atmosphere.

The overall effect is that the paper industry invests in forests. This results in an accumulation of new wood as a result of incremental growth exceeding the wood harvested by a good margin. Furthermore, the amount of the CO_2 used to produce the wood harvested exceeds the amount given back by the use of biofuel in the manufacture of paper and paperboard and at its end of life when it is incinerated with energy recovery or biodegraded.

Hence the paper and paperboard industry effectively promotes forest development and removes CO_2 from the atmosphere, features which support the, desirable, aim of sustainable development.

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Paper and Paperboard Packaging Technology
Edited by Mark J. Kirwan

3 Paper-based flexible packaging

Mark J. Kirwan

3.1 Introduction

Flexible packaging is the fastest growing type of packaging.

Paper-based flexible packaging comprises sachets, pouches, bags made on form, fill, seal equipment and overwrapping materials. It is also used as lidding and to provide product protection and as tamper evidence when used as a membrane (diaphragm) in rigid plastic, metal and glass containers. Paper-based flexible materials are also used for bag-in-box lining material, multiwall and single-wall bags.

Paper-based flexible packaging is usually printed and is lighter in weight than the other forms of packaging. Here are some facts about paper-based flexible packaging in the USA:

- flexible packaging is the second largest type of packaging in the USA (17%)
- most flexible packaging is used in retail (54%)
- largest application is for food in the retail and institutional markets
- medical and pharmaceutical packaging usage is 8%
- usage for industrial, consumer products and institutional non-food is significant (FPA, 2003).

The position in Europe is similar with flexible packaging, accounting for nearly one third of total annual expenditure on consumer packaging. The packaging of food products accounts for 75–80% of this flexible packaging (AMCOR, 2003).

Flexible packaging based on paper uses composite structures in which the properties of the paper are combined with those of other materials, such as plastics, aluminium foil, wax and other materials by means of coating, lamination and impregnation. Depending on the combination of materials used, paper-based flexible packaging can provide the following properties:

- barrier to moisture and moisture vapour
- barrier to gases, such as oxygen, carbon dioxide and nitrogen, making flexible packaging suitable for vacuum and gas-flushed packaging and for the protection of products sensitive to flavour and aroma loss or contamination
- resistant to products, including those containing fat
- barrier to light
- sealable by heat sealing and use of cold-seal coatings
- medical packaging applications place special requirements on paper-based packaging, such as: to be sterilisable by gas, irradiation and steam, to provide

satisfactory pack seals, using both heat and cold sealing, which peel without generating loose fibres, and to be permeable to a sterilising gas but impermeable to the entry into the pack of microbiological contamination
- strength for packing, distribution and use
- printable by several printing processes.

Flexible packaging is usually supplied on reels for forming, filling and sealing by the end-user (packer), although some pouches/sachets and die-cut lids are supplied to packer/fillers, especially for small-quantity orders.

Flexible packaging is used for the packing of:

- solids in the form of free-flowing products such as powders, granules and agglomerates
- solids in the form of blocks, slices, bars and tablets
- individual items and groups of items
- liquids and pastes
- multipacks
- medical devices, kits and consumables such as dressings and surgical gloves.

Sachets and pouches may be single-portion, or single-dose, packs and they can also be multiportion packs, for example for coffee, with a recloseable feature. These packs may be sealed under vacuum or may be gas flushed.

The main materials, or substrates, used in flexible packaging until the middle of the twentieth century comprised paper, aluminium foil and regenerated cellulose film (RCF). Paraffin wax-coated paper was widely used as a barrier to moisture, moisture vapour and volatiles, and it has product-release properties. Subsequently, the uses and properties of waxes were enhanced with microcrystalline waxes and plastic additives which provided better heat sealing, barrier properties and made them more versatile for use as a laminating adhesive, for example paper to paperboard, paper to aluminium foil and RCF to plastic films.

From the 1950s onwards, plastics began to play a larger role in packaging. The change was particularly significant in flexible packaging. Plastics became available as films, emulsion coatings and in extrusion coatings and laminations. Plastics were also used as adhesives and heat-seal coatings. New conversion equipment, ancillary materials and higher-performance adhesives became available, and printing processes and inks were modified to suit their use with plastics. The development of plastics themselves and new techniques in blown film, cast film, biaxial orientation, co-extrusion, lamination and coating significantly increased the use of plastic flexible packaging such that by 2004 approximately 70% of flexible packaging was *solely* plastic in composition.

The availability of plastics has, however, widened the opportunities for paper-based flexible packaging. The use of wax has diminished though its use in several types of application is still an option, and other non-food packaging materials, such as bitumenised kraft papers (kraft union), whilst still available in some markets, have been replaced by polyethylene film.

However, paper and aluminium foil are still widely used in flexible packaging. Papers are used in the form of laminates and as a substrate for coating and impregnating.

Paper is used in flexible packaging because:

- paper is a strong material available in reel form in a range of widths and substances (grammages or basis weights), which meets the needs of printing, conversion and packaging machinery and also, thereafter, in distribution and consumer use
- paper is a suitable substrate for providing functional packaging properties. This may be achieved in paper manufacture, for example greaseproof or glassine paper, or by addition of other materials by subsequent conversion in the form of a coating, lamination or impregnation
- paper imparts stiffness in the packed sachet or pouch
- paper can be printed by all the main, commercially available, inks and printing processes
- there is a wide choice of the print quality which can be achieved depending on the colour, surface finish, smoothness and gloss of the paper surface and whether the surface has a mineral pigmented coating
- the surface promotes adhesion in a range of conversion processes including those using water and solvent-based adhesives, wax and curing (cross linking) 100% solid adhesives as well as plastic extrusion coatings and laminations
- fibre choice, stock preparation and papermaking can be varied to achieve specific product characteristics, for example porosity and heat sealing in an infusible tissue for a tea bag, grease resistance in a greaseproof, glassine or size press treated for grease resistance, mould resistance, etc.
- paper-based medical packaging meets specific requirements for sterilisation, sealability, peelability, porosity and microbiological barrier
- paper is cost-effective when used in flexible packaging, it is environmentally benign and naturally sustainable.

Aluminium foil is used in flexible packaging as a barrier to moisture, moisture vapour and common gases, and it is also a light barrier. Some applications for aluminium foil have been replaced by metallised paper, metallised film and ethylene vinyl alcohol (EVOH).

Regenerated cellulose film is usually discussed within plastic packaging but as it has its origin in bleached chemical woodpulp some mention is justified here. It is a clear transparent film. In its various specifications with respect to coating and additives, it has a wide range of applications because of its barrier properties and composition together with its suitability for lamination to paper, aluminium foil and plastic films. All the properties listed above can, however, be matched in most respects with lower cost plastic films, particularly oriented polypropylene film, and this has led to a significant fall in usage. Today its marketing is based on the fact that it is derived from a renewable resource, i.e. forestry, and that it has excellent stiffness in packaging machineability and point-of-purchase (POP) display. RCF can also be produced specifically for applications where high twist retention is required, for example wrapping of sugar confectionery. Coloured RCF is available.

3.2 Packaging needs which are met by paper-based flexible packaging

It should be noted that this discussion is limited to paper-based flexible packaging as used for food products in various forms together with, for example, confectionery, pharmaceuticals, tobacco, horticulture, agrochemicals, DIY and electrical goods. The needs of medical packaging will be discussed separately in Section 3.4.

3.2.1 Printing

Flexible packaging must carry information, including safety information where appropriate, about the product and its use. In many instances, depending on the product and how it is marketed, flexible packaging must provide visual impact at the point of purchase.

The main processes used in printing paper for flexible packaging applications are flexography and gravure. Several systems are available including water based, solvent based, UV cured and digital printing. The print quality can be varied depending on the surface and colour of the paper. In terms of colour, the choice is usually white, i.e. based on chemical-bleached pulp, or brown, i.e. based on either unbleached chemical pulp or dyed recovered fibre or mixtures of these two types of pulp. The surface may be either machine finished (MF), machine glazed (MG), supercalendered (SC), on-machine coated or cast coated. The whiter and smoother coated papers will give the best print reproduction – sharper dots in colour illustrations, fine text, good contrast and solid uniform colour.

3.2.2 Provision of a sealing system

A sealing system may be used to construct the pack, for example a sachet which is sealed on two or three sides prior to filling, and to seal the package after filling. Where the package has to provide product protection through the provision of barrier properties, it is necessary for this sealing to be pinhole free.

The main method for providing sealing to paper so that it can be formed and sealed is through the application of a sealable material. Examples are by applying:

- Polyvinylidene dichloride, PVdC, from an aqueous dispersion, also acrylics. Another vinyl-based heat-seal coating is VMCH (Dow Chemical Co.) which is applied from a solvent-based solution. Where a higher solids or lower viscosity coating is required, Dow recommends VMCC. (*Note*: VMCH and VMCC are carboxyl modified vinyl copolymers. They are functional terpolymers of vinyl chloride, vinyl acetate and maleic acid [Dow, 2005].)

- Hot melt coating by roll application, or slot die, based on a wax blend containing plastic polymers, such as ethylene vinyl acetate (EVA) and other additives which improve initial tack and seal strength.
- Extrusion coating with polyethylene (PE) and EVA modified PE. Other plastics can also be heat sealed but they would not be chosen purely for their heat sealability on grounds of cost. They may be chosen where they perform an additional function such as that of an oil or grease barrier, for example an ionomer such as Surlyn® (DuPont), and heat resistance, where polypropylene (PP), polyethylene terephthalate (PET or PETE) or polyamides (PA) would be used.
- Cold seal, based on either natural rubber or synthetic latex on a smooth paper surface, such as glassine or bleached kraft, sealing is activated by pressure. Cold sealing can be carried out at high speed and is particularly favoured for the packaging of chocolate and other heat-sensitive products.

3.2.3 Provision of barrier properties

3.2.3.1 Introduction to barrier properties

Barrier properties are necessary in paper-based flexible packaging to protect the product. It is always necessary to define the nature of the product protection, for example texture, flavour, aroma, etc., required to achieve the required shelf life in the expected environment(s) of storage, distribution and use. It is then necessary to determine the type and amount, in terms of thickness and coating weight, of the barrier material(s) required to provide the product protection required.

Several types of protection relating to moisture, texture, flavour and aroma, etc., and the choice of barrier materials which are available to provide that protection will be discussed in this section. It must be appreciated that the materials are not necessarily interchangeable because the degree to which each provides a particular barrier property varies, for example, aluminium foil compared with, PVdC or PE.

Furthermore, the amount or degree of any particular form of protection will vary with the amount of material applied in terms of thickness or coating weight. Both these causes of difference have commercial implications in that the weight or thickness necessary to achieve the required performance may rule out the use of a particular material where the cost is uncompetitive.

3.2.3.2 Barrier to moisture and moisture vapour

The effect of moisture on packaged products depends on the product. For some it is necessary to maintain the moisture content at a high level to prevent the product from drying out. For others the reverse may be the case as by absorbing moisture the product may loose texture, (for example, crispness in a snack food) and metal products containing ferrous iron can rust when exposed to high humidity and oxygen.

Every food product has an optimum moisture content with respect to its stability as well as its texture and flavour. Non-food products, such as tobacco, also have an optimum moisture content range within which the quality is satisfactory. There will, however, be a moisture content level at which the quality of the product concerned would be deemed unsatisfactory. Assuming that the product is at the correct moisture content when packed, it is the aim of the packaging to ensure that an unsatisfactory moisture level is *not reached* within the intended shelf life in the recommended storage conditions.

Food products affected by moisture will, however, gain or lose moisture until equilibrium is established with the relative humidity (RH) of the atmosphere to which they are exposed. In the case of a packed product, this environment will be that existing within the sealed package.

It is therefore necessary to know the moisture content specified at the point of manufacture/packaging and the equilibrium relative humidity (ERH) at that moisture content. The next important consideration is the relative humidity of the environment in which the packaged product will be stored, distributed and merchandised. In order to simulate temperate conditions, testing is carried out on sample packages stored at 25 °C and 75% RH where the product will gain moisture and 40% where it would lose moisture. For tropical conditions, 38 °C and either 90 or 40% RH is used.

At 25 °C/75% RH there will be a tendency for packaged products with a low ERH to gain moisture from the external environment and for those with a higher ERH to lose moisture to the external environment. It is the function of the packaging to ensure that any movement of moisture either into, or from, the product still ensures that the product does not achieve a moisture content, within the specified shelf life, at which the product is judged unacceptable.

Many flexible packaged food products are required to have shelf lives of from 6 to 18 months depending on the product and where they are marketed and used. This would be an inconvenient length of time to carry out a shelf-life test and therefore laboratory studies have been developed to give guidance on shelf life and barrier based on accelerated storage tests (Paine, 2002).

Dried foods, such as instant coffee and potato chips (crisps), have a typical moisture content of around 3% and the ERH is 10–20%. These products require a high, or good, barrier to water vapour – note this means a *low* water vapour transmission rate (WVTR). Dried foods such as breakfast cereals with ERH 20–30% are less stringent with respect to the water vapour barrier. For dried fruits and nuts the ERH is 30–60% and for salt and sugar, 75 and 85% respectively. A cake has an ERH of around 90% and it maybe thought that the barrier should *prevent* the loss of moisture from the cake. However, an RH of 90% *inside* the package is an ideal condition for mould growth. So rather than trying to prevent moisture loss it is necessary to allow some loss but to slow down the rate to prevent the creation of too high an RH within the package (FOPT, 1996).

Low water vapour permeability, i.e. a good or high barrier, may be provided in several ways:

- laminate/extrusion coating, paper/aluminium foil//PE
- laminate/extrusion coating, metallised PET/paper/PE

- dispersion coating, paper/PVdC
- hot melt coating, paper/hot melt
- wax coating, paper/wax blend (microcrystalline wax plus additives)
- extrusion coating, PE/paper/PE or paper/PE
- laminate/extrusion, SiO_x coated PET/paper/PE.

A moderate or medium barrier to water vapour would be provided by PE extrusion coated paper.

3.2.3.3 Barrier to gases such as oxygen, carbon dioxide and nitrogen

This barrier is necessary for the protection of products sensitive to flavour and aroma loss or contamination. Products where atmospheric oxygen causes product deterioration through oxidative rancidity, for example potato chips (crisps), may be gas flushed with an inert gas such as nitrogen and carbon dioxide. Ground coffee is sensitive to oxygen and may be vacuum packed.

The barrier is provided by either aluminium foil, EVOH, PVdC, aluminium metallised PET, SiO_x coated PET or wax. If aluminium foil is used, the heat sealing is provided by hot melt or PE. Some end-users have discouraged the use of aluminium foil on the grounds that the structure is not easily recyclable in post-consumer waste management systems. EVOH is an excellent gas barrier but the barrier deteriorates significantly in a high RH environment. It is therefore sandwiched, when used in a paper-based flexible material, between layers of PE or PP. An EVOH structure of this type is offered for liquid packaging.

3.2.3.4 Barrier to oil, grease and fat

This is required where the product has an oil, grease or fat content which must be retained within the pack because loss of these ingredients would be reflected in a lower quality product and because any permeation to the surface of the package would be unsightly.

This barrier is provided by aluminium foil, PVdC or ionomer extrusion coating. If aluminium foil is used, the heat seal needs to be a plastic coating with oil, grease and fat resistance. Medium density PE, high density PE, PP and ionomer resin such as Surlyn® all provide oil, grease and fat resistance, the degree of the barrier property being given here in ascending order, with Surlyn® providing the best barrier.

It may be sufficient to use an ionomer resin as a thin coating between PE and aluminium foil. This will provide a good product barrier and also ensure that the adhesion between the aluminium foil and the PE does not break down in the presence of the product during storage. The use of ionomer resin in this way also ensures that good PE adhesion is achieved without resorting to higher temperatures at which there would be a danger of odour and product taint.

Greaseproof paper and glassine also have oil, fat and grease resistance, but will also require a heat or cold seal coating for flexible packaging applications.

3.2.3.5 Barrier to light

Some, particularly fat containing, products can deteriorate in light, especially sunlight, containing a UV component, which can promote oxidative rancidity. Therefore an opaque barrier is required which is only really guaranteed by including aluminium foil in the construction.

3.3 Manufacture of paper-based flexible packaging

3.3.1 Printing and varnishing

Printing is normally the first process in the manufacture of flexible packaging. Flexible packaging is printed reel to reel. The main processes used are flexography and gravure. In addition, some printers use web offset litho. Digital printing can be used, and normally it would be used on short runs. All the usual ink systems are used, including metallic and fluorescent inks. UV cured systems are used to give a high gloss, a rub and product resistant surface together with high heat resistance in the, subsequent, heat sealing areas. Whereas printing is used for text, illustrations and overall decoration, varnishing is used for surface finish, i.e. gloss, matt or satin, protection of the print for rub and product resistance and for the control of surface friction.

The print quality depends on the paper surface. To obtain the best print results, a mineral pigment-coated paper should be used. Some applications of printed paper do not require further conversion. Examples of paper products supplied, printed on reels, to end-users for forming, filling and sealing include flour/sugar bags (Fig. 3.1) and labels for use in injection moulding, for example ice cream tub lids.

Patterned heat-seal and cold-seal coatings may be applied on the reverse side of paper in register with print on the other (outside) surface using printing techniques.

Figure 3.1 Sugar/flour bags. (Reproduced, with permission, from Robert Bosch GmbH.)

3.3.2 Coating

Coating is the simplest method of adding other functions to paper. The active functional material, for example VMCH, PVdC, PE, wax, etc., is either applied from a solvent solution, water-based dispersion or as a solid, in the molten state.

3.3.2.1 Solvent-based coatings

Solvent-based coatings applied to paper by gravure mainly comprise varnishes which impart heat resistance so that the surface does not pick under heat-sealing bars. The varnish could be 100% solids UV cured and has high gloss, product and heat resistance.

3.3.2.2 Water-based coatings

Water-based coatings for paper include PVdC with the coating applied by roll. The coating weight and smoothness is controlled by air knife – a non-contact technique (Fig. 3.2). Several applications may be applied and dried in one pass through the coating machine, giving a total coating weight up to around 30 g/m^2.

3.3.2.3 Coatings applied as 100% solids, including wax and PE

Wax is the oldest paper-based functional coating. Originally paraffin wax was used. From the 1950s, the main wax component has been microcrystalline wax to which polymers such as PE and EVA have been added by blending to improve the barrier in folded areas and also the hot tack in heat sealing. Wax is applied as either 'dry waxing' or 'wet waxing'. In the former, the wax is applied and the weight controlled by roller application. It is then passed over heated rolls so that the wax is driven into and saturates the paper. Alternatively, after application the wax can be rapidly chilled, usually in a water bath, thereby creating a high gloss and keeping most of the wax on the surface.

Polyethylene (PE) is supplied as pellets which are melted by a combination of high pressure, friction and externally applied heat. This is done by forcing the

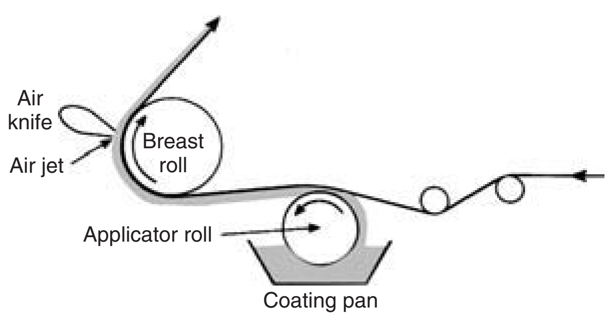

Figure 3.2 Principles of air knife coating. (Reproduced, with permission, from The Paper Industry Technical Association, PITA.)

pellets along the barrel of an extruder using a polymer-specific screw under controlled conditions that ensure a homogeneous melt prior to extrusion (Fig. 3.3).

The molten plastic is then forced through a narrow slot or die onto the paper, or the aluminium foil surface of a previously laminated paper/aluminium foil laminate. As it comes into contact with the paper or foil it is brought in contact with a large diameter chill roll with either a gloss or sand blasted matte finish which determines the surface finish of the PE (Fig. 3.4). To render the surface suitable for print and/or adhesion with an adhesive, it is treated with a corona discharge. A coating weight of 20 g/m^2 would be typical though higher and lower coating weights are possible. Usually the coating is confined to one side but if two side coating is required then in order to avoid blocking in the reel only one surface may have a gloss finish. Extruders having two extruding dies can coat both sides of a sheet in one pass through the machine (Fig. 3.9).

The simplest PE application is Kraft/PE as an overwrapping material – e.g. as a transit overwrap for 10×20 cigarette cartons. In this case, labels would be applied over the envelope end seals.

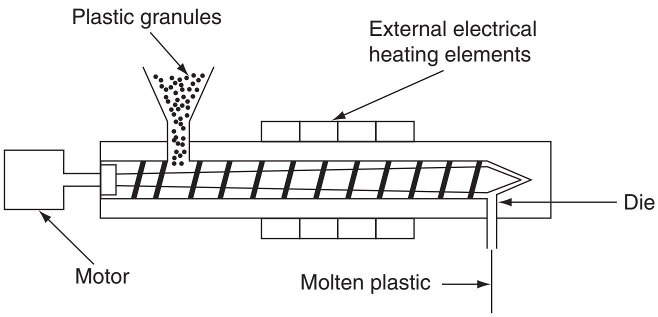

Figure 3.3 Plastic extruder.

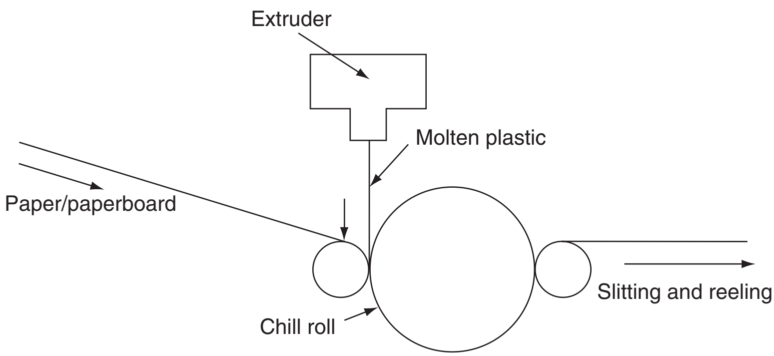

Figure 3.4 Extrusion coating of paper or paperboard.

There is a wide range in the choice of PE. Hot tack in heat sealing is improved by blending EVA with LDPE. If a medium density PE is used, it improves the puncture resistance. This is important for providing better puncture resistance when packing granules with sharp edges. Surlyn® ionomer improves adhesion to aluminium foil and provides resistance to essential oils and other oil and fat-type products. EVOH can be sandwiched between outside and inside coating of paper-coated PE to significantly improve the barrier to oxygen, which causes rancidity in fat-containing products, and other gases.

3.3.2.4 Metallisation

Metallisation is a process whereby aluminium is vapourised in vacuum and deposited to form a thin film on the surface of a substrate (Fig. 3.5). This process has been applied to paper but it is more usually applied to film. There are three problems with paper. First, the time required to create the vacuum in the material extends the time required at a reel change and reduces the moisture content so that the paper requires rehumidification after metallising. Second, being thicker than film the length of material processed per reel is lower and hence the area coated in a given time is lower than with plastic film, and third, the surface of paper is not as smooth as film and the barrier improvement is not sufficiently significant.

These features can be overcome at a cost. The paper surface can be clay coated and prelacquered to make the surface smoother and improve the metallised appearance. The moisture changes can be avoided by using a transfer metallising process whereby the metallising layer is first transferred to a reel of PP. The metallised layer on the PP is transferred to the paper with the help of an adhesive. In this process, the plastic film (PP) can be reused.

The advantage of metallised paper is that it can replace aluminium foil in some applications. The barrier is, however, poor compared to foil unlike the situation

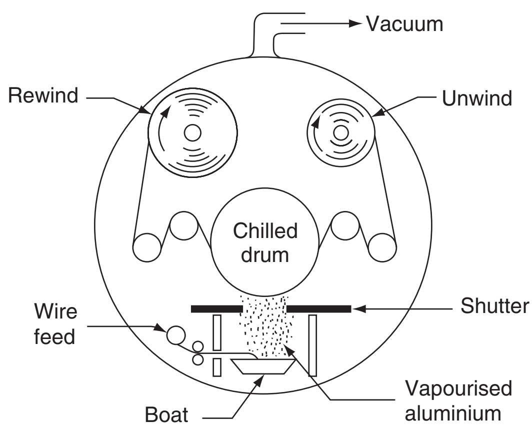

Figure 3.5 Metallising process. (Reproduced, with permission, from The Institute of Packaging.)

when plastic film is metallised. Due to the on-costs required to metallise paper the price differential compared with aluminium foil is not significant. Metallised polyester film (PET or PETE) has been laminated to paper and paperboard as an aluminium foil replacement. A large usage of metallised paper is for the bundling of cigarettes prior to packing in a carton or soft pack.

3.3.2.5 Hot melt coatings

Hot melt coatings are also wax-type blends but they have higher viscosities than the simpler waxes discussed under Section 3.2.3. They are either applied by roll coating or by extrusion, though the extruder would be a simpler design than the type used to extrusion coat PE.

Hot melt-coated paper is used as an in-mould wrap-around label on thermoformed plastic tubs for yoghurt.

A typical specification is:

- overlacquer for gloss and print protection
- gravure or flexo print
- bleached kraft paper (95–100 g/m^2)
- hot melt coating.

The labels are fed from the reel into the pot moulds just before the sheet of plastic, for example polystyrene, also fed from reels, is thermoformed. The hot melt coating seals to the plastic. It also seals where it overlaps the print. The coefficient of friction is an important property of the overprint lacquer to ensure efficient runnability on the machine.

One of the main applications for hot-melt-coated paper is in the wrapping of soft cheese. The packaging in this application is designed to participate in the maturing of the cheese.

A typical specification is:

- 20 μ OPP film reverse side printed by flexo or gravure
- adhesive laminated – sometimes in stripes – to 25–40 g/m^2 bleached kraft paper
- hot melt coating.

The OPP is microperforated after printing to allow cheese respiration and a controlled water vapour transmission rate. The hot melt coating which is used in the direct wrappage of food provides:

- controlled oxygen permeability (which influences the development of the cheese bacteria and, therefore, the taste)
- good folding around the product
- heat sealing for a better pack closure
- glossy finish to the product.

This specification can be modified by metallising the OPP film over the print.

3.3.2.6 Cold seal coating for pack closure/sealing

For specific applications in flexible packaging, an alternative to heat sealing is *coldseal*. This technology requires only mechanical pressure to bond two cold seal coated surfaces together, without any heat being required. Sealing at room temperature, excellent seal integrity and a wider variety of substrates are the main advantages of cold sealing compared with heat sealing. When a packing machine using heat seal stops, heat from the sealing jaws can result in significant product damage and high rejection rates, especially with a product involving chocolate. Coldseal is not particularly sensitive to the sealing dwell time and allows a higher tolerance to variations in line speed. The main applications for cold seal are on horizontal form, fill, seal (HFFS) bar lines and overwrapping, although some vertical form, fill, seal (VFFS) operations exist as well.

Coldseal technology is based on a coating technique. A water-based emulsion is printed onto a web substrate by means of the gravure process. The key component of the emulsion is natural rubber latex which provides cohesive features. The coatings stick preferentially to each other when two coated surfaces are brought together.

Other ingredients are water, ammonia, surfactants, anti-oxidants, anti-foam agents, biocides and an acrylic component. The latter acts as an adhesive, bonding the coldseal to the substrate.

In the wet state, coldseal has a shelf life limited to six months. It must be stored away from frost and heat. Below 0 °C, an irreversible loss of sealing ability occurs. After printing, a shelf life, before use, of at least six months is guaranteed. Excessive ageing allows physical, chemical and biological degradation to occur and leads to loss of seal strength and the development of repulsive odours. After sealing, coldseal packaging keeps its seal integrity in a freezer, for example ice cream sticks.

Typical constructions are:

- release lacquer
- printing inks
- substrate, for example glassine
- coldseal applied in a pattern

and

- release film
- printing ink
- laminating adhesive
- substrate
- coldseal applied in a pattern.

Release lacquer or film is required to allow for easy unwinding (low cling) and prevention of blocking of the material in the reel. Release lacquer consists of polyamide resin. Release film is a low surface tension plain OPP. Glassine, which may be coloured, for example chocolate brown, would be a suitable paper substrate. (Typical plastic film substrates would be white pearlised polypropylene, transparent and metallised polypropylene as well as metallised polyester.)

The coldseal pattern provides a sealing medium in the seal areas only (finseal and cross seal). The central area, where the contents are in contact with the wrapper, must be free from coldseal in order to minimise the direct contact between coldseal and food. Coating weights range from 2 to 6 g/m^2, depending on the application. Typical seal strengths are 5 N/30 mm. Apart from the seal force, as measured after flat sealing and pulling in a tensile tester, a certain coating mass must be present to ensure seal integrity in the pack folds and edges.

Frequently encountered coldseal issues are:

- foaming in the gravure press coldseal distribution system
- formation of lumps as a result of high shear conditions between gravure (application) cylinder and doctor blade
- quality variations due to seasonal fluctuations in rubber latex (natural agricultural product)
- lack of sealing strength
- scumming (appearance of a coldseal ghost in the food contact area)
- misregister of the coldseal pattern with respect to the printing
- smell, for example residual ammonia
- blocking upon unwinding reels due to transfer of coldseal to the release side or damage to the printed side.

In recent years, a synthetic version of coldseal has been developed at the request of the market (food end-users). Main drivers for this are the elimination of natural rubber latex, suspected of causing allergy in sensitive individuals, and the reduction of the unpleasant organic smell. In the synthetic version, a reduced and different odour level was observed as well as excellent converting and sealing behaviour.

Despite the advantages of the synthetic coldseal, which is a higher cost material, it has not been widely adopted. There have been successful developments such as minor modifications in the formulation to reduce smell (flash stripping of residual acrylic monomers, improved centrifuging of latex), more consistent natural latex (rubber from large plantations with cloned trees), to allow higher converting speeds (through the use of surfactants) and changes necessary to comply with evolving legislation.

Due to its presence at the food contact side of a wrapper, coldseal is subject to very strict limitations as to the ingredients used in order to comply with food packaging regulations.

3.3.3 Lamination

In the laminating process, the functional usage of paper is enhanced with the addition of one or more additional layers, or webs, of material using an adhesive to achieve the bonding of the materials. Different adhesive systems which differentiate the various laminating processes are discussed below.

3.3.3.1 Lamination with water-based adhesives

Water-based starch and polyvinyl acetate (PVA) adhesives are used to laminate paper with aluminium foil. Casein and sodium silicate can also be used as adhesives. The adhesive is applied to one of the surfaces and the other surface combined with it by nip pressure between two rolls. Water from the adhesive is absorbed by the paper leaving the active part of the adhesive in a tacky state on the surface. The combined material then passes through a heated tunnel which dries the adhesive (Fig. 3.6). Examples of laminates which are widely used are greaseproof paper/aluminium foil for butter wrapping and bleached kraft/aluminium foil for subsequent PE extrusion coating for many types of sachet and pouch, for example for dry food products such as dehydrated soup and instant coffee.

3.3.3.2 Dry bonding

There are two types of dry bonding (Fig. 3.7) adhesive:

- There is a type where a solvent based adhesive is applied to one substrate and passed through an oven to remove the solvent after which it is combined with the other substrate between two rolls with nip pressure. The laminating nip may be heated if the adhesive is activated by heat, otherwise the adhesive arrives at the nip in a tacky state. Dry bonding is usually associated with two plastic films or one plastic film and aluminium foil, and is not a usual process for laminating when paper is one of the substrates.
- Alternatively the adhesive may be a two component 100% solids system which is applied to one surface which is then combined with the second surface. Adhesion is activated by heat under nip pressure. This is suitable for bonding a printed paper with a plastic film, such as OPP or BOPP. A typical application of this technique enables strips of paper to be laminated with film whilst still allowing product visibility in the finished packaging.

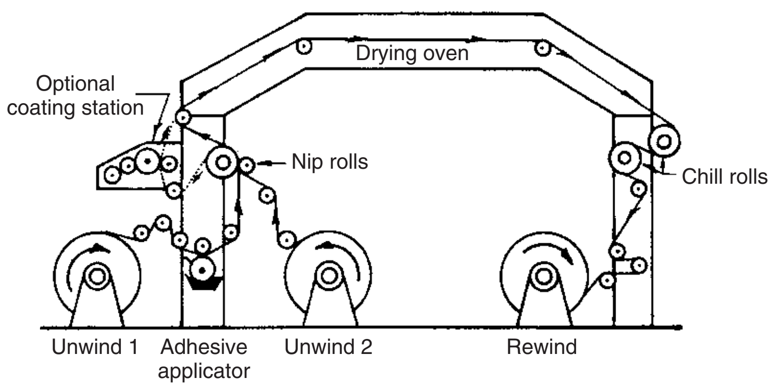

Figure 3.6 Wet bond lamination. (Reproduced, with permission, from The Institute of Packaging.)

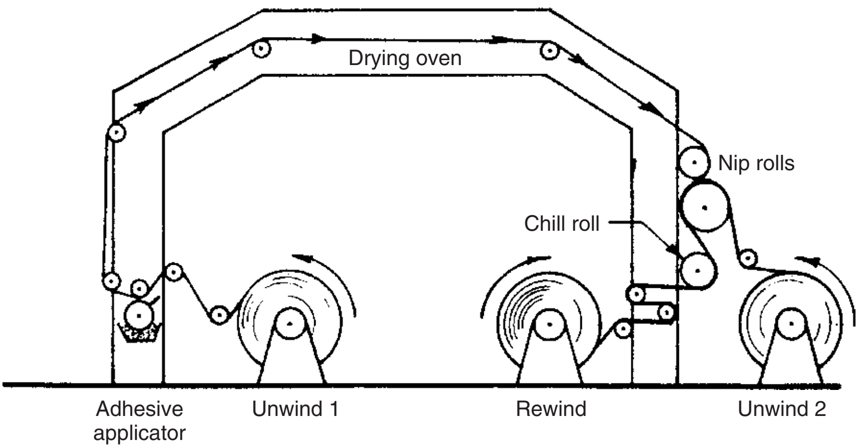

Figure 3.7 Dry bond lamination. (Reproduced, with permission, from The Institute of Packaging.)

3.3.3.3 Extrusion lamination

Extrusion lamination is often used to laminate paper or paperboard to aluminium foil (Fig. 3.8).

On an extruder with two dies it is possible to extrusion laminate the paper with aluminium foil and then extrusion coat the aluminium foil in one pass, Figure 3.9.

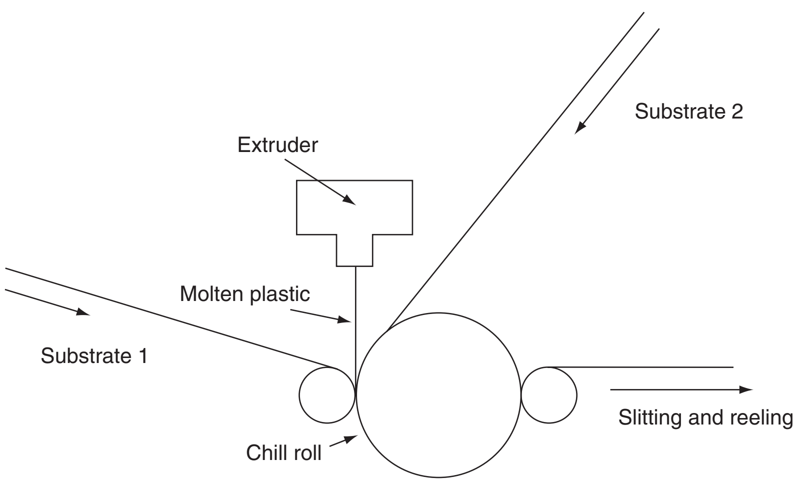

Figure 3.8 Extrusion lamination.

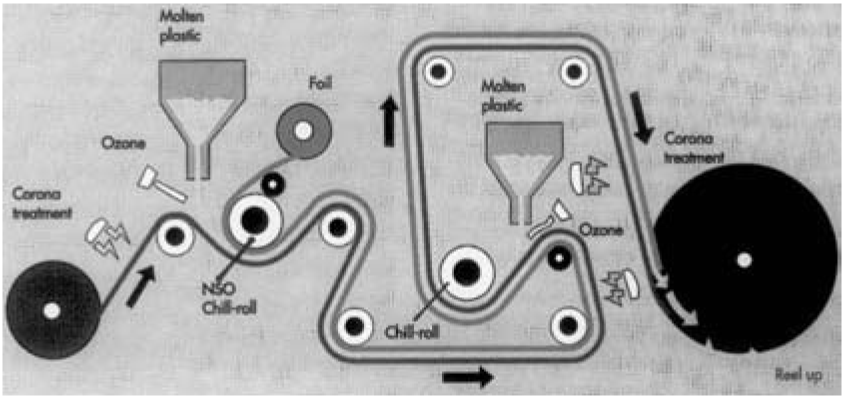

Figure 3.9 Extrusion lamination and coating (courtesy of Iggesund Paperboard).

Examples of paper-based extrusion coated/laminated materials and their properties and advantages are as follows:

Aluminium foil/PE/MG bleached Kraft/PE

- Material suitable for horizontal form, fill, seal machinery
- Suitable for flow packs, sachet packs and stick packs
- Bleached MG paper suitable for simple decorations and flexo printing
- Excellent oxygen and water vapour barrier
- Suitable for powdered products
- Good tearing of, for example, stick packs

Aluminium foil/PE/coated bleached Kraft/ionomer

- Material suitable for horizontal form, fill, seal machinery
- Suitable for flow packs, sachet packs and stick packs
- Clay-coated paper suitable for advanced decoration, flexo or gravure printing
- Excellent oxygen and water vapour barrier
- Suitable for powdered products and outer wraps
- Good tearing of, for example, stick packs
- Good sealing properties through product contaminated seal areas
- Good seal strength
- Very good hot tack
- Suitable for high-speed applications

Aluminium foil/PE/MG bleached Kraft/ionomer

- Material suitable for horizontal form, fill, seal machinery
- Suitable for flow packs, sachet packs and stick packs
- MG paper suitable for simple decors and flexo printing
- Excellent oxygen and water vapour barrier
- Suitable for powdered products

- Good tearing of, for example, stick packs
- Good sealing properties through product contaminated seal areas
- Good seal strength
- Very good hot tack
- Suitable for high-speed applications

Aluminium foil/PE/coated bleached Kraft/PE
- Material suitable for horizontal machinery
- Suitable for flow packs, sachet packs and stick packs
- Clay-coated paper suitable for advanced decoration, flexo or gravure printing
- Excellent oxygen and water vapour barrier
- Suitable for powdered products and outer wraps
- Good tearing of, for example, stick packs

3.3.3.4 Lamination with wax
Wax is used as an adhesive with barrier properties to water, water vapour and gases and odours (Fig. 3.10). For example:

- aluminium foil/wax/greaseproof paper – the aluminium foil can be printed and embossed for use as a butter wrap
- paper/wax/unlined chipboard – the paper can be printed and this material is used for detergent powder cartons where the product requires moisture and moisture vapour protection
- aluminium foil/wax/tissue.

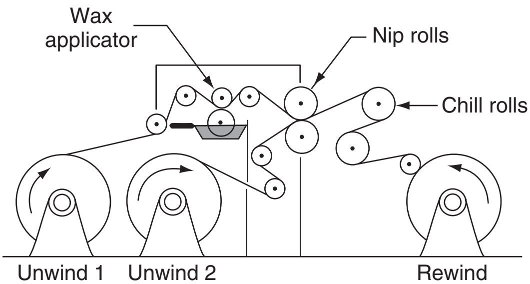

Figure 3.10 Wax lamination. (Reproduced, with permission, from The Institute of Packaging.)

3.4 Medical packaging

3.4.1 Introduction to paper-based medical flexible packaging

Paper-based packaging is used to pack medical devices such as catheters, surgical instruments, operation kits and consumables such as dressings and surgical gloves.

Unlike the flexible packaging discussed so far, paper-based medical packaging has the following special characteristics:

- products are all sterilised after packaging by one of several processes, viz. steam in an autoclave or other form of steam sterilisation, ethylene oxide (EtO) gas and gamma radiation
- packs must thereafter maintain a microbiological barrier – in the case of paper, this is achieved by limiting the maximum pore size
- all sealing must remain secure until the product is required for use at which point the seals must be capable of being opened in a peelable manner which does not generate loose fibre
- there must be no possibility for resealing medical packing once it has been opened.

A wide range of flexible packaging incorporates paper, such as:

- pouches (Fig. 3.11), sachets, strip packs which are all formed, filled and sealed
- lidding for thermoformed plastic packaging on horizontal form, fill seal machines
- bags, pre-made pouches and die-cut lids.

The following account of the background to the use of paper in medical packaging has been prepared by Bill Inman, formerly Technical Manager at Henry Cooke – a company specialising in the manufacture of medical packaging papers.

> Paper is used in the construction of packaging for terminally sterilised medical goods in a number of ways. The earliest large scale application was in the hospital environment, where items to be sterilised were first wrapped in a sheet of special sterilisation paper then sealed inside paper bags which were subjected to sterilisation in a steam autoclave. The bags were sealed either by a heat seal or by folding and taping the top. The contents could vary from a few swabs or dressings up to a full surgical procedure pack, so the bags were made in a range

Figure 3.11 A medical pouch. (Reproduced, with permission, from Amcor Healthcare.)

> of different sizes to accommodate this. When the contents of the bag were used, the bag would be cut open and the sheet of wrapping paper opened out to form a sterile working surface. UK hospitals were pioneers in this application, and initially both the sizes and construction of the bags and the specification for the paper to be used were covered by UK Department of Health Standards, first published in 1967. In the 1980's these were converted into British Standards, which themselves were a major consideration when European Standards for terminally sterilizable medical packaging were formulated during the period 1990–2000. The special feature of the bag paper was that it had to have sufficient air permeability (sometimes referred to as porosity) to allow the rapid transfer of air and steam during the autoclave cycle but on the other hand it must provide an adequate barrier to prevent the passage of contamination. Traditionally, high strength bleached kraft papers, with wet strength and high water repellency, have been used for this application. This continues to be an important use for paper.
>
> Another important use of paper is in combination with plastic films and laminates in the construction of peel open systems, the paper forming one side of the pack, the plastic the other, with the two webs heat sealed around the edges of the pack. Whilst these are sometimes used to package goods in hospitals, their overwhelming use is by industry where large volumes of small items such as syringes, needles, catheters etc are packed at the end of production using web fed techniques. The plastic web may be flat or heat formed into a blister shape. Sterilisation is likely to be by gamma radiation or ethylene oxide. The key in this application is to achieve a sufficiently strong bond of the two webs around the edges of the package to maintain its integrity but yet allow a clean, controlled and easy peel on opening. Much of the development in this area has been concerned with achieving this through the use of coatings and lacquers. When steam and ethylene oxide sterilisation is used, the paper must meet an air permeability specification, but for radiation sterilisation this is not necessary.
>
> Currently, materials for medical packaging are covered by the European Norm EN868, 'Packaging materials and systems for medical devices which are to be sterilized'. This is a multi-part standard in which Part 1, 'General requirements and test methods' is a horizontal or 'umbrella' standard applicable to all materials, Parts 2 to 10 defining specific requirements for individual materials.
>
> ISO 11607:2003, Packaging for terminally sterilized medical devices, may also need to be considered. (Inman, 2004)

ISO 11607 incorporates sections dealing with packaging materials (similar to EN 868-Part 1) pack formation, validation, integrity and shelf life (James, 1999).

The importance of the requirement for seal peelability without the generation of loose fibre has already been mentioned. If a pack is torn on opening, the device may come into contact with the outer pack surface which is likely to be non-sterile. Excessive tearing can result in loose fibres being released into the environment. If these enter a wound site, there is a potential for vascular inclusion, or they can irritate sensitive tissues (Merrit, 2002).

An important aspect associated with opening some sterile packs is the practice whereby one person peels the pack open and a second person removes the sterile product (Figure 3.12).

Figure 3.12 Typical syringe pack showing how pack is opened. (Reproduced, with permission, from Amcor Healthcare.)

3.4.2 Sealing systems

There are several types of sealing system used with paper-based medical packaging:

- *Heat seal lacquer.* This can be applied in an all-over grid pattern to maintain the porosity of the paper for EtO sterilisation. This method of sealing is also suitable for radiation sterilisation but not for steam sterilisation as it would soften and melt at the temperatures used.
- *Cold seal.* In the 1990s, cold seal coatings began to be used successfully in this market. Both natural and synthetic latex are used. Zone coating of cold seal can be applied on the inside of the pack in register with print on the outside. This is necessary where there is a possibility of the product being packed sticking to the inside of the pack, for example in the packaging of surgical dressings and surgical gloves. Cold seal coated papers run at high speed on form, fill, seal machines. The seals peel with random transfer and disruption of the seal interface. Cold seal coated packs can be sterilised by EtO and radiation.

- *Water based heat seal.* A white water-based heat-seal coating can be applied to the paper using the air knife technique for smoothing and weight control. This material seals to rigid and flexible plastic surfaces and has the added advantage that when opened the white coating in the seal area transfers cleanly, with an extremely low risk of fibre tear, to the plastic surface, thereby providing a simple check of seal integrity. This specification is suitable for sterilisation by EtO and radiation.
- *Direct seal paper.* A type of kraft paper has been developed which can seal directly to non-corona-treated PE. This seal gives minimum fibre lift from the surface of the paper. The paper used is known as direct seal (DS) and it requires special manufacturing procedures in papermaking. These procedures relate to a good internal bond strength within the paper, surface treatment, including controlled calendaring, and a higher disposition than normal to encourage the fibres to align themselves in the MD. This latter feature is taken into account when the pack is designed so that when the pack is opened tension is applied, and hence peeling occurs, in the MD of the paper. This results in less surface disruption and the loose fibre generation which is associated with surface disruption (Fig. 3.13).

  Direct-seal papers have been developed as a cost-reduction option for mature products in the medical packaging market, such as suction tubing, conventional gauze dressings and urinary catheters. The sealing mechanism is in direct contrast to other systems which rely on a coating to minimise fibre lift (Merritt, 2003).

  Direct-seal papers have required changes in papermaking technology and in packaging machinery heat sealing. Seals which are too weak cannot be allowed and if they are too strong fibre tearing and loose fibre generation will occur. The operating window on the horizontal form, fill, seal machines which are typically used for this type of packaging in respect of heat, pressure and dwell time, is critical. Temperature control within a range of 2 °C across the entire sealing surface and timers able to control dwell time to within hundredths of a second have been incorporated (Merritt, 2002). Typical basis weight is 60 g/m^2 (37 lb).

Figure 3.13 A fully peelable package incorporating grid lacquered paper and thermoformed nylon/PE. (Reproduced, with permission, from Amcor Healthcare.)

Other cost-reduction areas of interest are:

- ‘peelable polymer’ films, for example multilayer (co-extruded) polyamide film, are designed to give minimum fibre lift when seals to uncoated papers are opened, thereby eliminating the necessity for the application of a special peelable coating to the paper during conversion
- in-line flexographic printing on the packing line – this is more appropriate where the packing programme involves short runs of many different products.

3.4.3 Typical paper-based medical packaging structures

Printing for medical packaging applications is normally by either the flexographic or gravure processes. Typical paper-based medical packaging structures are tabulated in Table 3.1.

The ‘thermoformed base webs’ are typically plastic laminations and co-extrusions. The cavities in which the product concerned is placed are formed from the reel on horizontal thermoform, fill, seal machines. The specification in any particular case depends on the product, its size and weight, whether it has protrusions or sharp edges, whether it is soft and compressible or hard, etc. The plastic material used may range from PE, PP, PET or PETE, ionomer, for example Surlyn®, to polyamide, for example nylon.

Where products in pouches and four-side sealed packs require a moisture vapour or light barrier, aluminium foil is incorporated in the lamination.

Bags and pre-made pouches are predominantly used in hospitals. They are used to a limited extent in industry for short production runs. Bags can have a tear string opening feature, side gussets and either flat or folded bottom seams.

Plastic-film bags can be provided with extra strength through the inclusion of a paper or Tyvek® header for use with heavy and bulky products which require EtO and radiation sterilisation. Tyvek® is a non-woven fibrous sheet material produced by DuPont. It is made from very fine, high density polyethylene (HDPE). The process of manufacture is described as HDPE flash spinning to produce fibres which are then laid down randomly and non-directionally on a moving bed. The fibres are bonded using heat and pressure. This results in a strong sheet with high tensile, tear and puncture resistance. It has resistance to microbial penetration. It is heat sealable and seals can be opened with lint-free, i.e. loose fibre free, peeling. Tyvek® can be sterilised by existing procedures. Tyvek® is therefore frequently used in medical packaging applications as lidding material, pouches, bags and as strengthening/breathable headers in film bags.

Table 3.1 Typical paper-based medical packaging structures

Structure	Sterilisation by	Application (sealing)
50 g/m^2 Kraft/30 g/m^2 LDPE 31 lb Kraft/18 lb LDPE	Compatible with EtO and radiation	Backing web to peelable materials on four-side seal machinery
108 g/m^2 Kraft/13 g/m^2 overall heat seal 70 lb Kraft/8 lb overall heat seal, white, air-knife coating	Suitable for EtO (sufficient porosity) and radiation	Lidding for thermoform, fill and seal, die-cut lids pouches
44 g/m^2 Kraft/29 g/m^2 LDPE/4 g/m^2 overall heat seal 27 lb Kraft/17.8 lb LDPE/2.5 lb heat seal	Radiation	Peelable for four-side sealing with uncoated paper and also lidding for thermoformed base web
60 g/m^2 Kraft/6 g/m^2 overall grid heat seal 37 lb Kraft/3.7 lb overall grid heat seal	EtO and radiation	Lidding for thermoformed base web
60 g/m^2 Kraft/11 g/m^2 overall grid heat seal 37 lb Kraft/6.8 lb overall grid heat seal	EtO and radiation	Lidding for thermoformed base web
100 g/m^2 Kraft/11 g/m^2 overall grid heat seal 61 lb Kraft/6.8 lb overall grid heat seal	EtO and radiation	Lidding for thermoformed base web
40 g/m^2 Kraft/12 g/m^2 LDPE/8 mu Al foil/14 g/m^2 Surlyn® 25 lb Kraft/7 lb LDPE/32 ga Al foil/ 8.6 lb Surlyn®	Radiation	Suitable for four-side sealing with equivalent peelable lacquer- coated material
40 g/m^2 Kraft/3 g/m^2 overall synthetic cold seal 25 lb Kraft/1.8 lb overall synthetic cold seal	EtO and radiation	Seals to itself
60 g/m^2 Direct-Seal paper (Kraft) 37 lb Direct-Seal paper (Kraft)	EtO and radiation	Seals to a partner web with sealing layer is non-discharge treated PE

Note: lb in this context refers to the basis weight in pounds per 3000 square feet or a ream of 500 sheets of 24 in. × 36 in.

See Lockhart & Paine (1996) for pharmaceutical and healthcare packaging.

3.5 Packaging machinery used with paper-based flexible packaging

Flexible packaging is usually associated with form, fill, seal machinery. Vertical form, fill, seal machines (Fig. 3.14) are used to pack free-flowing food materials and liquids. Packs made in this way are either flat or incorporate gussets and block (flat) bottoms. Flat-bottom bags can be made in compact 'brick' designs with a wide range of top closures/reclosures (Figs 3.15 and 3.16).

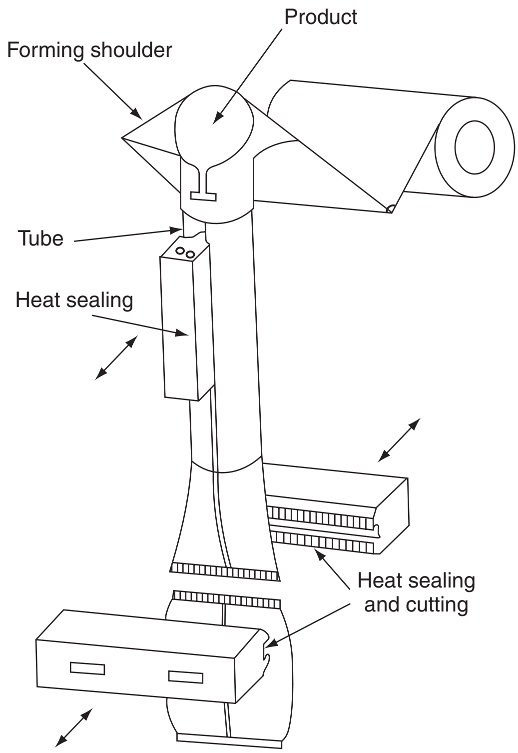

Figure 3.14 Vertical form, fill, seal machine.

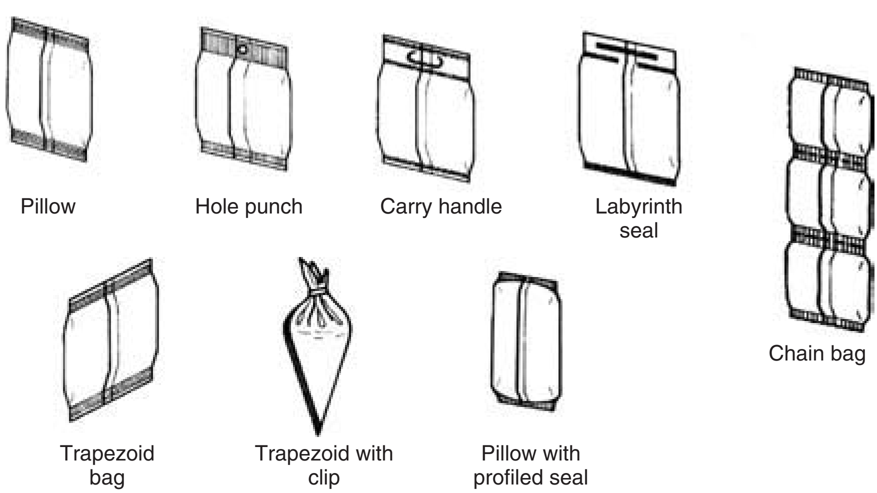

Figure 3.15 Range of typical pillow-type packs produced on vertical form, fill, seal machines, including chain or strip packs. (Reproduced, with permission, from Rovema Verpackungmaschinen GmbH.)

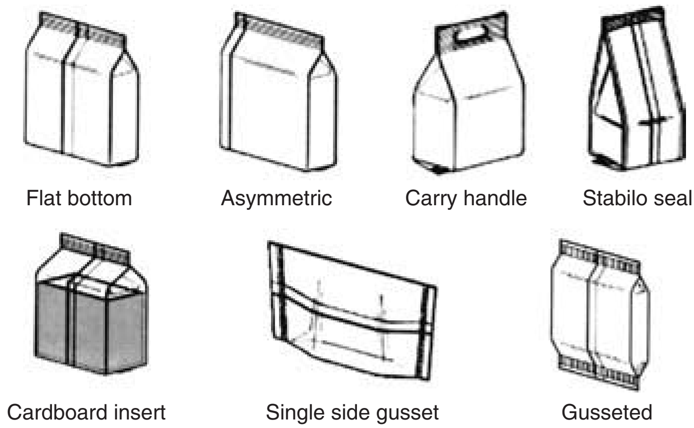

Figure 3.16 Range of typical gusseted/block bottom bags produced on vertical form, fill, seal machines. (Reproduced, with permission, from Rovema Verpackungmaschinen GmbH.)

Another type of machine is filled *vertically* but the pack is formed *horizontally*. It can be formed with a base gusset (Figs 3.17 and 3.18). This type of pack is suitable for a powder, granular or liquid product. Single items can be packed and cut off in multiples forming strip packs – the heat seals separating adjoining individual packs can be perforated so that the individual sachets can be used progressively.

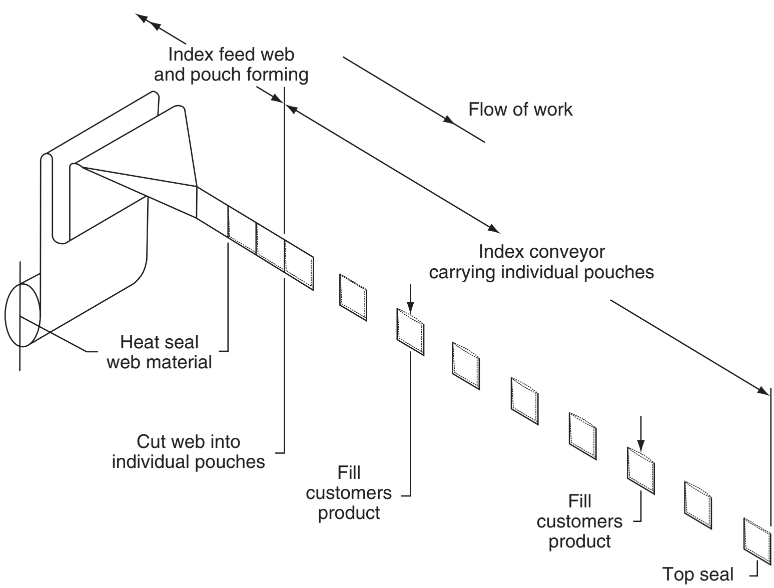

Figure 3.17 Horizontal pouch/sachet form, fill, seal machine for dry mixes (soups, sauces etc.), pastes and liquid products.

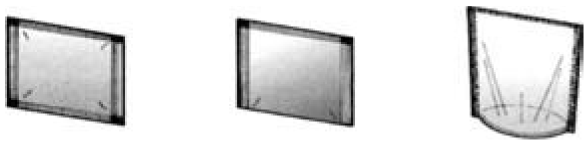

Figure 3.18 Typical horizontally formed pouches/sachets with 3-side sealing, 4-side sealing and base gusset providing a 'stand-up' feature. (Reproduced, with permission, from Rovema Verpackungmaschinen GmbH.)

The flow wrap-type machine both forms and fills the pack in a horizontal plane. It is used to pack single solid items, such as confectionery bars or multiple products already collated in trays, which may be made of paperboard or plastic (Figs 3.19 and 3.20).

In-line thermoforming is primarily thought of in the context of plastic packaging because the base web is made up of one or more plastics. The lidding and in-mould labelling of such packaging is, however, frequently achieved with paper-based materials. This was discussed under medical packaging though there are many food-based applications, chiefly yoghurts and cream-based desserts (Fig. 3.21).

There are machines which form bags around mandrels, sealing being made with adhesives, so that they have a rectangular cross section and a block bottom. (This type of machine can also wrap a carton around the paper on the same mandrel to form a lined carton.) Roll-wrap machines pack rows of items, for example biscuits and sugar confectionery. Individual confectionery units may be wrapped in waxed paper for moisture protection and to prevent them sticking together. These may be twist wraps, dead folded or plain waxed liners overwrapped with a folded printed paper.

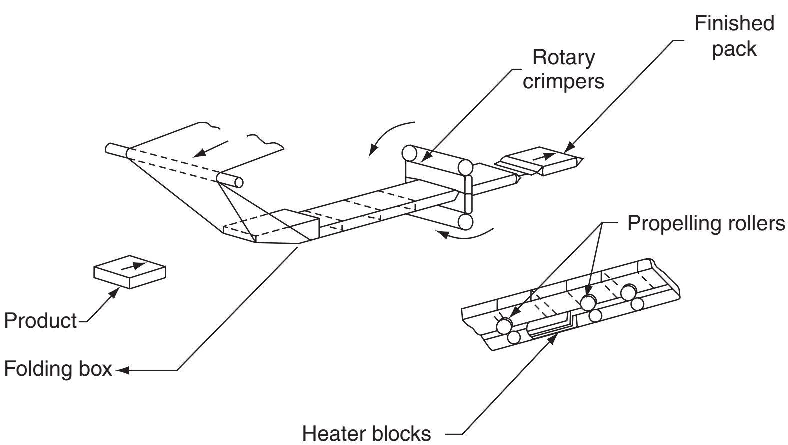

Figure 3.19 Horizontal form, fill, seal type machine.

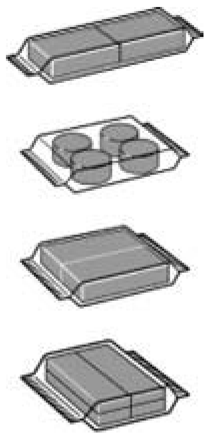

Figure 3.20 Typical horizontal form, fill, seal pack. (Reproduced, with permission, from Rose Forgrove (MOLINS PLC).)

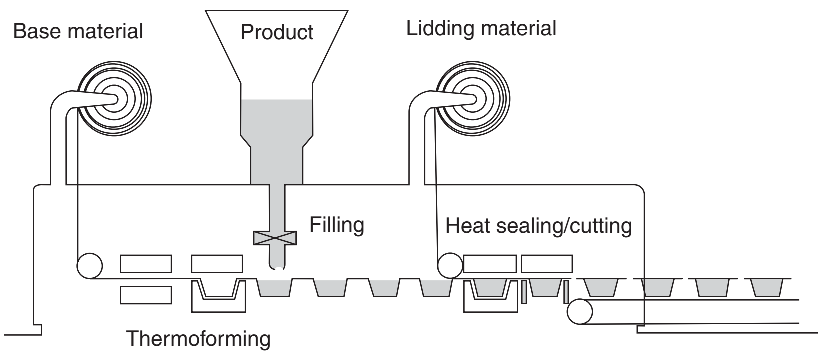

Figure 3.21 In-line thermoforming and lidding.

Overwrapping square or rectangular shaped cartons with paper coated with PE or wax with neatly folded heat-sealed end flaps is also used, for example overwrapping of chocolate boxes, teabag cartons and a grouped overwrap of 10 cartons each containing 20 cigarettes (Figs 3.22 and 3.23). Another form of overwrap is the waxed paper bread wrap with ends folded progressively and heat sealed.

3.6 Paper-based cap liners (wads) and diaphragms

Paper-based flexible materials are used inside plastic caps and closures for rigid plastic and glass jars. They are referred to as discs or innerseals.

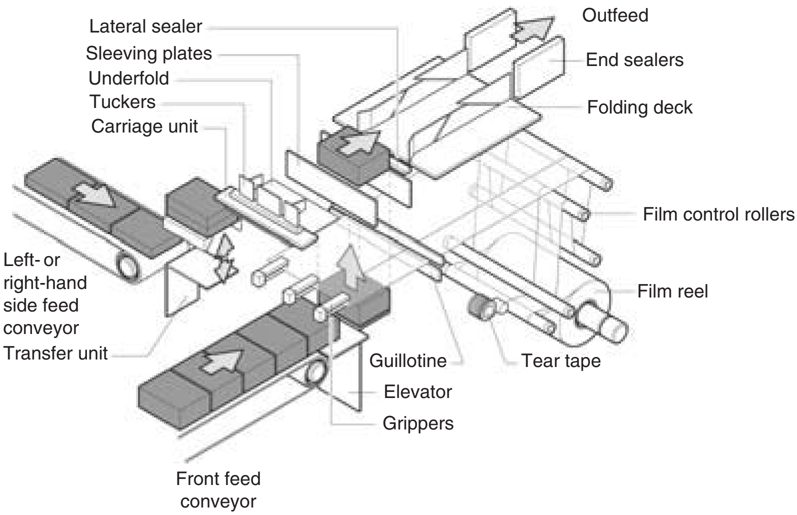

Figure 3.22 Overwrapping machine. (Reproduced, with permission, from Mardon Edwards Ltd.)

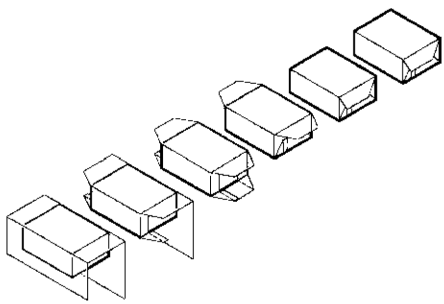

Figure 3.23 Overwrapping envelope end-fold folding sequence. (Reproduced, with permission, from Mardon Edwards Ltd.)

3.6.1 Pulpboard disc

The simplest type of cap liner is a pulpboard disc made from mechanical pulp fitted inside a plastic cap. The cap liner or wad has to be compressible and inert with respect to the contents of the container, usually a food product. This liner could be faced with aluminium foil or PE where the nature of the contents requires separation from direct contact with the pulpboard.

3.6.2 Induction sealed disc

The disc comprises pulpboard/wax/aluminium foil/heat-seal coating or lacquer (Fig. 3.24). The cap with the disc in place is applied to the container and secured.

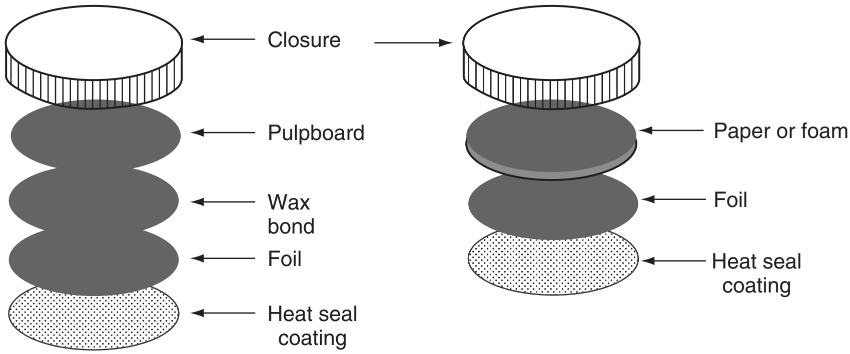

Figure 3.24 Pulpboard discs for induction-sealed cap liners. (Reproduced, with permission, from The Institute of Packaging.)

It then passes under an induction heating coil. This heats the aluminium foil which causes the wax to melt and become absorbed in the pulpboard. It also activates the heat-seal coating and seals the aluminium foil to the perimeter of the opening of the container. When the consumer removes the cap the adhesion between the pulpboard and the aluminium foil breaks down leaving the foil attached to the container. This seal therefore provides product protection and tamper evidence. Where subsequent contact between the contents and the pulpboard is undesirable, the pulpboard is permanently bonded to the aluminium foil. (A simpler version dispenses with the wax and replaces the pulpboard with paper.)

3.7 Tea and coffee packaging

There are many different types of tea and coffee packaging (Fig. 3.25). In the context of paper-based flexible packaging, the main interest is in tea and coffee

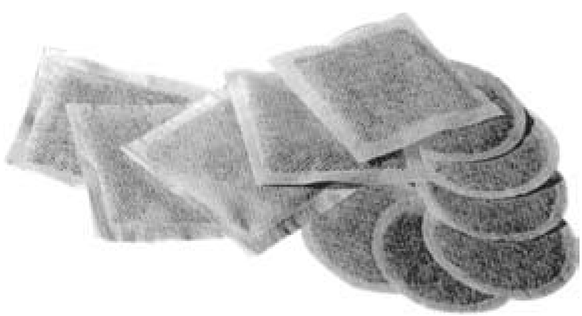

Figure 3.25 A selection of heat sealed tea and coffee bags. (Reproduced, with permission, from IMA, Industria Machine Automatiche.)

bags and the printed, heat-sealed envelopes, and tags which are associated with them in some of the forms of marketing product presentation.

The bags themselves are made from very lightweight porous tissue. The tissue is either heat sealable or non-heat sealable. A typical heat sealable tissue is 17 g/m^2 and contains a heat sealable thermoplastic fibre such as PP in addition to its long fibred structure. Bags may be flat, square, four-side perimeter sealed. Two webs are used at high packing speeds. Alternatively, bags may be round or pyramidal in shape. Non-heat sealable tissue is used to make a bag which is folded and stapled giving a larger surface area for infusion and using a lighter weight tissue, typically 12 g/m^2. All these bags are closely associated with the machinery which forms, fills and seals the bags – both types may have strings and tags (Fig. 3.26).

It is possible to link such machines with enveloping machines which can comprise paper, or paper laminated or coated with moisture and gas barrier properties. Tea and coffee bag packing machines can include, or be linked to, cartonning or bagging machines.

Figure 3.26 Tea and coffee bag with tag, string and envelope. (Reproduced, with permission, from IMA, Industria Machine Automatiche.)

3.8 Sealing tapes

Sealing tapes have much in common with labels but they can be considered a flexible packaging product as paper reels are subjected to a reel-to-reel conversion process and sometimes they are also printed.

Sealing tapes are narrow-width reels comprising a substrate and a *sealing* medium which can be dispensed and used to close and seal corrugated fibreboard cases, fibre drums, rigid boxes and folding cartons. Sealing tapes are also used by the manufacturers to make the side seam join on corrugated fibreboard cases and tape the corners of rigid boxes, thereby erecting or making-up corner-stayed boxes.

A traditional and commonly used substrate is hard-sized kraft paper, both unbleached (brown) and bleached (white). Where higher strength is required the kraft is reinforced with glass fibre, and up to four progressively stronger specifications are typically available from some suppliers. Reel widths start at 24 mm, though

50-mm width tape would be a typical width to seal the flaps of an average sized corrugated fibreboard case.

In the case of gummed tape, adhesion is achieved by coating the kraft paper with a modified starch adhesive; animal glue has largely been superseded. The adhesive is then dried and the reels are slit to size. In subsequent use the adhesive is automatically, and evenly, reactivated by water in a tape dispenser. Tape dispensers which can cut pre-set *lengths* for specific taping specifications are available.

The advantages of gummed paper tape are that it is permanent and provides evidence of tampering, it can be applied to a dusty pack surface without loss of adhesion, is not affected by extremes of heat and cold and does not deteriorate with time. Pressure-sensitive tapes, on the other hand, are used on all types of packaging from paper and paperboard to metal, glass and plastic containers. Pressure-sensitive adhesive can be applied to several types of substrate, including moisture-resistant kraft paper which has been coated on the other side with silicone to facilitate dispensing from the reel.

Heat-fix tapes are based on kraft paper where the adhesive is applied as a thermoplastic emulsion, dried, subsequently reactivated by heat when applied to the sealing surface with pressure. Sealing tapes used are plain, preprinted or printed at the point of application.

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4 Paper labels

Michael Fairley

4.1 Introduction

The use of labels in a format that would be recognised today can be traced back to the early 1700s. At that time, labels were used mainly to identify products such as bales of cloth and medicines. Labelling of products for sale using printed labels had not evolved to any significant extent at that time, largely because few of the population could read or write and because there was no trade of mass produced and packaged goods.

All that began to change with the advent of education and mass literacy programmes in the 1800s, together with the evolution of the mass production of food and drink in bottles and cans – the need to put descriptive and brand information on products, and to produce labels in volume quantities, now became a necessity.

By the later part of the nineteenth century, the introduction of the papermaking machine and the invention of lithography provided the means to produce economically long runs of the same quality (label) papers and to print them, in sheeted form, in colour. It was the advent of cost-effective colourful labels produced in this way that enabled manufacturers to take advantage of the opportunity to individually package and label their products themselves, rather than having them individually weighed and wrapped by the provision merchant. Product labelling, as we know it, had arrived.

Initially labels were printed onto plain paper and cut to a rectangular size by guillotine – even scissors or punches, if a special shape was required – before being applied with a wet-glue or gum. Early methods of labelling used gums and adhesives which were brushed on to the label and then the label applied by hand. These first slow labelling methods eventually evolved into full-blown applicator machines and systems which applied a wet-glue to the back of each label and then applied the label to the bottle or can. Wet-glue paper labelling in a form that would be recognised today became a reality. Pre-gummed paper labels for application to paper and paperboard packaging was a later evolution, helping to speed up address labelling for the dispatch of transit packaging.

With these developments, the product manufacturer was able to use the label as a means of contact with the customer so as to promote a product or brand, add information regarding contents or usage, provide the name and address – even claim all kinds of (unproven) health, digestive, beauty or other benefits of the product. Indeed, it was the widespread growth of such claims that led governments to start introducing legislation to protect the consumer from misleading claims.

The dominance of the wet-glue applied label for product labelling of glass bottles and cans, and gummed paper labels for addressing and shipping labelling of paperboard containers, continued until the early 1970s. At that time wet-glue paper labelling (70% of the market) and gummed paper labelling (22%) were still the only significant labelling technologies.

Self-adhesive labels, invented in the mid-1930s, started to make an impact on the product decoration and labelling market in the late 1960s, initially as a means of applying price labels to products and then eventually evolving to become a high added value method of labelling cosmetics, pharmaceuticals and shorter-run applications with both primary and secondary labels.

Since then, many factors have begun to change the world of labels:

- rapid growth and emergence of computer-impact printed address labels
- bar code labels and variable imprinting
- major explosion and rapid volume growth in the use of plastic containers and forms
- relatively low growth in the use of glass bottles and cans
- new demands for anti-theft, tamper evident and anti-counterfeit labels
- new requirements for promotional, booklet and leaflet labels.

All of these have brought many changes in the use of labels over the past thirty years or so.

In addition, when one considers the changes which have taken place in consumer lifestyles, leisure activities, global travel and legal requirements (consumer, health and safety, environmental legislation), the growth in label usage and the technologies used become even more dramatic. Changes in consumer lifestyle include:

- need for more convenience in the home, this has led to a decline in the purchasing of preserved food in cans and jars in favour of the purchasing of freezer packs and ovenable/microwaveable reheatable meals and ingredients
- packaging of carry home beers and soft drinks in cans rather than bottles
- regular eating out – decline in home cooking and increase in packaging for the catering market
- leisure life that includes overseas travel, gardening, DIY, sports, healthy lifestyle and 'keep-fit' activities.

These changes have created needs for new types of label.

Pressures in the early to mid-1980s to find new ways of labelling very long runs of blow-moulded containers led to the development of in-mould labelling, whereby the label is placed in the mould prior to the forming of the container, thus becoming an integral part of the bottle. Originally only used for decorating blown plastic containers for hair care and under-the-sink products, in-mould labelling later extended to the labelling of injection-moulded biscuit containers and to tubs for soft spreads and margarines. Most recently, in-mould labelling has been used for the labelling of thermoformed tubs, again for soft spreads.

Also in the 1980s came the development of plastic shrink-sleeve labelling where a continuous web of film is printed, formed into a tube and then, for application, cut to the appropriate length, placed over the container and then shrunk to fit. Having the advantage of 360° decoration, sleeve labelling has created new markets and applications for labels and also added the potential to extend the shrink capability to provide a tamper-evident cap seal. An alternative and more recent technology for 360° decoration came with the introduction of stretch-sleeve labelling in the 1990s.

Other new labelling technologies developed in the 1990s, primarily for the labelling of plastic bottles, include wrap-around film labelling, cut-and-stack film labelling, roll-on shrink-on (ROSO) labelling and spot-patch film labelling. Used for the decoration of soft drinks, carbonated beverages and some beers, these newer label technologies are achieving some of the highest growth in the label and end-user market.

With the rapid expansion of supermarkets and hypermarkets in the past 20–30 years has come the development of 'own brand' labels, successfully competing with and gaining market share from brand owners. This coupled with faster and faster store throughput, and a significant increase in pre-packed fresh produce has brought about the need for shorter and shorter run lengths, a major requirement for price-weight labels, ever reducing lead times, Just-In-Time (JIT) manufacturing practices, improved supply-chain management and demands for improved quality standards. All these trends and pressures have had an influence on the types of labels used, the printing process required, pre-press technology, label application and label usage.

Apart from labels, brand owners, packaging and marketing companies can also choose from:

- direct decoration by screen printing onto glass and plastic containers
- offset printing directly on to cans
- tamper and pad printing onto pots and tubs
- transfer decoration of glass bottles
- metallic foiling directly onto containers.

These technologies compete with labels and may influence the continuing change between direct decoration and label solutions – all based on quality, performance, run length, image, cost, etc. Direct decoration makes up a near 30% of the total label, and alternative to label, decoration market.

4.2 Types of labels

Since the 1970s, there has been a major shift in the range and variety of label technologies used in packaging by the end-user, moving from dominance by wet-glue and gummed paper label technology in the 1970s to dominance by self-adhesives from the mid-1990s onwards – at least in the sophisticated markets of western Europe and North America. Today, self-adhesive labels make up over 50% of all label usage in these markets, although with wet-glue still well in excess of 30%.

Gummed paper labels, so widely used in the 1960s and 1970s, are now just a few per cent of usage, largely superseded by self-adhesives. Put together, all the newer labelling technologies of the 1980s and 1990s, developed primarily for the labelling of plastic bottles and containers, are now around 15% of the total label market.

The other key shift in label usage has been a steady and continuous move to the usage of non-paper labels to meet the growing demand for new ways of labelling plastic bottles and containers. Driving forces behind this growth of filmic labels include:

- high annual growth of plastic bottles (compared with glass bottles and cans)
- the requirement for compatibility of the label material with that of the bottles due to waste and recycling issues
- demand for clear, no-label-look packaging
- the ability to provide white, coloured, silky, iridescent or pearlescent surfaces
- the need to provide moisture protective, chemical or product resistant labels for use in demanding applications.

From almost total dominance by paper labels in the 1980s, the market has evolved rapidly to a point now where non-paper film labels make up over 20% of all label requirements and have been growing at a rate four or five times faster than paper labels. Mention is therefore made of film-labelling technologies in these pages.

When looking at label types today, they all fall into one of two key categories: those that are printed on paper or synthetic substrates (film, metallic foil, metallised paper, etc.) and to which an adhesive, glue or gum is applied at the point of application; and those substrates which already have the adhesive or gum on them before they are printed. This adhesive or gum is then activated by pressure, moisture or heat at the point of application. These two groupings and the range and variety of label types available can be seen in Figure 4.1.

A brief description of the main label types, along with some of the typical properties and applications of each type of label is as follows.

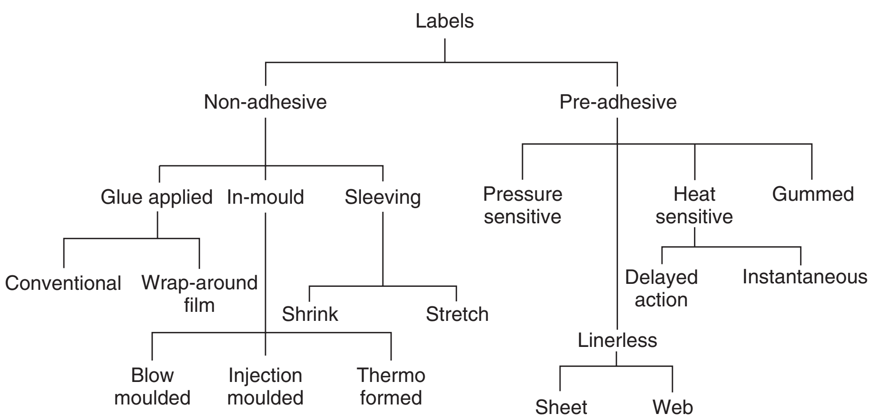

Figure 4.1 Types of labels used in the early 2000s. *Source*: Labels & Labelling Consultancy.

4.2.1 Glue-applied paper labels

The application of paper labels to a glass bottle or can using a wet-glue was one of the earliest methods of labelling, and for many years it was the dominant label technology. Even today, in spite of the rapid growth of self-adhesive and other label technologies, glue-applied labels are still, marginally, the main method of volume labelling bottles and cans with paper labels. Labels may be individual face, neck and back labels for application to beer, spirit or wine bottles, or wrap-around labels used extensively on canned foods and soft drinks.

Glue-applied paper labels are printed on plain paper, metallised paper or paper laminated materials in either sheet-fed offset (most common) or web-fed gravure (some flexo) presses. They are often also varnished, coated or lacquered to provide surface protection during labelling, handling and distribution, before being guillotine-cut to a rectangular or square size in stacks of 500 or 1000 labels, or punched into special cut-out shapes, again in stacks, ready for placing in a hopper in the label application machine.

4.2.1.1 Glue-applied paper label substrates

They include:

- one-side-coated grades and uncoated white or bleached, kraft paper 55–100 g/m^2
- metallised paper
- paper/aluminium foil laminates.

All of these have a similar base. For the one-side-coated grade, a special printable coating is applied. Foil-laminated paper is a more expensive and luxurious glue-applied label substrate and is made up of a thin aluminium foil laminated to a paper backing. Metallised paper substrates are one-side-coated papers onto which metallic aluminium has been deposited under high vacuum.

Selection of the one-side-coated, laminated or metallised paper-label substrate for glue-applied labels is determined by the effects required, the performance of the finished label, the nature of the labelled product and on the label-application method. Factors such as surface smoothness, opacity, stiffness, porosity, water absorbency, wet strength, grain direction and degree of curl, all need to be considered. Cost is also an important factor to be considered. Corrosion and/or mould inhibitors may be required for some applications.

4.2.1.2 Label application

It is undertaken on a machine in which either a wet-glue or hot-melt adhesive is brushed or rolled onto the back of each label just before it is applied to the container, enabling the most suitable adhesive formulation for the specific application to be selected. The type of adhesive application can also be selected from options such as skip, pattern or stripe, depending on adhesion, application speed or drying speed.

The key uses for glue-applied labels are in the high-speed, high-volume, low-change-over labelling of drinks bottles and for canned foods – both human and pet food – where application speeds of up to 60000–80000 or more containers per hour are available.

4.2.2 Pressure-sensitive labels

Pressure-sensitive labels were originally developed in America in 1935 by Stan Avery and, since the 1960s, have been gaining widespread acceptance and usage to become the dominant labelling technology used today.

More commonly referred to, outside the labelling industry, as self-adhesive labels, the pressure-sensitives offer the package-labelling market a wider range of face materials and adhesives than any other method of labelling, as well as the greatest range of in-line printing and converting options. With an adhesive which is already active and ready for immediate application, it is not surprising that they have rapidly gained popularity for a diverse range of primary and secondary labelling requirements.

4.2.2.1 Self-adhesive label substrates

These are more diverse than for any other method of labelling, using paper and board, films, synthetic papers, foils and laminates, as well as a whole range of surface treatments and top coating to meet specific applications. The most commonly used label facestocks include:

- uncoated paper and paperboard
- on-machine coated, double-coated, high-gloss-coated and cast-coated paper and paperboard
- polypropylene (PP), orientated polypropylene (OPP) and bi-axially orientated polypropylene (BOPP)
- polyester (PET or PETE)
- polyethylene (PE) and high density polyethylene (HDPE)
- metallic foil
- metallised paper and paperboard
- metallised film
- polyvinyl chloride (PVC)
- synthetic paper
- acetate.

Label thicknesses may vary from around 40–50 microns up to 80, 90, 100 or more, depending on requirement and application.

The release-backing paper or liner used for self-adhesive labels may be supercalendered unbleached kraft or glassine, coated with silicone or fluoropolymer. Filmic liners are used for some applications and for clear-on-clear films. Grammages can be as low as 50 g/m^2 or even lower.

The development of a whole range of self-adhesive solutions for the variable image printing (VIP) of batch and date codes, bar codes and price-weight information using thermal overprinting equipment has further extended self-adhesive label usage into the fast-growing field of logistics, distribution, warehousing and shipping applications, as well as into retail catch-weigh labelling – solutions which no other form of labelling can readily offer. Label facestocks for VIP labels have special coatings which are thermally sensitive or surface smooth for overprinting. VIP film substrates often have special top coatings to make them print more like paper with consistent results.

Although self-adhesive labels are more expensive than wet-glue, they are simple, clean and easy to apply using hand-held, semi-automatic or high-speed applicator systems that have no label change parts and the ability to apply almost any kind of label-face material at up to 300 containers a minute. Speeds up to 60 000 containers (bottles) per hour can be achieved with, say, a multiple (6-station) head applicator, see Fig. 4.2.

Almost all self-adhesive labels are made up of a sandwich construction in which there is a face material (the label), a sticky pressure-sensitive adhesive and a siliconised backing paper or liner. The face of the material is printed (usually on narrow-web presses in web widths up to 300 or 400 mm wide), die-cut on the face and the matrix waste removed, slit into individual label widths, and re-wound for transportation to the end-user's labelling line.

4.2.2.2 Self-adhesive label application

It is undertaken on machines in which the label is dispensed from the liner and applied to the bottle, container or pack. The waste liner is disposed of. Consequently, pressure-sensitive label materials are higher in cost than those of unsupported labels. However, the labels are only applied where needed and not as a complete wrap-around or as a whole sleeve.

The direct transfer of labels from a reel permits exact placement of labels in front, back or neck positions, top or bottom placements if required, into recesses, around corners, etc., and can be easily changed in any combination depending on the number of application heads on the machine. Changeover of labels from one design or one bottle type to another takes about 15 min or so. Any combination of one, two or three labels (on a 3-head applicator) can be changed at any time, thus providing extreme flexibility.

Self-adhesive labels are well regarded by industries such as cosmetics, toiletries, healthcare and beauty, pharmaceutical, foods and industrial products because of the range and variety of decoration possibilities available, and by production departments due to their potential for precise application. They are also finding increasing interest in the added-value drinks markets for wines, spirits, iced beers, speciality beers, etc., particularly for iced or chill-cabinet drinks where the exclusive bottle dress of the pressure-sensitives is a key attraction.

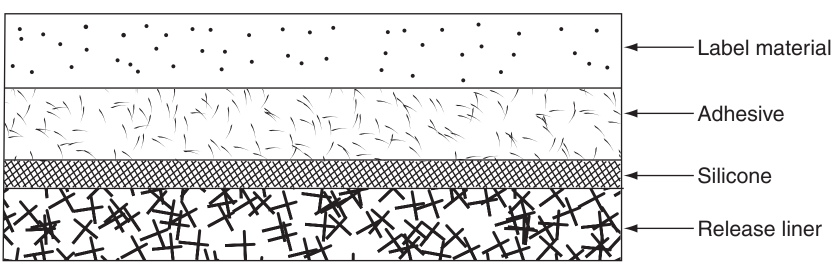

Figure 4.2 Self-adhesive label. *Source*: Labels & Labelling Consultancy.

4.2.2.3 *Linerless self-adhesive labels*

It should be noted that several developments have been made in the past 15–20 years to produce linerless self-adhesive labels, the first of these being the Monoweb system developed in the mid-1980s. In this system, the web was first printed, then silicone coated on the face before finally being adhesive coated on the reverse. The web of self-adhesive labels was then wound on itself without the need for a separate release liner. A key limiting factor to this technology was that the labels had to be die-cut to shape on the label-applicator line.

Linerless self-adhesive labels for thermal printing are also produced by some label converters in-house. This can be done on a label converting or press line using coating heads to apply again a silicone face coating and an adhesive reverse coating and then winding the web on itself. Slit into narrow single label widths, the labels are then overprinted electronically, cut to length and dispensed.

More recently, developments have been taking place in which self-adhesive labelstock is coated onto both sides of a single- or double-sided release liner web. Printed and die-cut in one pass, front and back labels are carried on one backing web. A special label applicator has been developed to apply these two-sided labels. The system saves press time, reduces liner waste at the application stage and ensures that there are equal numbers of front and back labels on the reel, thereby reducing reel changes and wastage of labels.

4.2.3 *In-mould labels*

The technology of in-mould labelling has been available for over twenty years and involves placing pre-printed rectangular- or square-shaped labels within a mould immediately prior to blowing, injection moulding or thermoforming of plastic into it to form a container, for example bottle, pot or tub. In this way, the label becomes an integral part of the finished item, with no subsequent requirement for label application equipment, or filling on the packaging line.

4.2.3.1 *In-mould label substrates*

Initially, the process involved placing paper labels coated with a heat-seal back layer into the mould before blow moulding. This layer must fuse to the bottle during the blow moulding process. More recently, for recycling and performance considerations, synthetic paper materials such as Polyart or Synteape have become more common as labels for under-the-sink labelled products, as well as specially developed OPP films (which fuse directly to the container and eliminate any tendency to produce an orange-peel effect) which are used for the labelling of injection-moulded tubs for soft spreads. All in-mould label substrates must have good lay-flat properties for trouble-free feeding from the moulding-machine hoppers.

In Europe, some 80% of in-mould labelling is with injection-moulded or thermoformed tubs and lids for dairy foods, such as soft spreads, margarines, cheeses, sauces and ice-cream, with 20% used with blow-moulded containers for under-the-sink products, household chemicals and industrial, laundry products, personal and hair-care products and some juices. In the USA, it is in-mould labelling of blow-moulded containers which dominates the market.

In-mould labels are mainly printed by sheet-fed offset or by web-fed gravure. Narrow to mid-web flexography, letterpress and offset are also used by some printers – with off-line die-cutting to shape. Inks are critical to the process with labels protected on the surface with a UV or EB curable top coat. Die-cutting is also critical, particularly when labels printed in sheets are stacked and rammed through a tunnel, emerging cut to size. Edge welding may be a consequence of this process.

4.2.3.2 In-mould label application

Because of the high cost of the basic moulding equipment and moulds, plus the need to modify these to be able to insert and position labels accurately into the mould, in-mould labelling has had a somewhat limited acceptance in the market place, with little more than a 2–3% market share. Relatively long runs have traditionally been needed to make the process viable, particularly difficult when short-run, 'just-in-time' label manufacturing is being increasingly demanded by the label user.

Against this, the requirement for both recyclable and/or pre-labelled containers, the potential of higher packaging line speeds and in-case filling, improved appearance and better squeeze resistance, spurred on by environmental and economic issues and more economic methods of producing and inserting in-mould labels, are all expected to aid the growth of the process in the coming years.

A recent development of in-mould labelling is with the use of single portion thermoformed pots for yoghurts and cream-based desserts where the label is applied in the mould – yet the labelstock is on a reel with a conventional pressure-sensitive adhesive. The machine used for this application forms the pot, fills and seals 12 or more pots per cycle.

4.2.4 Plastic shrink-sleeve labels

Plastic shrink labelling is not paper based, but in order to give an overall view, it has been decided to discuss plastic shrink labelling, especially as it is a serious competitor to paper-based labelling.

Shrink sleeving was originally developed in the early 1970s as a method of combining two or more products together for promotional or marketing purposes. Adding printing to the shrink film, twin pack or multi-pack promotions soon followed, with the evolution of the technology into a high quality 360° method of decoration for unit packaging/labelling developing in the 1980s. Today, shrink-sleeve labelling is quite widely used for the decoration of beverages, food, home and bodycare products, dairy produce and for a variety of special projects.

Sleeves are usually reverse gravure printed with photographic images, graphic design, text, colour and special finishes, and then formed into a tube – which is collapsed for re-winding, handling and shipping. Flexo printing is also used. Origination of the design and images for shrink sleeving is a special technique as the image for printing needs to be distorted, even differentially distorted, so that the final shrink image on the bottle is correct.

4.2.4.1 Shrink-sleeve label films

These were initially made from pre-stretched PVC. Now the market also uses OPP, polyester and low-density polyethylene (LDPE) in a variety of surface finishes. Films are generally made using either a bubble extrusion or calendering process. Thicknesses of films range from 35 to 90 microns, combining various shrinkage and thickness variations. Additives allow UV blocking or the inclusion of UV fluorescence for security and reconciliation, as well as to provide anti-static or fire-retardant features.

Besides primary decoration, shrink sleeves offer good tamper-evidence features, using tear strips and perforations across and along the sleeve. Integrated holograms can add an additional anti-counterfeiting role.

4.2.4.2 Shrink-sleeve label applications

Compared with many other bottle-labelling technologies, shrink sleeving does tend to have somewhat higher costs. Relatively thick filmic materials are used, the bottle is completely covered by the sleeve and the sleeve has to be converted into a tube after being printed. As such, raw material costs tend to be high. Furthermore, print costs are high; even if only five colours are required on the label, it is still necessary to print an opaque white base. Gravure cylinder costs are also quite high. This gives a higher overall print cost for shrink-sleeve labels before capital costs and investment are considered.

Against this, the technology is currently achieving good success for high quality, high added-value all-round bottle decoration and, when used with glass bottles that have been lightweighted, the strength of the shrink sleeve compensates for the lower strength provided by the glass such that the performance of the pack is maintained. The cost of the sleeve can be offset against the savings resulting from the lighter-weight glass bottle.

4.2.5 Stretch-sleeve labels

Stretch-sleeve labelling is a more recent development of sleeve technology which, instead of shrinking the film tube to fit over the bottle, uses a stretchable film which is cut to size and then opened up to slide over the bottle. It then collapses elastically to fit the shape of the container.

Stretch sleeves provide advantages when applied to PET containers in that flexible sleeves compensate for the expansion of PET containers that occurs after filling. Returnable bottles can be easily de-sleeved before entering the bottle washer, since, unlike the more traditional types of label, the sleeve is not glued to the bottle.

4.2.5.1 Stretch-sleeve label films

These are LDPE materials. Like the other unsupported film labelling solutions – reel-fed wrap-around, cut-and-stack wrap-around, shrink sleeving – stretch-sleeve films are primarily printed with gravure or flexo technology. However, unlike shrink sleeving, there is no need to use image distortion techniques in the stretch-sleeve process. Again, films can be reverse-side printed to minimise ink scuffing or rubbing.

4.2.5.2 Stretch-sleeve label application

Because of the nature of the stretch-sleeve labelling process, it can only be used for body decoration of straight-sided containers. It cannot be used with tapering necks or shaped bottles – although it can be combined in an application system with, say, a pressure-sensitive neck label. No flexibility in terms of front, back or neck labelling options exists. However, stretch sleeving can be carried out at higher speeds than shrink sleeving – although it is far more limited in applications. Costs are lower than shrink sleeving.

Today, stretch sleeving is primarily used for large size bottles for carbonated soft drinks (CSDs). The expansion of carbon dioxide (CO_2) inside the bottle is accommodated by the stretch label. Stretch sleeving is generally seen as more relevant where easy removal of body labels on returnable bottles is required. If returnability is a key criterion, then the option of stretch sleeving may have higher priority.

Roll-fed stretch sleeves also work well with straight-sided single-serve bottles and are often used with PET bottles in pints or other sizes.

Despite its limited applications, an advantage of stretch sleeving is that the elasticity of the material obviates the need for heat-shrink tunnels in the production line.

4.2.6 Wrap-around film labels

A relatively new variant of wrap-around glue-applied paper labelling, wrap-around film labelling, was developed to allow the labelling of PET bottles and beverage cans with reel-fed, tear-proof plastic film labels. The labels can be reverse-side printed to provide a non-scuff, scratch-resistant print quality.

4.2.6.1 Wrap-around label films

These are plain coated BOPP films. Plain uncoated films come in thicknesses from 19 to 50 microns, while coated films range from 30 to 70 microns. Super-white BOPP films are made with a cavitated core and specially developed outer layers which provide a bright-white high-gloss finish. Metallised BOPP films have a vacuum-deposited aluminium layer on one side and an acrylic coating on the other.

4.2.6.2 Wrap-around film label application

Wrap-around film labelling machines incorporate a label feed system with computer-cut control, rotary cutting, gluing station and a mechanically assisted vacuum gripper for transfer of labels to the container. Large capacity reels minimise the operator workload.

In operation, glue is applied onto the leading edge of the film via mechanically driven rollers. The film is cut to length and wrapped around the bottle or can and then glued on the trailing (overlap) edge to form a complete wrap. Glass, plastic and metal containers – square, cylindrical or oval – can be handled. Label application speeds up to 800 bottles a minute are achievable when using 2-applicator stations.

A new variant allows wrap-around labelling of returnable PET bottles with very thin plastic film labels. A small amount of a casein-based adhesive is applied to the bottle for label pickup. This cold glue crystallises after curing, which facilitates subsequent label removal from the returned PET bottle. The lap overlap is sealed with hot-melt adhesive. Label removal is carried out using a de-labelling machine, which cuts the label vertically with a knife. The label can then be flushed from the bottle using a high-pressure water jet.

The wrap-around reel-fed labelling system is primarily designed for the wrap-around body labelling of straight-sided bottles or cans. It is possible to apply a wrap-around label to a slightly contoured bottle or jar but it is not possible, using standard equipment, to apply a neck label to a bottle with a tapered neck. However, this can be achieved with a combination applicator line that can apply a wrap-around body label and a separate wet-glue or pressure-sensitive neck label on the same line.

As far as cans are concerned, wrap-around film labelling provides a number of advantages over the use of pre-printed cans, including reduced can inventory, reduced lead times, greater flexibility for sales/marketing activities (special offers, proof-of-purchase promotions, etc.).

With the addition of a second carousel in the labelling system, it is also possible to positively shrink the label film to fit contoured cans or bottles. Label technology for wrapping-around or rolling-on film from reels, followed by a light shrink, may also be referred to as ROSO labelling.

4.2.7 Other labelling techniques

A fairly recent development is the use of a printed paperboard wrap-around label on a tapered plastic pot for single portion desserts. The label is held in place by the plastic rim of the pot, though the label has a glued side seam. It enables easy separation of the plastic pot from the label for recycling purposes.

4.3 Label adhesives

The vast majority of labels require an adhesive to bond the label to the container, or to some other surface. Being between the label material and the container or product surface, the adhesive must be compatible with both. If all the variations of label substrate (paper, paper-backed foils, metallised materials and plastics) and container/surface type (metal cans, glass bottles, plastic bottles, wrapping films, corrugated cases, etc.) are incorporated into the adhesive requirements, the challenges for adhesive manufacturers are quite formidable.

In addition, there are many different types of plastic containers (PE, PP, PET, etc.), different metal container types – some with special coatings and varnishes – and glass bottles that also have a variety of coatings to increase surface strength and minimise breakage. There are also certain performance criteria that have to be incorporated into adhesives, from cold-temperature application, wet-bottle application, food contact, removability, immersion in water, repulpability, recyclability and more. Consequently, adhesives are custom designed to meet all the required label types (wet-glue, self-adhesive, gummed), the required surfaces to be bonded and the necessary performance characteristics.

4.3.1 Adhesive types

To meet the demands of different label types, different surfaces to be bonded, and different user-performance characteristics, labelling technology uses four main types of adhesive – hot-melt, water-based, solvent-based and curable adhesive systems.

4.3.1.1 Hot-melt adhesives

These are thermoplastic materials with 100% solids that are heated to temperatures above their melting point and applied to substrates in the molten state. Unlike water-based or solvent-based adhesives, hot-melt adhesives do not require drying. They have a high initial tack and set as quickly as they can cool down to their solidification temperature, which makes them ideal for picking up labels in high-speed labelling lines. They are popular because of their high setting speed and because they form a virtually invisible line on glass, metal, PET and other plastic containers.

Key criteria in the use of hot-melt adhesives are temperature – which controls viscosity – and adhesive film thickness, which affects speed of setting, tack and open time. The thicker the adhesive applied, the longer it will take to set.

4.3.1.2 Water-based adhesives

They have had a dominant place in the label industry for many years and are used in wet-glue, self-adhesive and gummed paper formulations. They are made up of materials or compounds that can be dissolved or dispersed in water to become tacky and form a bond and they dry by losing water through evaporation or by penetration into the label substrate. At least one surface must be absorbent or porous to form a strong bond.

Water-based adhesives are available in a variety of chemistries and compositions, and are categorised as either natural or synthetic polymers, as follows:

Synthetic polymers	Natural polymers
Polyvinyl acetate (PVA)	Casein
Acrylics	Dextrine/starch
Polychloroprene	Natural rubber latex
Polyurethane dispersions	

Key points relating to some of these water-based adhesives are as below:

- Dextrine/starch-based adhesives were one of the first ready-to-use label adhesives. Made up from water-soluble natural polymers, they are used either cold or warm, depending on application. Resin/dextrine adhesives are used for the labelling of some types of coated glass and plastic containers.
- Casein adhesives are some of the best-known adhesive types for wet-glue labelling. Fast drying, they adhere well to cold, wet bottles, yet can be easily removed in caustic cleaning solutions when used for labelling returnable bottles.
- Water-based acrylic adhesives are usually used in self-adhesive applications where, unlike organic-solvent-based adhesives, their flame-spread resistance is an advantage. They are used in many UL applications. (Underwriters Laboratories (UL) is an independent not-for-profit product testing and certification organisation which helps manufacturers to achieve global product acceptance.)
- Polychloroprene – used for some self-adhesive applications – was developed as a substitute for natural rubber and offers a unique combination of adhesive properties:
  - outstanding toughness
  - chemical resistance
  - weathering resistance
  - heat resistance
  - oil and chemical resistance.

4.3.1.3 Solvent-based adhesives

These are noted for their fast bond strength development, good heat resistance, adhesion to a wide range of substrates and tolerance to a wide variety of production conditions – including low temperatures and high humidity. However, organic-solvent-based pressure-sensitive formulations have been widely displaced by water-based and hot-melt systems for economic as well as ecological reasons. Solvent recovery and/or incineration is now essential to meet clean air legislation requirements. This is expensive and can only be justified for large output operations.

4.3.1.4 Curable adhesives

Those that use UV or electron-beam systems to ‘cure’ or set the adhesive are a relatively new development and are used in some speciality tape applications and have also found some (limited) application in the self-adhesive label sector. Curable adhesives are cross-linked during the curing process.

4.3.2 Label adhesive performance

Label adhesives are a key element in the label application process and have to perform as required on the labelling line and throughout all handling, shipping and end-use stages.

Important features of a label adhesive are as follows:

- It must 'wet' the label surface, i.e. flow out onto the label substrate to which it is applied. It must not reticulate.
- It must have a good 'initial tack' as the label is applied to the container or product surface.
- The initial bond must be maintained, as applied, until the adhesive is fully set, and there must be no 'edge lifting' or blistering.
- It must meet any required end-usage performance criteria – food contact, chemical or product resistance, water resistance, heat or cold storage, etc.

With the wide range and variety of end-use and performance requirements of self-adhesive labels, there are, of necessity, also a wide range of special adhesive performance needs which include:

- *Semi-permanent adhesives* which remain removable and re-positionable for some time after application before fully becoming permanent. Often used for labelling high-value items.
- *Removable adhesives* have low tack and peel values to avoid damage to labels or goods when the labels are removed. The removal must be accomplished without leaving any adhesive residue behind.
- *Filmic adhesive grades* can be permanent, semi-permanent or removable and are used specifically with synthetic film labelstocks.
- *Freezer-grade adhesives* are permanent adhesives that stand up to the full range of temperature extremes found in cold storage and freezer chest applications.
- *Repulpable adhesives* are specifically designed so as not to interfere with the paper repulping process used during the recycling of paper materials. A major requirement of such adhesives is that they must not produce 'stickies' in the pulp-filtration process.
- *Permanent adhesives* need to bond quickly to the surface of the paper and paperboard to which they are applied and also have an instant fibre-tearing bond. Permanent adhesives are also used with fragile substrates to provide tamper-evident label properties.
- *UV-curable adhesives* have been developed to stand up to the toughest challenges and provide outstanding heat, plasticiser and chemical resistance.

As far as wet-glue label adhesives are concerned, there are three main adhesive groups:

1. *Glass-container label adhesives* are water-based casein, non-casein, synthetic or resin-based adhesives which offer high performance, superior water resistance, moisture and ice resistance throughout the label application, bottle line handling and conveying, palletising, shipping and end-use stages. If labels need to be removed after use then a non-water resistant adhesive is used.
2. *Rigid plastic-container label adhesives* are designed to provide good wet tack and adhesion when labelling at high speeds.

3. *Metal-container label adhesives* are hot-melt adhesives developed specially for the labelling of cans and offer hot pickup for roll-through labelling equipment and good hot-melt adhesive performance in rotary labelling equipment.

4.4 Factors in the selection of labels

Each label technology or label type has its own advantages and disadvantages in the provision of label solutions for different applications. Factors to be considered when selecting a label type include:

- cost of label material (non-adhesive or pre-adhesive, opaque or clear, metallised, etc.)
- cost of printing and converting (number of colours, in-line options, sheet or web printed)
- visual appearance and image (paper, film, design capabilities, aesthetic appeal, premium quality, tactile ‘feel’, no-label look)
- durability (resistance to scuffing, scratching or image deterioration)
- production flexibility (ease and speed of label line changeover)
- environmental considerations (recyclability, returnability, waste disposal)
- volumes required (short, medium or long runs)
- speed of application (high-speeds required?)
- capital investment of label line equipment (wet-glue high; self-adhesive lower)
- running cost/hourly rate of label line (operator and machine)
- down-time (set-up, clean-up, removal of misapplied labels)
- performance needs of labels (chemical or water resistance, labels for autoclaving or sterilising, wet-strength, high or low temperature usage or application)
- information needs on label (reverse-side printed, leaflet or booklet label)
- security features (tamper-evidence, anti-theft, brand protection, hologram).

Rather than looking at any one or more criteria in isolation when selecting a label type, it is more usual today to look at the chosen solution or possible solutions in terms of total applied label cost. This is the end-of-line cost of labelling a bottle, jar, can or other type of pack. It comprises both the cost of the application technology, including investment, to achieve the desired application speed and the cost of the materials used. The materials used mainly comprise the label which must meet the needs of appearance and performance at every stage from application to end-use. The label cost will depend on the cost of the plain label material together with the costs of printing and conversion. In many cases, it will be found that there is more than one labelling solution for any one particular application.

4.5 Nature and function of labels

Many packages and containers carry more than one label. Some unit containers have two, three or more labels, each with its own specific brand or informational purpose while transit and distribution packaging may carry more functional types of labels for addressing, tracking and tracing or security purposes. Some of the key roles and functions of labels are set out below.

4.5.1 Primary labels

These are designed to carry the product's brand name or image identification that will attract attention on the retail shelves and appeal to prospective buyers. The labels usually promote a specific logo or brand name, incorporate special brand or house colours and may carry a picture, drawing or representation (which generally may not hide, obscure or interrupt other matter appearing on the label). For some applications, the primary face label may be reverse side printed with secondary information. Used with clear liquids and clear bottles (glass or plastics), the information is read from the back of the container, through the container and contents, thus eliminating a separate secondary label.

4.5.2 Secondary labels

Secondary labels are usually smaller and are used to carry information such as a list of ingredients, health or safety requirements, nutritional details, instructions for use, EAN (European Article Numbering) Code, warnings, manufacturer or supplier name and address or registered office of the manufacturer or packer, prices, volume, weight or quantity and possibly promotional or special offer deals. If appropriate, the label may also contain any special storage conditions or conditions of use, and particulars of the place or origin.

Information contained on primary and secondary labels is normally required to be clear, legible and indelible, readily discernible and easy to understand, and is likely to have to conform to one or more of the regulations, standards or legislations that relate to labels and to labelling.

With one-piece wrap-around can and bottle labels, the primary and secondary elements are all incorporated into one label, rather than being two separate labels.

4.5.3 Logistics labels

While primary and secondary labels are found on unit packs – the individual bottles, cans or packs – there is a need for labels on transit packages that are used to distribute goods and track and trace their movement in the supply chain to ensure they reach the correct delivery address. These logistics labels are frequently printed with computer-generated graphics, variable text and unique numerical or bar code symbols using thermal, laser or inkjet imprintable labels.

Logistics, bar code and variable information printed labels are predominantly printed in one colour (black) only, often during the transit packaging, palletising or warehouse/distribution chain stages; and applied to cartons, trays, boxes, cases and pallet loads prior to shipment. Print and apply label equipment is commonly used for these applications, with the variable information entered through a keyboard or keypad.

More recently, major developments have been taking place in what are called smart, intelligent or chip labels which are finding applications in the logistics chain for identification, traceability, track-and-trace and smart logistics applications. Many of these new label solutions are based on smart label RFID (Radio Frequency Identification) technology where the label/tag costs less than one dollar. Most smart labels are in the form of very thin labels or laminates to get the price down and to make them suitable for targeted applications, which are, in the main, new ones where the label must usually be disposable.

Smart (RFID) labels in the logistics chain are used to:

- implement a step change into the supply-chain operation
- provide full visibility of the stock in the supply chain
- automate the processes associated with the management of stock.

The full implementation of RFID technology has been slow because: the (still) relatively high cost of the labels/tags, the need to develop standards, there is no one company that can manage large-scale implementation, and the economies of scale are not yet available.

4.5.4 Special application or purpose labels

In recent years, an increasing need has arisen for additional product or pack labels that are used to provide unique brand protection, and the prevention of retail theft, tamper-evident or promotional solutions.

The range and variety of 'security' labels and solutions available to brand owners and end-users now includes:

- security papers and films for labels with special fibres, coatings, planchettes, threads, watermarks, etc.
- special security inks for labels from which the print cannot be erased or which may have to be fluorescent, indelible, infrared, luminescent, magnetic, photochromic, water-fugitive, thermo-chromic or optically variable
- security-label design systems incorporating guilloches, fractals, special rasters, microtext, curved distortion to scrambled indicia, anti-colour photocopy features from special coated papers, void materials, reactive imaging, etc.
- optically variable devices (OVDs) ranging through chromograms, colourgrams, micrograms, destruct foils, hologram materials, micro-embossed films, etc.

Note: Guilloches are printed security lines, the layout of the intersections and geometry is unique. Copying is inhibited by the layout arrangement of thin lines, rainbow print and the exact colour calibration. Indicia are distinct marks, signs or symbols – they are especially relevant to corporate or brand identity, and they are also used for postal-address identification.

The choice of security device(s) to be incorporated into brand protection, anti-counterfeiting or authentication labels will depend on level of security, cost, process, application method and effectiveness.

Such special labels may require purpose-built presses or converting lines incorporating silicone or adhesive pattern printing and folding units as well as special units to combine the label with the product, by either application or insertion.

Leaflet and book labels with multiple pages are used in the labelling of chemicals or agro-chemicals, for some DIY products and on computer software packs. Variations may also be found in promotional applications. Tactile warning labels for packaging of products for the blind are another special type of label.

Form and label combinations – where one or more self-adhesive labels are found on a form – are used in distribution applications. One pass through a computer printer provides both the paperwork and labels that can be peeled off for pack/distribution labelling, order picking or job/production identification purposes.

Other specific label types include labels used to produce a collar or neck label. These may be pre-formed, slipped on and then locked, rather than glued in place. Tie on labels, tags or swing tickets may be used in the packaging/labelling of luxury items.

4.5.5 Functional labels

On-occasion labels may also be used during a packaging, processing or end-usage operation, for example to indicate successful sterilisation or autoclaving by colour change or provide evidence of significant adverse temperature change. Others may be used to provide a tamper-evident or security seal (Fig. 4.3), or can be peeled off and re-placed to provide a re-closure device.

Labelling/packing lines may incorporate systems for applying a carry-home strip or label which can be applied to one or two bottles of lemonade or mineral water.

4.5.6 Recent developments

Over the past few years, ‘no-label’ look film labels, with matt or gloss surfaces, have become popular and part of the lexicon of labelling. Marketeers see these labels in

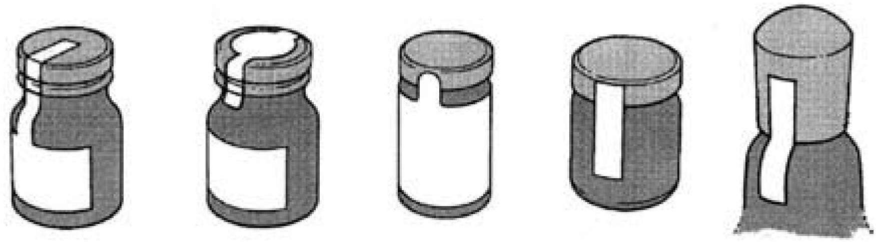

Figure 4.3 Types of tamper evident security labels. *Source*: Labels & Labelling Consultancy.

image-enhancing terms to encourage people to buy expensive products in glass or plastic containers (hair-care products, cosmetics, near-beer drinks). This type of labelling competes with direct decoration because it achieves similar graphic effects.

Glass-clear labels and adhesives are also used in pharmaceutical labelling where glass vials have to be visually checked for contamination of the contents before use. Any particle or bubble in the adhesive could be mistaken for contamination of the contents and could lead to unnecessary rejection of the vial.

Furthermore, clear-on-clear labels eliminate pre-printing of containers for stock, offering bottle or brand owners logistics flexibility in terms of total inventories and sizes of containers. Coloured containers can also be used, with the clear label allowing the colour to show through, rather than having to match the container colour with printing ink.

Another more recent labelling development is the use of OVDs and diffractive optically variable image devices (DOVIDs), generically called holograms, which have gained considerable prominence in the fight against counterfeiting. They cannot effectively be reproduced by colour copiers or scanners, or by conventional photographic and printing processes. They are versatile enough today to be bonded to labels, tags and textiles, providing complex 3D structures which provide anti-counterfeit, tamper-evident, plain, numbered or other imaging solutions.

4.6 Label printing and production

The printing and production of labels is undertaken on a wide variety of presses – from sheet-fed to web-fed – and using almost every available printing process. The type of press or process used is determined by:

- the specific label or printing requirement
- the availability and quantity of labels
- the nature and quality of the printing
- the number of colours
- whether subsequent converting operations (die-cutting, embossing, metallic foiling, laminating, waste stripping, etc.) are carried out in-line on the press or are separate stand-alone operations
- how the labels are to be shipped to the packaging or bottling line (in slit reels, cut to size or punched to shape in stacks).

Apart from the mechanical-printing processes used to produce pre-printed labels – rotary and semi-rotary letterpress, flexo and UV-flexo, screen process, offset litho, gravure, hot or cold foiling – there are a range of on-demand, VIP solutions used by the label industry. These include thermal printing, laser and ink-jet printing and, more recently, complete digital colour printing presses.

The mechanical-label printing processes can be categorised by the way in which the area of the printing plate or cylinder that carries the printing ink (the image carrier) is defined when compared to the non-printing area. Printing plates and cylinders that print from a raised, inked surface are known as relief printing processes. These include letterpress and flexographic printing.

Printing processes that carry the printing ink in a recessed pattern of etched or engraved cells are known as intaglio printing. These include gravure and rotogravure. A printing process that prints from a flat, chemically defined, printing plate is known as planographic printing. The most commonly used planographic printing process used for labels is offset litho.

Each of these mechanical printing processes has undergone developments in recent years which have led to better quality, colour and speeds. As such there is no 'best process'. Each of them is capable of high quality printing at economic speeds, and each can impart a quality or characteristic to the overall design and image of the finished label. These characteristics include such things as evenness or brightness of colours, thickness of the ink film, fineness of reproduction, quality of halftones, the texture and feel of the label, etc. Some can also impart a range of special effects such as impregnated inks, which can be used with perfumes, fruit flavours or other aromas, rub-off or scratch-off inks, colour or temperature change inks. Raised tactile images, for example braille characters, can be printed to provide product information, including the warning of hazardous contents, for the blind and partially sighted.

An important market need which none of these mechanical printing processes can handle in a commercially viable way is that of printing variable information. Examples of such information include bar codes, batch and date codes, sequential numbers, price and/or weight information and print runs of short length, i.e. where the time to print is short compared with the time to set up the press. To meet these requirements a number of methods of electronically printing variable images or short runs have been developed. Some can be run in line with fixed-image mechanical presses, some are stand-alone machines and some are meant for adding variable information off-line.

Most recently, digital printing technology – in which the image is defined or created by computer – has begun to find a place in the label printing industry for full-colour and spot-colour short-run printing of labels. By the end of 2002, there were some 200 digital presses in label plants worldwide.

A brief guide to each of the key mechanical, variable information and digital label printing processes and techniques is set out below.

4.6.1 Letterpress printing

Letterpress printing was the earliest method used to print labels back in the eighteenth and nineteenth centuries, and is still a key technology in the printing of quality prime and secondary self-adhesive labels today.

Modern letterpress printing (Fig. 4.4) uses photosensitive polymer plates onto which an image (ink-carrying area) is produced by photographic or direct-imaging plate-making techniques. After exposure, the plate can be treated in a special wash-out solution (chemical or water-based) to develop the image and non-image

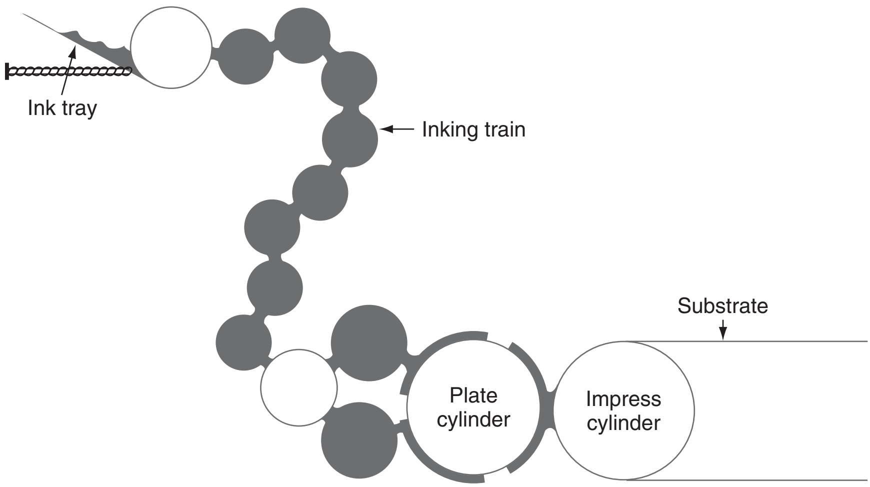

Figure 4.4 Letterpress printing process. *Source*: Labels & Labelling Consultancy.

areas of the printing surface. The relief image area plate can then be affixed around a printing cylinder and placed in the printing press. During the printing cycle, the raised surface is rolled with a sticky ink and the inked image then transferred to the label substrate under pressure.

Letterpress printing roll-label presses, primarily used for self-adhesive label production, are narrow-web (200 mm, 250 mm, 360 mm, 400 mm or 450 mm) machines and are either web-fed semi-rotary, intermittent-feed, machines or web-fed full rotary printing presses – both of which can include up to six, eight or more printing units, together with all the necessary reel unwind, die-cutting, waste-stripping and rewinding capabilities. Almost all are utilising UV-curing inks which have the advantage of being fully dried on the press, thereby reducing lead times and allowing subsequent in-line finishing operations, such as lamination and embossing, to be carried out immediately. UV inks also have excellent resistance to rubbing and are chemically resistant to a wide range of products.

In intermittent-feed roll-label presses the web of labelstock is progressively and intermittently advanced to the printing position, printed and then moved on for die-cutting and waste-stripping operations. The presses are slower than full rotary presses but do offer advantages for short (10 000 or so labels) to medium (25 000–50 000) label runs where they can provide press flexibility and quick changeover capabilities and, due to the variable feed length that can be selected on an intermittent feed system there are no costly changes involved in changing cylinders, gears, etc.

Rotary letterpress in-line, common impression drum (Fig. 4.5) or stack roll-label presses (Fig. 4.6), started to be installed in label printing and converting plants in the late 1970s, and by the mid-1980s made up almost 70% of all new roll-label presses being installed in Europe. Even today, in spite of the rapid growth of

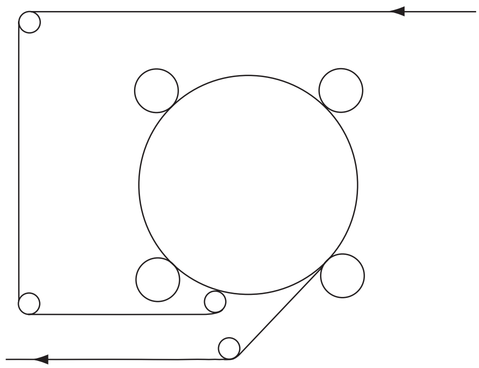

Figure 4.5 Diagram of a common impression drum label press. *Source*: Labels & Labelling Consultancy.

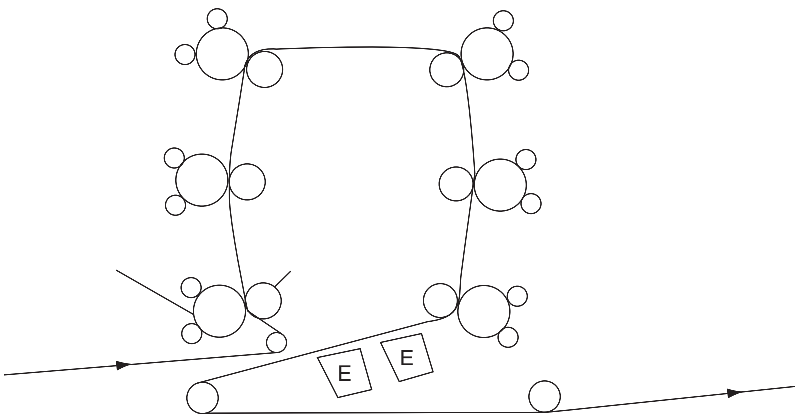

Figure 4.6 Diagram of a stack label press. *Source*: Labels & Labelling Consultancy.

flexographic label printing, rotary letterpress still has around half of the total installed presses in Europe; much less in North America.

Compared with intermittent-feed letterpress machines, rotary letterpress offers significant market advantage in that they can produce up to three times or more output – and all to a high quality, consistent result with, probably, less dependence upon operator skills than is required by other printing processes. Rotary roll-label presses may have an in-line printing head configuration, or the print heads may be placed around a common impression drum or arranged in a satellite or stack pattern.

4.6.2 Flexography

Like letterpress, flexography is a relief printing process (Fig. 4.7) in which ink is applied only to the raised surface of the image on the printing plate and, transferred

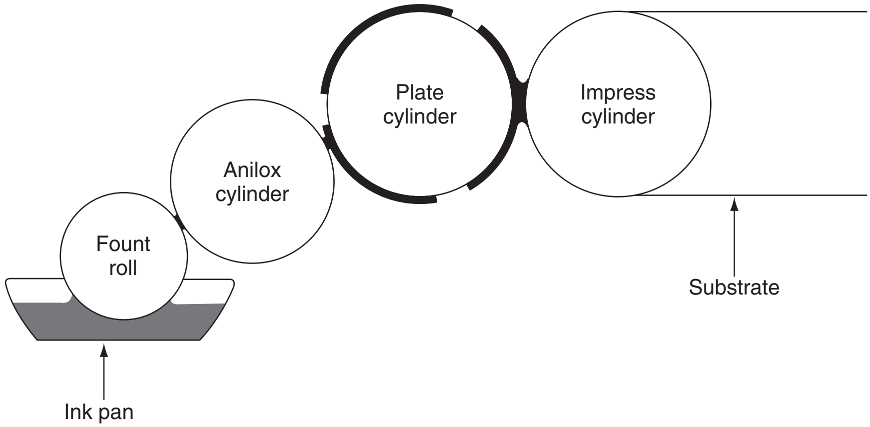

Figure 4.7 Flexographic printing process. *Source*: Labels & Labelling Consultancy.

from there, to the surface of the label substrate. The key differences between letterpress and flexographic printing lie in the method of metering and applying the ink to the raised surface, and to the plate itself.

Narrow-web flexographic printing is the most widely used label printing process worldwide for the production of self-adhesive labels. In the USA, it makes up more than 90% of the installed press base, and around 40–50% of the installed base in Europe. It is used for the production of almost all types of labels available today and has become increasingly accepted for the production of higher quality prime labels, particularly with digital plate imaging and the latest UV-curing flexographic press technology. Like rotary letterpress, there are three basic types of flexographic press configuration: in-line, common impression drum and stack. Any of these configurations may be used for printing a wide range of materials.

Printing plates for flexographic printing may be made from a softer, more resilient rubber or flexible photopolymer plate material than letterpress, though similar exposure and wash-out stages to that of letterpress plates are required. However, rather than the thicker, sticky ink used for letterpress printing, the flexographic process uses a very thin solvent (declining) or water-based (growing) ink. The thin ink requires a special type of ink metering system which uses an engraved anilox roll containing thousands of tiny recessed cells – which carry the ink – and a doctor roll or blade which removes excess ink from the anilox roll surface. The degree of fineness and the shape of the cells can be changed depending on the effect required.

The last print station on a flexographic label press is frequently used for applying a varnish so as to provide additional scuff, rub and chemical resistance. For self-adhesive-label printing flexographic presses also incorporate a die-cutting station (with flexible dies on a magnetic carrier or a full rotary cylinder), matrix waste removal, slitting units and a re-winder.

Quality of origination, pre-press, press maintenance and good press fingerprinting are important factors in the production of good quality flexographic printed labels.

It is essential to get everything correct at the beginning, as it is not easy to make modifications on the run.

In recent years, UV-flexographic label printing has gained ground to successfully compete with UV-letterpress label production for multi-colour and half-tone work and, with the latest origination (which is closer to that used for letterpress and offset litho) and direct-to-plate imaging technology, is now claimed by the best flexographic printers to come close to offset litho quality. As such, the process has become widely accepted for the printing of food, supermarket, retail and other process colour labels.

Apart from narrow-web flexographic presses used for self-adhesive label production, the process is used in wide-web formats (500 mm, 600 mm wide and upwards) for the printing of some sleeve labels and wrap-around film labels, as well as for cartons.

4.6.3 Lithography

Lithography, mostly referred to as offset lithography or simply as offset, is the most commonly used printing process for the printing of glue-applied paper labels using a wide variety of sheet-fed presses. More recently, offset is also being used in roll-fed press formats for high quality self-adhesive label production and in both sheet-fed and roll-fed versions for in-mould label production and for some new developments in cut-and-stack and patch film labels.

Offset lithography is a high quality planographic process (Fig. 4.8) in which the image and non-image areas of the printing plates are on the same plane (flat) surface but are differentiated chemically in a way in which the image areas are

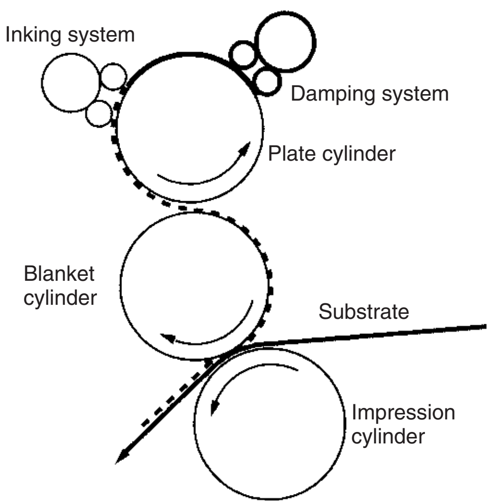

Figure 4.8 Offset lithographic printing process. (Reproduction, with permission, from Iggesund Paperboard.)

made ink receptive and water repellent, while the non-image areas are water receptive and ink repellent.

Plate-making is relatively simple. Thin sheets of a grained and light-sensitive coated (aluminium) plate are exposed through a negative or positive film – or by computer imaging – to create the image and non-image areas, and then treated chemically to aid ink or water receptivity as required.

Once mounted on the plate cylinder in the press (whether sheet-fed or roll-fed), the plate is repeatedly contacted after each print with damping and inking rollers; damping, which is mostly water, to the non-image areas, and the ink to the image areas. UV-cured inks are widely used and many labels are UV varnished in-line wet-on-wet on the printing press.

For self-adhesive label production, web-fed in-line offset presses will also incorporate multiple print heads, die-cutting, waste stripping and rewinding in one pass. More commonly in self-adhesive label production, offset litho print heads are used in combination with another process, i.e. screen, hot stamping or UV flexo varnish, for high added-value applications in, say, the cosmetics or wine-labelling sectors.

In the last few years, a new generation of mid-web (400–600 mm wide) roll-label offset presses have been developed to target the more efficient, higher added-value in-line printing and converting of traditional sheet-fed glue-applied labels for the wines and spirits markets.

4.6.4 Gravure

Gravure, or photogravure, is a true photographic process which is able to reproduce high quality pictures, excellent colour densities and strong solid areas. It is primarily used as a long-run process for wet-glue applied labels and for flexible packaging. Now, gravure units are also being incorporated into narrow and mid-web presses for labels and flexible packaging where the ability of gravure to apply varnishes, lacquers, metallic inks and top coatings is a particular advantage.

The image carriers for gravure primarily consist of steel cylinders with an outer shell of copper onto which images – consisting of millions of tiny cells of varying depths and areas – are produced by chemical etching, laser etching or electromechanical engraving. Although the most expensive of all the image carriers used for printing labels, they have the advantage of being able to print very long runs in millions. For additional run life, the cylinders can be chromium plated.

Gravure printing presses are the simplest of all label-printing presses (Fig. 4.9). The printing cylinder containing the cells rotates in a thin, fluid, solvent or water-based ink which fills the recesses. Surplus ink is scrapped from the cylinder surface by a flexible doctor blade, the ink in the cells (the image) then transferring to the label substrate using pressure against a rubber-covered impression cylinder.

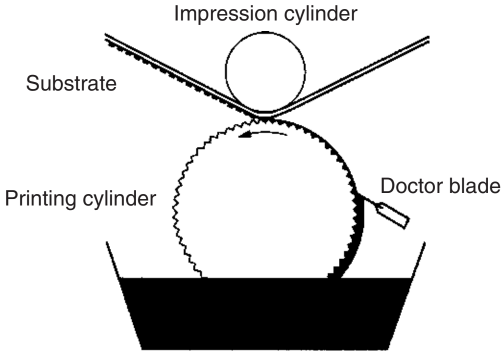

Figure 4.9 Gravure printing process. (Reproduction, with permission, from Iggesund Paperboard.)

4.6.5 Screen process

One of the oldest methods of printing, screen process (silk-screen, Figure 4.10) is mainly used for the production of self-adhesive labels for cosmetics and toiletries, pharmaceutical and industrial and outdoor applications. Most frequently found in combination in a press line with letterpress, UV flexo or offset, the screen process has the ability to print a smooth, controllable lay-down of ink and to provide durable, high quality labels where good ink coverage is required for resistance to weather, moisture, chemicals and abrasion. It can also print a good opaque white image, something which other label printing processes find it difficult to achieve.

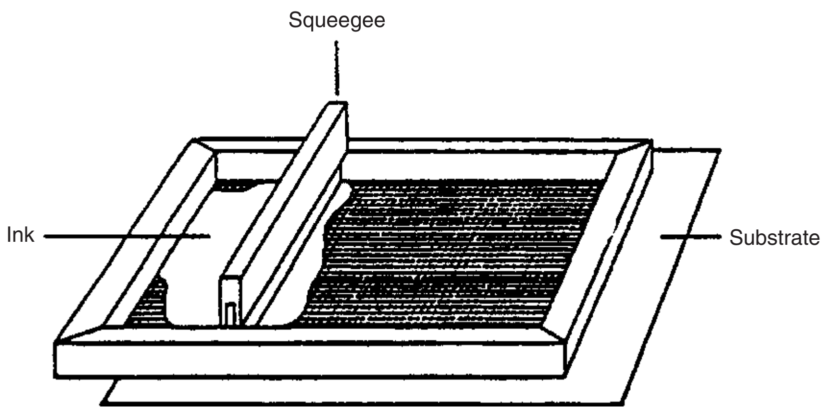

Figure 4.10 Silk screen printing process. (Reproduction, with permission, from The Institute of Packaging.)

The image carrier for screen printing is most often made from a nylon, polyester or fine wire mesh onto which a photo-sensitive coating has been placed. Exposure to light through a film positive of the label image causes the coating to harden in the non-image areas enabling the unexposed (unhardened) areas to be washed away. This leaves a negative image of the label remaining on the screen mesh.

For printing, the screen is mounted on a frame and placed in position on the screen printing and die-cutting press. Ink is pressed through the open areas of the mesh by a blade called a ‘squeegee’ to produce a print on the label substrate – which in the screen process can be virtually any material. Ink drying today is mainly undertaken by UV curing.

Screen printing lays down a very thick film of ink and is the only process that allows a light colour to be printed over a dark material with satisfactory results. Very high quality work is possible and fine line or tonal work can be produced with equal success. This process is ideal for achieving visual impact with fluorescent inks and for printing raised tactile characters (braille).

Screen presses used for self-adhesive label production either use a flat-screen in a stop-and-go motion, or use rotary screens in which the squeegee is mounted inside the cylinder. Flat screen printing is a relatively slow process as it requires the web being printed to come to a stop for each print cycle. Although the rather slow, flat style of printing unit gained partial acceptance with label printers, the move towards building presses in which a combination of printing processes, including screen, demanded something more – rotary screen, which is faster and has a continuous motion.

The rotary method of screen printing has been used, for many years, for the printing of fabrics and wallpaper and this technology was developed to create narrow-web rotary screen units that could be interfaced with, say, letterpress, flexographic, offset or, today, even gravure units for high quality and special effect multi-process printed self-adhesive labels. In the rotary format, both the mesh carrying the photographic image and the label substrate come together as cylinders, which reduces the possible area of contact and sharpens up the image being printed. The supply of ink is retained inside the rotary screen and the squeegee is also located inside the cylinder.

Rotary screen or screen combination narrow-web presses make up around 10–15% of all narrow-web roll-label presses installed each year.

4.6.6 Hot foil blocking/stamping process

Foil blocking is being used more and more as either the sole printing process or as a process incorporated alongside letterpress, flexographic or offset printing in a combination process press, in order to add an extra added-value capability to the printed label. It is a dry printing process, using no inks and involving no colour mixing or matching. The process can print on a wide range of surfaces and produce bright effects from metallics, or high opacity colours and uses relatively simple equipment. Hot-foil printing presses may be narrow-web, web-fed machines, such as those used for self-adhesive label production, or larger sheet-fed presses used for foil blocking of large sheets of glue-applied or in-mould labels.

Units designed for the hot-foil printing or decoration of labels come in a variety of configurations and widths, and can be in the form of a stand-alone press or, in the case of some narrow-web self-adhesive label presses in combination in-line with other printing processes, provided the press is fitted with a suitable drive and registration system.

The printing plate used for hot foil blocking needs to be of a hard material and to have a raised image similar to that used by the letterpress process. The fact that image transfer relies upon both heat and pressure restricts plate materials to either a very hard thermoformed plastic plate for very short runs or plates produced from brass, steel or zinc for longer runs. While rotary foil blocking has gained some ground, the majority of hot foil blocking for label printing is performed in the flatbed format.

The actual hot-foil printing process is achieved by transferring either a coloured pigment or a metallic coating from a ribbon of plastic material known as the 'carrier' onto the surface of the label material to be printed. This transfer is performed through the application of heat and pressure, and the length of time the heated coating area is in contact with the substrate is known as the 'dwell time'. The balance and control of these elements is critical and must be individually calculated for the surface to be printed, and the type of ribbon or foil being used.

A more recent development of foil blocking is a cold-foil process in which a print unit is used to print a special adhesive on the label web in the area where the metallic effect is required. When foil is brought into contact with the adhesive, it adheres to it to produce the printed foil design on the label. Cold foiling is a less expensive means of achieving foiling than the hot process.

Once printed, the surface of hot or cold foil images may be varnished, overlaminated or encapsulated in order to provide a hard-wearing, durable surface. Foiling is used to provide a luxury (metallic) look on many cosmetics, toiletries, health and beauty labels, on wines and spirits labels, and in other higher added-value label applications.

4.6.7 Variable information printing, electronically originated

The one aspect that none of the conventional mechanical label printing presses can handle economically is the printing of variable text or images that include bar codes, sequential numbers, batch and date codes, price-weight information, lot numbers, names, mailing addresses, etc. To perform these functions using letterpress, flexography, litho, gravure or screen presses would involve stopping the press after each print, changing all or part of the printing plate, then printing the new image. An expensive and time-consuming operation.

To overcome these limitations, a number of methods of electronically producing VIP have been developed. These methods include ion deposition, laser printing, direct thermal, thermal transfer, dot matrix and ink jet. Some of these operate as stand-alone printers or presses, some run in-line with fixed image printing presses, or they are added on to some types of label application or print-and-apply systems. Brief descriptions of these VIP methods are described below.

4.6.7.1 Ion deposition

Ion deposition is an electronic printing system that uses an electrographic, non-impact imaging process in which a latent image is created on a sensitive drum by bombarding it with ions. Powder toner is applied to the latent image – the powder printed from the drum to the substrate using pressure, and then the drum cleaned ready to receive the next image. Ion deposition printing is capable of printing bar codes and other information onto substrates such as paper, boards, vinyl, polyester and other filmic materials at reasonably high speeds. It may need to be over-varnished or laminated to improve durability, rub or scuff resistance.

4.6.7.2 Laser printing

Like ion deposition, laser printing requires a latent image to be created on the surface of a sensitised drum (this time by light). Electronically charged particles of a powder toner are deposited on the image and the toner transferred to the substrate using heat and some pressure. Because of the heat involved in laser printing, there may be limitations on the label substrates that can be used. There are also the so-called ‘cold’ lasers or cool lasers which require less heat and can print on a wider range of materials.

4.6.7.3 Direct thermal printing

Direct thermal printing of labels is the main process used for adding price-weight information, product description and bar codes to supermarket fresh-produce labels – meat, fish, cheese, fruit, vegetables, etc. – which are weighed and priced on the pre-packaging and labelling line or, in some cases, printed and labelled in-store.

The print head for direct thermal printing consists of numerous styli (needles) in the form of a grid or matrix that are heated and cooled selectively by a micro-processor controller. A special heat-sensitive coated paper is required which, when heated by the styli, changes colour within the areas of contact to form the required letters, words, numbers or codes.

As the special thermally printable coating is heat-sensitive, direct thermal printing is primarily used for fresh and chill cabinet products that have a short shelf life in store of several days. It is not normally used for long shelf-life labelled products or for labelling for use in warm or hot conditions.

4.6.7.4 Thermal transfer printing

Thermal transfer printing also makes use of styli which are heated and cooled selectively. However, this time, rather than using a special thermally sensitive coated paper, the styli come into contact with a thin film one-pass ribbon which carries a heat-activateable ink or coating on the underside. The required image is therefore created by transferring the heat-activated ink coating from the film carrier to the substrate, according to the pattern or shape of the heated styli.

Thermal transfer printing is used for printing variable information, such as batch codes, date codes, sequential numbers, text, diagrams and bar codes onto pallet, carton or box end labels, for warehousing and distribution requirements, for bakery labels and for DIY and industrial labelling. Printers may be incorporated into packaging and/or weighing lines or be stand-alone. Some are also print-and-apply systems.

4.6.7.5 Dot matrix printers

Dot matrix label printing involves the firing of pins or hammers against an inked ribbon and thus transferring ink onto a label face material, rather like the early typewriter techniques. Each pin or hammer produces a fine dot and these can be positioned in a grid to produce letters, words, numbers, codes or simple graphics.

Impact printing systems such as dot matrix printers have applications for printing onto card or for form/label combinations where an image may need to be created through more than one layer of material. They are far less common today than in the past.

4.6.7.6 Ink jet printers

Ink jet printing uses minute jets of ink which are activated and fired at a label surface by means of electrical charges to form the desired image. Ink jet is a non-contact method of VIP.

The various ink jet-printer manufacturers use a variety of techniques to form the image. These include a single continuous jet, a multi-head jet, impulse jet and a system using solid ink which is converted to liquid at the moment of transfer.

Ink jet printing can operate at speeds which are compatible with presses, label applicator line or packaging line speeds and are therefore often used in in-line operations to produce batch or date codes, sequential codes, batch codes and product or delivery details.

4.6.8 Digital printing

The means to print labels digitally in four or more colours direct to paper or synthetic materials began to emerge in the early 1990s and has now become a label printing technology in its own right with around 200 digital label presses installed worldwide by the early part of 2003. These presses are predominantly dry toner (Xeikon) or liquid toner (HP Indigo) technologies. The first of a new generation of digital colour ink jet machines also began to be installed in the label industry during 2002/2003.

In the toner-based digital printing process, a latent image of one of the colour separations is created on a drum. That image is then developed for printing with the dry powder or liquid toner before being transferred to the label substrate as a printed image. Each colour is printed in turn. In the HP Indigo machine, each image is first transferred to a rubber blanket before printing from the blanket on to the substrate. It is therefore a digital offset printing process.

The most recent digital press innovation is that of colour ink jet using the Dotrix engine. The first of these presses has undergone beta testing and are now available for commercial label-printing purposes.

All these digital printing systems may be controlled from a computer keyboard with the copy and images to be printed having been prepared on a visual display unit (VDU) screen for accurate composition.

Whilst attracting considerable interest for short run, multicolour printing – with each print varying from the next if required – digital printing has had a number of limitations that are only now being addressed in the latest generations of digital presses. These limitations of the earlier digital machines included:

- difficulties in matching bright and special brand/house colours
- limitations in availability of substrates (especially of top-coated filmic substrates)
- poor performance in rub or scuff testing
- cost of labels
- press reliability/durability.

Against this, digital colour printing offers benefits to brand owners in terms of short-run proofing, extended proofing, test marketing and for product trialling. Potential additional benefits, yet to be fully exploited, include the ability to produce colour labels with special brand protection, anti-copy or anti-counterfeiting features on each label or batch.

Whilst the early generations of colour digital presses were cost-effective for very short runs of say 5000–10 000 labels, runs over this size could be produced more economically by short-run mechanical printing presses. The new generations of higher-speed, longer-run digital colour presses are claimed to be cost-effective for up to 30 000–50 000 labels.

4.7 Print finishing techniques

4.7.1 Lacquering

Lacquering is similar to applying a coating on a press, but carried out off-press on a machine equipped with a roller coater after the printed label sheets have dried. Coatings, which may be UV cured, may be used at varying thicknesses to suit the requirement or function of the label. Being a separate operation, lacquering increases the unit cost of the labels.

4.7.2 Bronzing

Bronzing is a means of creating a metallic appearance – usually gold – on wet-glued labels printed in sheets. A special adhesive or bronzing base is applied to the sheet in the areas to be bronzed, on a single colour, sheet-fed press. This machine incorporates an in-line bronzing application system which applies the bronze powder to the sheet. Special dusting devices distribute the powder evenly all over the sheet but it only adheres in the treated areas. The sheet is then cleaned to remove excess bronze powder and burnished to develop the bronze lustre. The process is relatively slow and expensive. It is primarily used to produce labels for high added-value products such as expensive wines and spirits and cosmetics.

4.7.3 Embossing

Embossing is undertaken between a male and female die. The female die is a depressed image, while the male die is prepared so as to push the label paper into the female embossing die to create a raised (embossed) area on the label design.

4.8 Label finishing

4.8.1 Introduction

Once printed, most labels have to be cut or punched to a specific size or shape as part of the label manufacturing process. Cutting, in particular, is one of the most important operations in the finishing of most labels and this may be carried out by straight cutting or by die-cutting. Other labels (leaflet or booklet labels) may have to be applied from a carrier web for subsequent automatic application, while some others may be bronzed, embossed or laminated. These operations are all part of the various label-finishing stages and techniques.

Wrap-around labels for cans, for example, are cut to a rectangular size on a guillotine so as to wrap around the body of the can; wine labels are cut to rectangular shapes to be applied to the front or back of glass bottles; beer-bottle front labels or champagne labels may be punch cut in oval or special shapes, while self-adhesive labels are mainly all die-cut to size and shape.

The methods and techniques required to produce finished labels ready for application to bottles, cans or packs are:

- guillotining to cut sizes
- punching
- die-cutting
- on-press slitting and sheeting (for some applications).

Special label-placement techniques may be used to apply the label to the container as well as techniques for folding, inserting or crimping.

Originally, labels were simple, mainly rectangles or squares, sometimes with rounded corners – followed later by circles and ovals. However, as the market developed further, the demand for unique shapes – which would aid recognition – increased and, with these new and challenging requirements, a whole new separate industry and technology servicing the label printer evolved.

A guide to some of the main label-finishing options is as follows.

4.8.2 Straight cutting

Many labels are printed in sheets on offset presses with, sometimes as many as, 100–150 labels on each sheet. These sheets of multiple labels must be straight cut, either for use as square or rectangular labels or before cutting out or punching to shape.

Straight cutting requires piles of up to one thousand printed and properly stacked label sheets to be fed into the back gauge of a guillotine, usually using air glides which float the paper into position. With the pile against one of the rigid sides of the guillotine the pile is positioned for the first cut. Once positioned, a clamp descends on the pile to hold it in position while the cut is made with a guillotine knife. The clamp then rises ready for the pile to be moved to the next cutting position. All subsequent cuts on modern guillotines are carried out using programmed gauges, with the back gauge moving automatically to the correct position for the next cut. Tolerances for straight label cutting are fairly critical.

4.8.3 Die-cutting

Shaped designs of self-adhesive labels and some wet-glue and in-mould labels have to be die-cut as part of their manufacturing and finishing procedure. Depending on the type of label and the printing and/or die-cutting requirement, the operation may be performed using high or hollow dies (ram punching), flat dies, rotary dies or, most recently, with digital die-cutting.

High or hollow dies used for ram punching glue-applied labels to shape are made of cold-rolled steel which is forged and welded to create the required shape and height. The inside of the dies are parallel for about 25 mm, after which they flare out. In use, the stack of labels is either stationary with the die moving or the die is stationary and the stack is pressed against it. In either case, sufficient space must be allowed between each label to ensure clean cutting. Sharpness of the die is critical, as are finished cut label tolerances.

Flat dies are most commonly produced by bending lengths of accurately fashioned steel rule which has been finished to a cutting bevel along one edge. This rule is around 0.4 mm in thickness and nominally 12 mm in height. To form a cutter, the rule, once bent to shape using a special bending tool, is placed in a base into which the shape or shapes of the label(s) have been cut. In this way, the rule is supported during use on the press and retains a high degree of accuracy.

Rotary dies are engraved by electronic discharge from a cylinder of solid steel so as to leave the cutting edge standing proud around the cylinder circumference. An alternative method is to use thin steel plates that have the die configuration etched over the surface. They are then mounted for use by wrapping the thin steel around a magnetic cylinder (Fig. 4.11).

Each of the types of rotary die requires some form of final finishing following on from the machining or etching, which is undertaken using computer-guided equipment and which sets the seal of quality on the die.

Digital die-cutting of labels is a relatively new development which has evolved from laser cutting technology used to cut out die-base boards prior to inserting the rule. As with variable imaging or digital printing, the required shape and size of label are programmed by computer, with a laser beam and lens system used to direct the beam in cutting out the label shape. Both paper and filmic labels are being cut with a degree of success although the technology is still a somewhat expensive method of cutting labels to shape. However, if digital label printing is to fully develop its potential for printing self-adhesive labels in small quantities and on-demand, then a digital method of label die-cutting on demand to any shape or size will also be required. The technology is available; it will be demand and economics that determine its eventual usage and success in the label industry.

4.8.4 Handling and storage

Most labels form a relatively expensive element of the total finished, labelled product. Not unnaturally, the label-user organisations expect them to be in pristine condition and to perform well on the label application line.

For wet-glue labels, customers normally expect labels to be packed in bundles with flat packing pieces, for example cardboard top and bottom. PE shrink films or PE bags should be used to protect paper-based labels from moisture, changes in relative humidity (RH) and to maintain hygiene. Storage conditions are quite critical in maintaining flatness and the correct moisture content. Both RH and temperature storage conditions are likely to be specified by the end-user. Pre-conditioning of labels to a specified RH in the label-user plant is also recommended prior to usage.

Handling and storage of self-adhesive labels also requires special attention. Like wet-glue labels, self-adhesive paper labels are also affected by temperature and humidity. Higher temperatures can cause the adhesive to soften and flow; lower temperatures may cause the label to begin de-laminating from the backing paper. Again, recommended temperature and RH conditions laid down by the laminate supplier or end-use customer should be followed.

A further problem with self-adhesive labels is that excessive pressure on a stack of labels may squeeze the adhesive out around the edges of the labels. Reels of labels should therefore be stored and packed flat (cheese fashion). Reel stocks can take on curvature the longer the reels are stored. The curvature will be worse the nearer one gets to the core. Because of the limited shelf life of

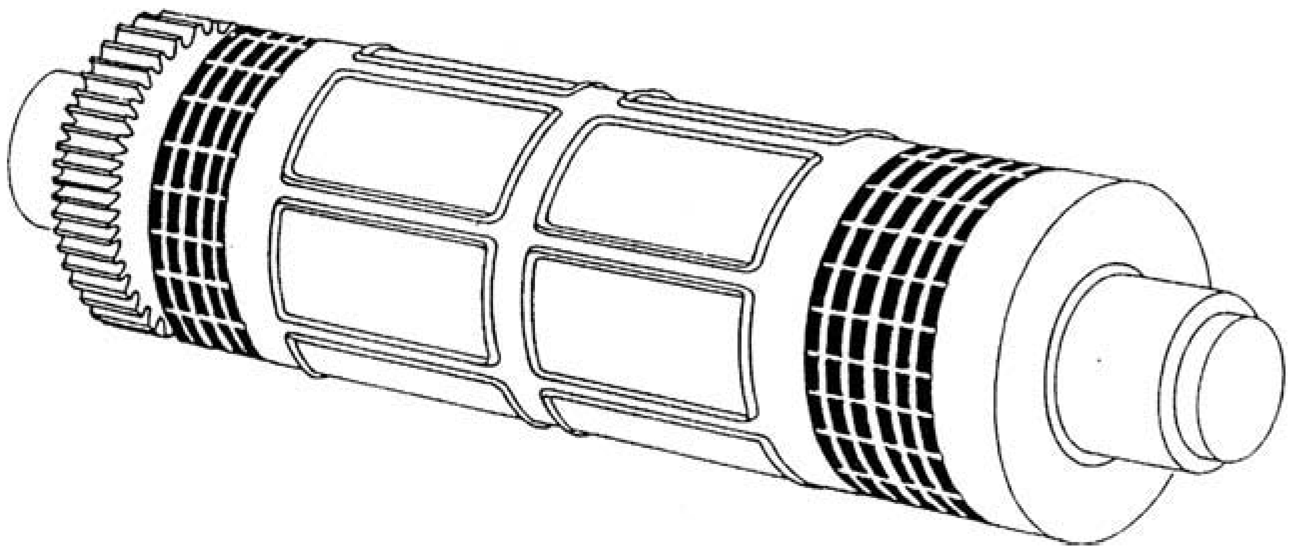

Figure 4.11 Magnetic cylinder with flexible die. *Source*: Labels & Labelling Consultancy.

self-adhesive labels and potential adhesive ageing, a recommended use-by-date should be followed.

4.9 Label application, labelling and overprinting

4.9.1 Introduction

Once labels have been printed and finished, whether in cut sheet label sizes, punched into shapes, in a roll on a backing liner (self-adhesive) or in reels for sleeve or wrap-around film labelling, they are despatched to the packaging and labelling facilities for application to bottles, cans, packs or products using a labelling or label-application machine – which may be hand-operated, semi-automatic or fully automatic – and for high-speed applications, incorporated into dedicated bottling or canning lines where de-palletising, washing, pasteurisation, inspection, container filling, capping, sealing, neck-foiling, labelling, dating/coding, carton or case filling, shrink wrapping and palletising are carried out in one in-line continuous operation.

The method of applying the label will vary according to the product to be labelled, the label type and the specific labelling requirement, i.e. front label only, front, back and neck, wrap-around body label, tamper-evident label, etc. Some of the key label application methods are set out below.

4.9.2 Glue-applied label applicators

All glue-applied labels, whether paper, metallic foil or film materials, are affixed to containers by a labelling machine into which the bottles or cans are fed on a conveyor line. Glue is applied to the back of the label or in a strip to the label on the container and then the labels are applied to the containers automatically and continuously at high speeds. Capable of handling glass and plastic bottles, metal and special-shaped containers (depending on the user requirement and system) glue-applied labellers can apply various combinations of body, shoulder, back, wrap-around, neck-around and deep-cone labels.

Modern wrap-around labelling systems have also been designed for the application of labels from the reel using low-cost paper labels as well as a variety of plastic film labels, including reverse-printed transparent film. In operation, glue is applied onto the leading edge of the film via mechanically driven glue rollers. The paper or film is cut to length and wrapped around the container and then glued on the trailing (overlap) edge to form a complete wrap. Glass, plastic and metal containers – square, cylindrical, oval – can be handled at speeds up to 800 bottles per minute when using 2-applicator stations.

Because of the high speeds used in most glue-applied label lines, there are usually special requirements for the glues/adhesives and the labels to ensure optimum productivity. The most important label characteristics for glue-applied paper label line efficiency are size tolerance, moisture absorbency, grain direction, wet strength and label memory, stiffness and curl characteristics.

Glue-applied labelling machines may be straight through lines, which have outputs up to 24 000 containers per hour or high-speed rotary systems, which today can achieve outputs of up to 160 000 containers per hour.

4.9.3 Self-adhesive label applicators

All machines for applying self-adhesive labels need a means of peeling the silicone-coated backing paper from the web of die-cut labels and at the same time applying the individual die-cut labels to the product to be labelled.

Removal of the backing paper is achieved by passing the backing paper over a 'beak', pulling the backing paper backwards and leaving the label to be dispensed moving forwards into the correct position for applying onto the container or pack. It is then pressed into contact by rollers, brushes, air jets or tamper pads (Fig. 4.12).

Depending on the design of the labelling head and method of pressing the label to the pack or container, self-adhesive applicators can be used to apply front, back and neck labels to the body of a container, to the top or the bottom of a pack or bottle, to apply labels around corners, into recesses, onto delicate surfaces (using air pressure) and onto all sizes of containers – from small pharmaceutical bottles up to large drums or beer kegs. They are therefore the most versatile of all labelling

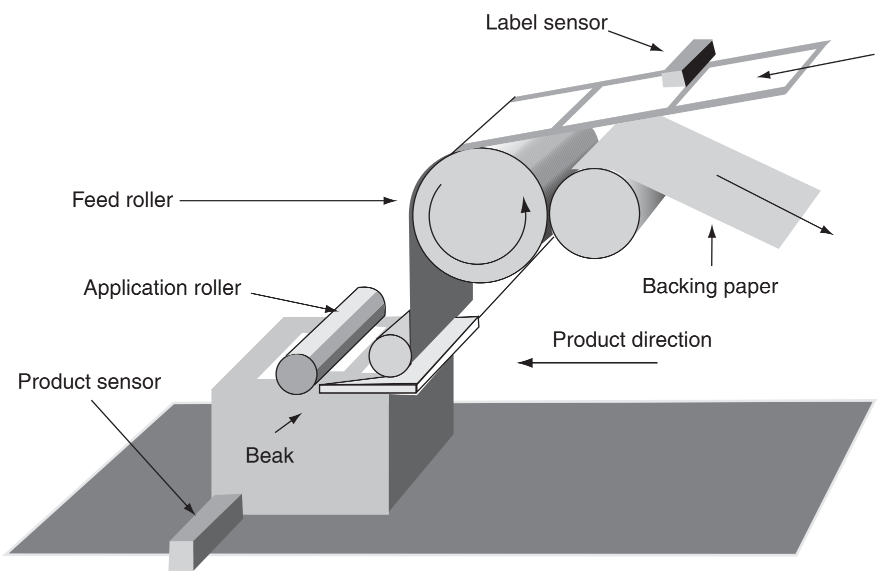

Figure 4.12 Diagram shows the operation of a self-adhesive label applicator. *Source*: Labels & Labelling Consultancy.

machines, yet have one of the lowest capital purchase costs, the greatest flexibility in use and application, high labelling accuracy – even for the smallest of labels – and provide ease and simplicity of operation with high operational efficiency and short changeover times (15–30 min).

These key advantages largely outweigh the higher cost of the self-adhesive label itself and make self-adhesive labelling a cost-effective solution for many industries and particularly for the cosmetics, toiletries, healthcare and beauty, pharmaceutical, industrial products, food/supermarket and added-value drinks sectors.

Self-adhesive label applicators may be manually operated, semi-automatic or fully automatic in-line filling and labelling systems that incorporate conveyors, filling and capping, web feed and dispensing, photo-electric controls and backing waste removal. They may also incorporate VIP heads into the line to add variable text, date or batch codes, bar codes and price-weight information. A wide variety of applicator output speeds are available for almost any labelling requirement and, by combining applicator heads in one line, it is possible to label, say, up to a thousand bottles per minute (60 000 bottles per hour), using a 6-station applicator.

Self-adhesive label application heads can also be installed as additional units on wet-glue and glue-applied labelling machines for applying tamper-evident labels, promotional labels, etc., or for applying neck labels to bottles decorated with wrap-around film labels.

4.9.4 Shrink-sleeve label applicators

Shrink sleeves are applied on an application machine which takes the reels of tubular sleeving, opens it on a mandrel and feeds the opened tube to a rotary knife which then cuts it to the required label length. After placing over the bottle, the labels need to pass through a heated tunnel so that the label can be shrunk to the required bottle shape – even if this means a shrink of up to 30 or 40%. To prevent movement of the sleeves before entering the shrink tunnel, a pre-shrinking unit can be incorporated.

Rather than just a label-applicator line (as with glue-applied or self-adhesive labellers) shrink sleeving is a complete system, which includes pre-heating and post-curing. The more shrink required, say, for a taper neck, the longer the heated shrink tunnel required. In simple terms, shrink sleeving is not just about slipping a sleeve over a bottle but about the technology of differential shrinking. Speed is not a constraint, as two carousels can label up to 42 000 bottles per hour.

Complete body and tapered neck bottles can be labelled with one sleeve although this means that a whole bottle sleeve has to be produced even if only a front, back or neck label is required. Either pre-fill sleeving or post-fill sleeving is possible.

Key advantages of shrink-sleeve labelling systems include 360° full body and neck decoration, decoration of complex bottle shapes, provision of tamper evidence and relatively low running costs.

4.9.5 Stretch-sleeve label applicators

Stretch sleeves are supplied to labelling lines in flat, collapsed form in a reel and are then passed through a buffer unit prior to cutting and application. To apply the sleeve, it is first opened up and guided by a mandrel and guide to a cutting wheel, where it is cut precisely to the desired length by servo-controlled cutting knives. Before the cutting process is complete, the sleeve is already positioned on the transfer element, which stretches the sleeve and pulls it down over the bottle to a pre-determined application height. The stretchable film then shrinks itself elastically to fit, thus offering a completely glue-free container-decoration process.

Generally seen as more relevant where easy removal of body labels on returnable bottles is required, stretch-sleeve labelling is primarily used for large-size bottles of carbonated drinks. Stretch-sleeve application is a glueless all-round 360° body labelling process which offers precise positioning and easy removal of labels for returnable bottles.

4.9.6 In-mould label applicators

Unlike all other methods of label application in which labels are applied on a packaging or decoration line after the container had been made, in-mould label application is undertaken as an integral part of the container-manufacturing operation, i.e. the label is placed in the mould before the bottle is blown or the tub is formed by injection moulding or thermoforming, so as to become part of the container itself. The label is therefore part of the container wall and does not have the raised edge characteristic of other labelling methods.

In blow-moulding label application, pre-printed and cut-to-shape labels are placed in the moulding machine in stacks, from which they are picked up and placed into the mould during the mould-opening cycle and held in place by a vacuum. Accuracy of label placement in the mould is essential for good results. The plastic that forms the bottle comes out in the form of a tube at about 200 °C (about 400 °F) and as high air pressure is blown into the tube, it expands to conform to the bottle shape. The hot plastic fuses the heat seal layer to the bottle.

In the labelling of injection-moulded containers, a PP label is used with PP injected container. Because of the high temperatures and pressure involved in injection moulding, the label fuses to the container without the need for a heat-seal layer.

To undertake in-mould label application requires special moulding equipment and moulds, and the necessary modifications that will enable labels to be inserted and positioned accurately in the mould before moulding.

4.9.7 Modular label applicators

One of the more recent developments in application technology is the introduction of modular labelling systems in which the wet-glue, self-adhesive, shrink or wrap-around film labelling heads are all incorporated into one labelling line. This offers bottlers complete flexibility in their bottling plant for body, neck, front and back labelling using any one, or combination, of label types and application method.

Modular systems are seen as cost-effective to purchase, flexible in application and offer brand owners a wide label and bottle image choice. Modular systems are seen as one of the fastest growing label application methods and are expected to continue finding a key role in bottle decoration and branding.

4.10 Label legislation, regulations and standards

In recent years, there has been an increasing range and variety of legislation, regulations, national or international standards, codes of practice, etc., which relate to labels and the labelling of a wide range of products and sectors – food, dangerous substances, cosmetics, textiles, floor coverings, crash helmets, aerosols, electrical appliances, medicines, toys, pet foods and materials handling.

Such legislation, standards or codes which have implications for labels or labelling may arise from Acts of Parliament, Statutory Instruments, British Standards, etc., in the United Kingdom, from European Commission (EC) Directives or from international sources such as the ISO, IATA (the International Air Transport Association) or the world's maritime or rail organisations.

4.10.1 Acts of Parliament

The law making body or Legislature in most European countries is Parliament. An Act of Parliament (viz. Consumer Protection Act, Food & Drugs Act, Weights and Measures Act) is enforceable by all courts as the law of the land, unless and until it is repealed or amended by Parliament.

4.10.2 EC Regulations and Directives

Apart from the legal requirements of national legislation relating to labels and label usage, it is also necessary to take account of regulations and directives emanating from the EC.

Directives are formulated by the European Commissioners in Brussels in the interests of harmonisation of trade and are implemented by Statutory Instruments (SI) in individual countries. SIs are legally enforceable and affect many aspects of manufacturing and trading, including labelling. Such SIs include those for Food Labelling, Cosmetic Products and Dangerous Substances.

4.10.3 Standards

National standards institutions, such as the British Standards Institution (BSI), are the recognised bodies for the preparation and production of national standards. Standards are co-ordinated internationally by the ISO.

Standards are prepared under the guidance of representative committees and are widely circulated before they are authorised for publication. They include glossaries of terms, definitions, quantities, units and symbols, test methods, specification for quality, safety and performance, preferred sizes and types, codes of practice, etc. Examples include 'Recommendations for informative labelling of textile floor coverings' or 'Standards relating to the testing and performance of labels for use in maritime conditions' or those for 'Safety signs and colours'.

It is always advisable to check for possible legislative or standardisation requirements when designing or developing labels for new applications, requirements or markets.

4.11 Specifications, quality control and testing

4.11.1 Introduction

Almost all label buyers and label end-users today will expect that the labels they purchase and use will meet key materials, colour, print, label line and end-user performance criteria. These criteria will be established with the label printer and set out in the label specifications prior to the commencement of the job and before the ordering of the label materials, inks, varnishes, etc.

Many packaging and label end-user organisations undertake their own tests during the development of new labelling solutions to ensure that the specifications they draw up for the label printer and converter will meet:

- all the necessary brand identity and image requirements
- brand or house colour criteria
- label line, handling, distribution and end-usage needs in terms of rubbing, scuffing, durability
- any product or usage resistance demands
- any legislative requirements (such as three months immersion in seawater)
- safety, waste or environmental demands.

Once established in the specifications, the materials suppliers (inks, papers or films), label printers and converters and application companies will be expected to check, test and confirm that all criteria and specifications are met throughout the label order.

Test procedures that are accepted by brand owners, label buyers, packaging and printing companies, paper and film suppliers, ink manufacturers and the like have been established over a long period of time by organisations such as Pira, Technical Association for the Pulp, Paper and Converting Industries (TAPPI), American Society for Testing and Materials (ASTM International), Graphic Arts Technical Foundation (GATF), or by the relevant trade or industry associations, such as FINAT, (the International Federation of Manufacturers and Converters of Self-adhesive and Heat Seal Materials on Paper and other Substrates) or Tag & Label Manufacturers Institute Inc. (TLMI). Some of the more common test procedures or requirements are set out below.

4.11.2 Testing methods for self-adhesive labels

Testing of pressure-sensitive adhesives has evolved from the subjective evaluations used in the early days of the industry to the standardised tests now used throughout the world. Standard tests to assess the adhesive properties of a self-adhesive label are now published by FINAT (see test methods below) and the European Association for the Self Adhesive Tape Industry (Afera) in Europe and by TLMI and ASTM in America. Test methods to measure the three fundamental properties – 180° peel, shear and quick stick – are described, plus a test for adhesive-coat weight, which is important not only for performance but also for commercial reasons.

4.11.2.1 Peel adhesion test method

Designed to quantify the performance or peelability of pressure-sensitive materials, peel adhesion is measured using a tensile tester, or similar machine, which is capable of peeling a laminate through an angle of 180° with a jaw separation rate of 300 mm per minute with an accuracy of ±2%. Adhesion is measured 20 min and 24 h after application – the latter being considered as the ultimate adhesion.

4.11.2.2 Resistance to shear test method

Designed to measure the ability of an adhesive to withstand static forces applied in the same plane as the labelstock, resistance to shear is defined as the time required for a standard area of pressure-sensitive coated material (using at least three strips) to slide from a standard flat surface in a direction parallel to the surface. The resistance to shear is expressed as the average time taken (for the three strips) to shear from the test surface.

4.11.2.3 Quick-stick test methods

Designed to allow end-users to compare the ‘initial grab’ or ‘tack’ of different laminates, the quick-stick value is the force required to separate, at a specific speed, a loop of material (adhesive outermost) which has been brought into contact with a specified area of a standard surface. It is tested using a tensile tester, or similar machine, with a reversing facility and a vertical jaw-separation rate of 300 mm per minute with an accuracy of ±2%. It is an extremely useful test for those working with automatic labelling equipment where a ‘grab’ or ‘tack’ value is of particular importance.

4.11.2.4 Adhesive coat weight test method

Designed to determine the amount of dry adhesive material applied to the surface of a pressure-sensitive label construction, adhesive coat weight is expressed as the weight of dry adhesive on a standard area of material – in grams per square metre (g/m^2). It is tested using a template to cut samples, a circulated hot-air oven and accurate balance and a beaker of solvent.

4.11.3 Testing methods for wet-glue labels

A wide range of equipment and apparatus is available for carrying out various test procedures to establish individual wet-glue label properties. In practice, however, most bottling and packaging plants only need to apply a limited number of tests. The more important tests for wet-glue labels and label papers include the following:

4.11.3.1 Tear strength test method

Designed as a simple test for use by bottling plants and small printing companies, tear strength testing is normally carried out using a tensile testing machine and a 10 or 15 mm wide paper strip.

4.11.3.2 Water absorption capacity test method

Designed to ensure that labels bond quickly and positively, water absorption is measured by the 'Cobb' test. Suitable labels should have an absorption capacity of between 7 and 11 g/m^2 after 60 s of water contact. Labels with a low absorption capacity may have problems due to the edges lifting after application. Labels with excessive water absorption capacity will tend to curl excessively. The standard time for water contact is 60 s, but when comparing more absorbent papers a shorter time may be preferred. In all cases, the time for water contact used in the test must be recorded.

4.11.3.3 Caustic soda resistance test method

Designed to test the resistance of the label to the effect of caustic soda, resistance can be tested by placing 120 cm^2 of label paper in a sealed measuring vessel containing 20 cl of 1.5% sodium hydroxide solution and shaking vigorously (around 30 times). A sample with adequate caustic soda resistance will not disintegrate, while there should be no contamination of the solution caused by 'pulping' of the fibres.

4.11.3.4 Paper weight test method

Designed to test the weight per unit area (basis weight) of a label paper, testing can be determined with sufficient accuracy by the use of pocket scales. Thickness or calliper can be measured using a standard micrometer or a special paper micrometer.

4.11.3.5 Bending stiffness test method

Designed to measure the flexural stiffness, i.e. bending strength of paper and labels, bending stiffness is measured using a bending stiffness tester, e.g., Thuring-Albert Tester, which provides a comparison of the bending strength of new labels with that of labels known to handle satisfactorily in labelling machines.

4.12 Waste and environmental issues

Waste and environmental issues have been well to the fore in the label and packaging sectors for several decades and have acquired some notoriety, partly due to the high level of visibility that post-consumer packaging and label waste 'litter' arouses.

The driving force behind the prominence of environmental issues for packaging and labelling is threefold: governments, commercial factors and consumers/ consumer groups.

- *Governments* around the world, particularly in western Europe and North America, have introduced measures ranging from container deposits, packaging levies, bans on certain types of packaging and mandatory recycling rates.
- *Commercial factors* and supply-chain issues are playing a role as companies respond to the environmental challenge. Some retail chains have banned what they consider to be environmentally unacceptable types of packaging. They are also responding to pressures from customers and governments.
- *Consumers and consumer groups* are showing ever more interest in the environmental credentials of the products that people buy and the companies that they buy them from.

Environmental legislation, bringing these various issues together, has been a key issue for the packaging and labelling industry from the late 1980s, through the 1990s and into the current decade. This existing, and forthcoming new, legislation is likely to be one of the most important external drivers on the rigid plastics, metal, glass and paper-based packaging and labelling sectors in the coming years.

Labels and labelling environmental and waste issues follow from an EU Directive on Packaging and Packaging Waste, as well as from schemes and requirements introduced by individual countries.

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Paper and Paperboard Packaging Technology
Edited by Mark J. Kirwan

5 Paper bags

Welton Bibby & Baron Ltd

5.1 Introduction

Paper bags, in all their different forms, make an essential contribution to industry and are a vital part of everyday shopping. Made from a renewable and natural resource, paper bags are a proven packaging medium – part of the High Street scene beyond living memory.

Paper offers strength, rigidity, breathability and versatility, and is cost-effective.

This chapter traces the development and use of paper bags from the development of the early prototype machines right up to the multi-million pound industry into which it has grown in the first years of the twenty-first century.

The earliest record of machines to make paper bags dates back to 1850. The leaders in the new emerging market appear to have been Bibby & Baron of Bury, Manchester. Prior to that many products were probably wrapped in paper and secured with string.

There were major advances in the growth of the industry from 1850 until World War II during which period the basic shapes of bags and the machinery to make them were invented and were being developed. These shapes are flat, satchel (with side gussets) and – most importantly for the future of the industry – square-bottom bags, which were free standing. Section 5.4 examines these shapes in more detail.

Printing techniques were also being developed. We again hear the name Bibby & Baron as the inventors of the flexographic printing process in Liverpool in 1890 (Wmich, 2004). This company appears to have been central to the direction of packaging manufacture throughout the nineteenth and twentieth centuries. Interestingly, they still trade today as Welton Bibby & Baron in Midsomer Norton, Somerset, England.

By now, large quantities of paper bags were required for the packaging of staple foods, such as dried fruit, flour, sugar, tea and coffee. Other products, which used millions, even billions of paper bags, included coins, potato crisps, ice-lollies and gramophone records.

Expansion of the industry was checked during World War II. Paper was scarce and a quota system continued for several years after the war was over.

Manufacture of paper bags continued its inexorable expansion in subsequent years. Paper-bag makers increased production, new factories were opened and engineering companies were constructing more advanced machines to make and print paper bags. Coupled with this, a parallel industry emerged making machinery for the automatic opening, filling and sealing of paper bags in food processing factories.

Today, bags are widely used for catering foods, ingredients, pet food, bread, potatoes, sterilisation packs, vacuum cleaners and the travel industry. They are also increasingly in evidence at point of sale in the High Street.

The paper bag displays resilience as a form of packaging, quickly adapting to constantly changing needs and fashions.

5.1.1 Paper bags and the environment

Paper is increasingly recognised by consumers and governments as not only a natural, but also a renewable and recyclable resource from which to manufacture high performance packaging.

Paper recycling schemes have become widespread since the 1990s and there is increasing demand for packaging to be made from previously used materials. In addition, managed forestry in Europe and North America ensures that we have a secure future source of supply.

Legislation in the Republic of Ireland in 2002 imposed a levy on plastic carrier bags and this had an immediate and visible effect of litter reduction. In department stores, the paper carrier bag has provided a popular and economic replacement. Other EU nations are considering similar action as they strive to comply with collection and recycling targets.

5.2 Types of paper bags and their uses

5.2.1 Types of paper bag

The Introduction, Section 5.1 above, gave details of the main shapes of paper bags, which have been developed over the past 150 years. This section examines these shapes in more detail with illustrations of the types of bag, their main applications and the materials used. The main types of paper bags are:

- Flat and satchel
- Strip window
- SOS bags – pre-packed
- SOS bags – point of sale
- SOS carrier bags – pre-packed
- SOS carrier bags – retail/point of sale.

5.2.2 Flat and satchel

5.2.2.1 Flat bags

This is the most basic form of paper bag (Fig. 5.1). It is two-dimensional, and its use is confined almost entirely to retail point of sale. Much favoured in the retail

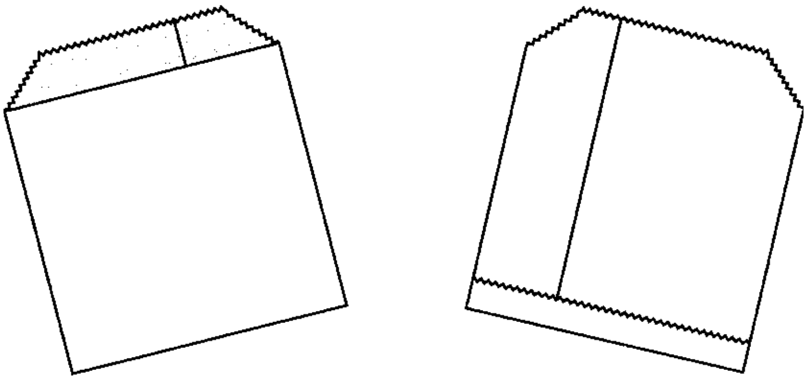

Figure 5.1 Flat bag.

sector by greengrocers, confectioners, bakers, clothes shops, pharmacies and iron-mongers, most of these bags are produced from white (bleached) or brown kraft.

5.2.2.2 Satchel bags – bags with side gussets

The construction of these bags is similar to the flat bag but additional paper is folded on each side to form the gussets – hence the term 'satchel' (Fig. 5.2).

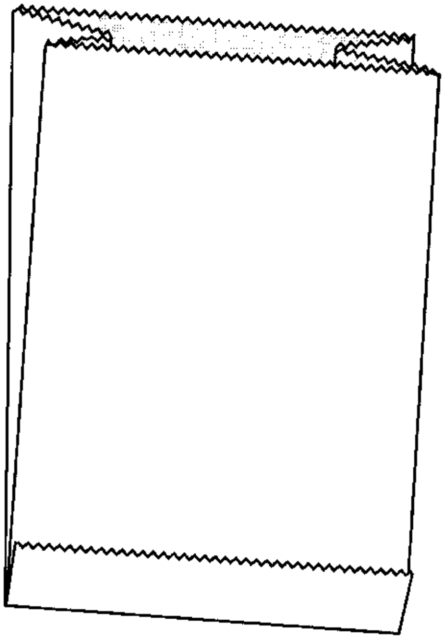

Figure 5.2 Satchel bag.

Satchel bags, when opened, have the advantage of being three-dimensional and provide greater ease of handling and filling compared with a flat bag. Their use is mainly in point of sale in the same retail sectors as flat bags. Although three-dimensional, satchel bags are not 'free-standing' and therefore have limited use in factories for pre-packed food and other products. Most satchel bags are produced from kraft paper but may have a coating or inner ply of a protective material if required for hot or greasy products, for example bakery and hot snacks.

5.2.2.3 Medical and hospital bags

An important and specialised application for flat and satchel shaped paper bags is sterilisation packs for medical and hospital use. Bleached white kraft is the preferred material. Due to the stringent requirements of the sterilisation process, the bag and the paper must have special properties, which are described in Section 5.3.4.

5.2.3 Strip window bags

These bags are satchel shape but merit a separate classification because of their special method of construction in which a paper reel is sealed to a reel of plastic film on the bag machine to produce a strip window. Developed entirely for bread and baguettes these bags (Fig. 5.3) are used in factory bakeries as well as in 'in-store' bakeries. The combination of paper and micro-perforated film ensures the bread remains fresh. Bags are supplied to large scale factory bakeries in 'wicketted' bundles to meet the needs of automatic packing machines, as will be described in paragraph 5.4.5.

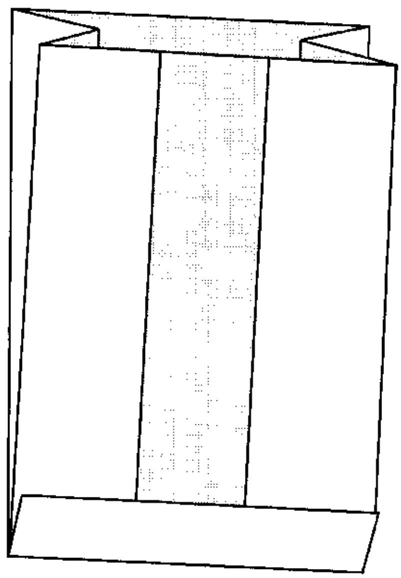

Figure 5.3 Strip window bag.

5.2.4 Self-opening satchel bags (SOS bags)

For a better appreciation of the uses of this shape of paper bag (Fig. 5.4), one needs to consider two entirely separate applications:

- pre-packed products
- point of sale.

5.2.4.1 SOS bags for pre-packing

The introduction to this chapter emphasises the essential contribution that the SOS shape of bag has made to manufacturing industry. Figure 5.4 shows the SOS bag in the folded form as delivered from the bag machine (a), fully open (b) and, lastly, filled and sealed (c). It shows that the SOS bag, when fully opened, is free-standing and consequently is ideally suited to being opened, filled and sealed on fully automatic machinery. Products packed in these bags comprise not only many basic foodstuffs, for example flour, sugar, cereals, tea, coffee, biscuits and confectionery, but also food mixes for both retail and catering requirements. Numerous other industries are served including cat litter, small pet-food packs, agrochemicals, horticulture and DIY.

The base material used is generally bleached kraft – brown kraft to a lesser degree. However, a wide range of coatings, lacquers, laminations and protective lining materials supplement the kraft paper with two main objectives:

- On the outside of the bag, the aim may be to achieve the maximum visual impact. This requires a coating on the paper to achieve the best print surface. Use of gloss or matt over-lacquer or a layer of transparent film printed on the underside for optimum effect.
- Inside the bag, additions to the base paper are chosen according to the nature of the product and protection required, for example length of shelf life, grease,

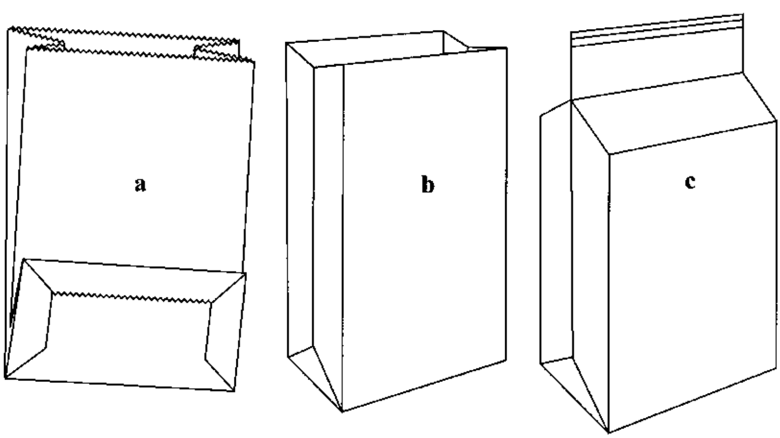

Figure 5.4 Self-opening satchel bags (SOS): (a) folded; (b) fully open; and (c) filled and sealed.

flavour and odour protection. This is achieved through grease-resistant or greaseproof papers, wet strength and plastic-coated papers. A lining of paper or plastic film or foil is sometimes added to provide additional mechanical strength or product protection.

5.2.4.2 SOS bags for use at point of sale

The SOS bag is constructed in such a manner that it forms a rectangular base and can stand up unsupported. This feature, essential for use on automatic machinery in factories, is also of benefit when used 'in-store' and at point of sale. It provides 'stackability'. Significant markets in this sector include bags, often with windows of various shapes, for doughnuts and cookies in supermarkets, popcorn bags in cinemas, 'pick "n" mix' confectionery selection and bags for prescriptions awaiting collection in pharmacies. Bleached kraft is the most popular material in this sector. Whilst graphic design is important for instant visual impact and the material must be compatible with the product, choice of material is less critical than that described in Section 5.2.4.1. The bag is handed to the consumer very soon after packing. 'Shelf life' can be measured in minutes rather than weeks and months.

5.2.5 SOS carrier bags with or without handles

This section is also divided into two separate categories:

1. pre-packed products
2. point of sale.

5.2.5.1 SOS carrier bags for pre-packing

A large proportion of carrier bags are delivered to factories for pre-packed products. Due to the weight and bulk of the contents, handles are fitted for ease of carrying (Fig. 5.5). Among the many products packed in these larger bags, pet foods, cat litter, potatoes, charcoal for barbeques and horticultural products predominate.

The range of papers used and the reasons for the selection of these materials is largely as explained in Section 5.2.4. However, physical strength is an additional factor. Two-ply bags made from strong papers are necessary for many of these larger packs, which weigh up to 12.5 kg. Many pre-packed carriers have punched windows using netting or plastic film – particularly those for the potato market, which were developed by Welton Bibby & Baron.

5.2.5.2 SOS carriers for use at point of sale

This sector, more than any, provides the most public profile for the paper bag. An attractive paper carrier bag offers excellent publicity for retail shops – a walking advertisement in the High Street. Not only the retail trades but also manufacturers who wish to promote their products make use of this powerful advertising medium by distributing carrier bags to retail outlets. Exhibitions and shows offer an additional means of publicity.

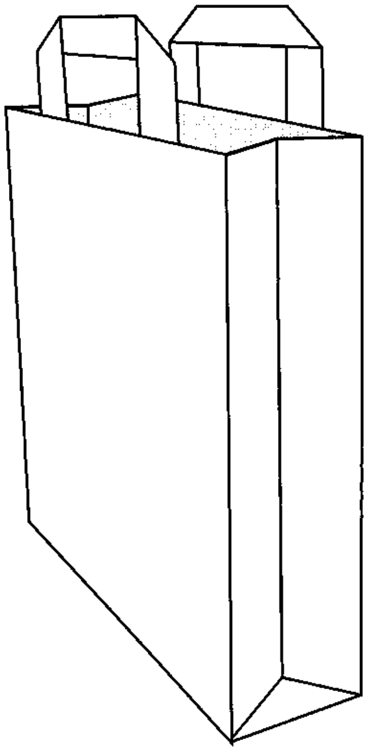

Figure 5.5 SOS carrier bag with handle.

The paper carrier bag is used extensively as a 'carry-out' or 'carry-home' pack for a wide range of ready meals and snacks for High Street fast-food outlets.

A smaller and specialised market exists for luxury gift carrier bags. These bags, often handmade, use high quality art papers with board attachments and coloured rope or cord handles. They are used as point-of-sale bags for luxury goods, such as perfumes and jewellery. In addition, they are sold empty, mainly in boutiques and greeting card shops for customers' use as presentation carriers.

Finally, mention should be made of the 'chuck bag' or supermarket check-out bag. These large capacity brown kraft SOS bags have fulfilled a demand in Europe and America for transporting goods from a supermarket check-out to a car boot (trunk). They are often re-used in the home as waste bags.

The papers used for this sector (apart from the chuck bags) are usually high quality coated papers to achieve the best printing results, combined with sufficient physical strength to protect the contents. Frequently, the contents are already in sealed containers to protect against moisture or grease penetration. If not, a wide range of coatings and protective layers can be added to the inside of the carrier bag.

5.3 Types of paper used

Section 5.2 refers to the different papers used in paper bags according to the application. This section examines these papers in more detail.

5.3.1 Kraft paper – the basic grades

'Kraft', the German word for strength, is the grade of paper most commonly used. Previously, sulphite paper has been used for flat and satchel bags but it lacks whiteness. Kraft paper is used in both unbleached form (brown kraft) and bleached form (white kraft). Within these two main categories numerous qualities are available according to the mill process. Machine glazed (MG) kraft, supercalendered (SC) and machine finished (MF) are all available according to the degree of smoothness required. Striped or ribbed krafts are used and are traditional for certain retail trades, particularly clothes and fashion shops. Coloured krafts can be obtained but minimum tonnages mean that a solid ink coverage is often a more practical proposition.

Other grades of paper used for special applications are as follows.

5.3.2 Grease resistant and greaseproof papers

Used widely for foodstuffs and pet foods where protection from greasy and oily products is required.

5.3.3 Vacuum dust bag papers

Special grades of paper have been developed for paper bags used in vacuum cleaners. The important factors are porosity and filtration to ensure the air flows freely through the paper but not the dust.

5.3.4 Paper for medical use and sterilisation bags

A special government approved paper has been developed for this purpose. Porosity, bacteriaproofness and wet-strength properties are all important factors, to ensure that sterilisation bags withstand steam autoclaving and remain sterile.

5.3.5 Wet-strength kraft

This grade is often specified where exposure to damp or moisture is likely. It is an essential requirement for hospital bags which are steam sterilised.

5.3.6 Recycled kraft

Recycled kraft is used for carrier bags and other applications where a recycled paper is acceptable and is often specified by customers. It is not suitable for medical or food grades where virgin kraft must be used.

5.3.7 Coated papers

Kraft papers can be coated with china clay to provide an extra smooth finish and achieve enhanced print standards. Extrusion coating of kraft papers with various grades of plastic film is used to both protect and enhance appearance.

5.3.8 Laminations

Kraft papers are used in conjunction with all plastic films and/or with aluminium foil to provide up to 4-ply laminations depending on the level of protection required from the bag. Aluminium is used particularly where odour, flavour retention and light protection are important factors.

5.3.9 Speciality papers

Many other grades have been used to produce bags with specialised requirements, some on an experimental basis. These include:

- Water soluble paper
- Flame retardant paper
- Wax impregnated paper
- Bitumenised kraft
- Creped kraft.

5.3.10 Weights of paper

Grams per square metre (g/m^2) is used for measuring the weight of paper. The range of weights used depends on the style of bag and machinery used. In general, lighter substances can be used to make flat and satchel bags and range from 40 to 100 g/m^2. The range for SOS bags is between 60 and 110 g/m^2 – the minimum weight is higher due to the manufacturing process of SOS bags. The total grammage of paper bags can, of course, be increased by making 2-ply bags. The grammage of some coated and processed papers needs to be increased to match the equivalent strength of a kraft paper. (Note: lbs/3000 sq ft = 1.627 g/m^2.)

5.4 Principles of manufacture

5.4.1 Glue-seal bags

5.4.1.1 Flat and satchel bags

The bags are formed from a reel of the required material which is usually about 20 mm wider than the total width of the bag, i.e. face + gusset × 2. The 20 mm of extra material becomes the overlap to form the seam along the bag.

The bag is shaped over a forming plate matching the size required. Guide wheels tuck in extra paper to form a gusset if a satchel bag is required. Paper from the reel is cut to the required length by a knife or a blade mounted on a rotating cylinder. Glue is applied to the web at two separate stations to seal the bottom seam and the side seam.

5.4.1.2 Self-opening satchel bags (SOS bags)

As can be seen from the illustrations in Section 5.2, the method of construction for SOS bags is more complex. The free-standing bag is formed by a series of folds, slits and creases. Heavier paper is needed to withstand this process and machine speeds tend to be slower than for flat and satchel bags. The principles relating to reel width and glue application are the same as for flat and satchel bags.

5.4.2 Heat-seal bags

As the construction depends on a heat seal, the reel or reels of paper must include a thermoplastic material to form the inside of the bag. This can be in the form of an extrusion coating or a separate web of heat-sealable film. Virtually all heat-seal bags are of SOS shape. The bottoms are formed by a series of folds, cuts and creases. Heat is applied to both the base of the bag and the sidewall by heated machine parts and a hot-air flow.

5.4.3 Printing on bag-making machines

Depending on the nature of the design required and the number of colours, the printing process is often included in the bag-making machinery. Paper from the reel is first fed through the printing unit – up to four colours – before passing through to the bag-making process. Quick drying inks are essential to avoid reduction in machine speeds.

5.4.4 Additional processes on bag-making machines

As paper from the reel passes through the bag-making machine, other processes and attachments can be included.

5.4.4.1 Punching
If windows are required in the bag, the paper web can have a punched cut-out. Unless the bag is totally lined with film, a narrower reel of film to suit the width of window is used. Bags can have a large number of very small holes punched, for example ventilation holes for bulbs.

5.4.4.2 Paper handles
Narrow reels of folded or twisted paper and reinforcing paper to secure the handles are fed on to the main web of paper to produce carrier bags.

5.4.4.3 Lacquers and adhesives
A strip of heat sealable polyvinyl acetate (PVA) coating can be applied to the top of the inside of the bag. Hot-melt adhesive can be sprayed on to the outside of the bag. These provide customers with the means to heat-seal bags when filled.

5.4.4.4 Metal strips
Metal strips can be attached to the bag when formed, to provide a means of reclosure.

5.4.4.5 Reinforcement strips
A supplementary reel can be used to provide a reinforcing patch on the base of the bag.

5.4.5 Additional operations after bag making

Additional processes include the following:

- Wicketting of bread bags to be used on automatic machines in bakeries. This is a process whereby the bags are collated in any quantity on a U-shaped metal wicket wire utilising holes pre-punched through the lip of the bag. The purpose is to enable packing on automatic filling lines where the bags are mechanically selected and air inflated to enable the product to be inserted. This packing method is most suited to factory bakers of bread and farm-produce packers.
- ‘Stringing’ of flat and satchel bags for use in retail outlets. This consists of threading a string through one corner of a stack of bags, which can then hang on a hook.
- Fitting of ‘tin-ties’ around the top of the bag for reclosure.

5.5 Performance testing

5.5.1 Paper

Standard tests exist in the paper trade for measuring the strength and properties of paper. These include burst, tear, tensile, stretch, smoothness, stiffness, thickness, porosity and substance. More specific tests are carried out on special grades, for example wet-strength and grease-resistant papers.

5.5.2 Paper bags

When the reels of paper have been converted into paper bags, performance tests can be conducted both by the bag maker and the bag user to ensure conformity with agreed standards. Many of these tests will be of a practical nature.

5.5.2.1 Hospital bags

These can be tested in a steam steriliser to ensure that they withstand the steam sterilisation cycle and remain sterile.

5.5.2.2 Dust bags

Performance tests are conducted in the vacuum cleaner. These tests are designed to ensure the maximum level of dust retention and maintain sufficient porosity to prevent strain on the motor.

5.5.2.3 Paper bags for food use

Food manufacturers are, of course, concerned that paper bags will preserve their product and provide the required shelf life. The moisture vapour transmission rate of the bag (MVTR) is an important factor in heat sealed bags. In addition, accelerated shelf-life tests can be conducted on the bags.

5.5.2.4 Physical strength

Drop tests have been devised to measure the resistance of a paper bag to bursting. There are weight tests designed to gauge the strength of handles on carrier bags.

5.6 Printing methods and inks

5.6.1 Printing methods

5.6.1.1 Flexographic printing, off-line

Due to advances in flexographic printing in the last 15 years, ‘off-line’ or pre-printing by the flexo process has become the norm for multi-colour illustrations with the additional use of ultraviolet (UV) lacquers. The use of the common impression (CI) cylinder for half-tone printing has resulted in ever-finer screens being printed on suitably smooth paper surfaces. It requires a trained eye to detect the difference between half-tone flexo and photogravure print.

5.6.1.2 Flexographic printing, in-line

The ability to print the paper reel on the bag machine from rubber plates was viewed as a major development in developing paper bags. (See the chronicle of events in Section 5.7.1) This in-line printing is used extensively for printing bags but is generally restricted to four colours. It is confined to line and type matter and coarser screens where close register is not essential.

5.6.1.3 Photogravure

This is an intaglio process as distinct from the relief printing of flexography. Gravure printing is synonymous with excellence in print quality and definition of very fine print. It has the drawback of high origination costs, which means it is only viable for long print runs. Its use has become more limited in recent years due to the advances in the quality of flexographic print.

5.6.1.4 Silkscreen

This stencil printing process is slow and expensive but achieves impressive results. Silkscreen may be used for printing or over-printing on paper bags after manufacture usually for the packaging of luxury items.

5.6.2 Inks

The nature and viscosity of printing inks depend, of course, on the process being used. In addition, printing inks which are used on paper bags for food and hospital products must conform to strict trade standards.

Special 'indicator' inks are used for paper bags for ethylene oxide (EtO) gas and steam sterilisation to show that the packs have passed through the sterilisation process.

5.7 Conclusion

5.7.1 Development of the paper bag industry

The introduction to this chapter referred to the age of the paper bag industry; listed below is a chronicle of some major events in the development of the industry. It is not comprehensive but serves to demonstrate the direction in which the industry was evolving.

1630	The first recorded reference to grocery bags.
1858	Bibby & Baron of Bury installs the first machine to make paper bags.
1870	Margaret Knight founded the Eastern Paper Bag Company (USA). Just before that, she had been an employee in a paper bag factory when she invented a new machine part to make square bottoms for paper bags.

1872	Luther Crowell also patented a machine that manufactured paper bags.
1872	Robinsons of Bristol acquires a New York patent for making 'satchel' shape bags, i.e. bags folded with a side gusset.
1902	Hele Paper Mills provided the idea of converting printed reels of paper into bags. This cheaper process was soon seen as a powerful advertising medium leading to rapid expansion of the bag industry.
1902	A Bristol factory has 17 paper bag machines but 400 workers are still engaged in making bags by hand.
1930	A Bristol factory, opened in 1912, now produces 25 million bags a week.
1932	The opening of the Welton Packaging factory to make paper bags and carrier bags.

During the 1930s, a European patent was registered for printing paper from rubber stereos. The ultimate aim of printing the reel of paper on the bag-making machine had now been achieved. The process was called Aniline or Densatone, but is now generally known as flexographic printing.

5.7.2 The future

The paper bag industry has shown that it is adaptable and responsive to challenges. Paper, the raw material, is a natural and renewable resource. Paper bags have an assured future in the forefront of all the available packaging materials. Having regard for the current packaging legislation trends in Europe, paper bags are well placed for a period of sustained growth.

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6 Composite cans

Catherine Romaine

6.1 Introduction

By utilizing the best combination of materials, composite-can construction ensures optimum presentation and mechanical strength as well as hermetic protection. This choice of materials and production techniques for can components – body, top and bottom – offers packaging solutions that are flexible and cost-effective for mass-consumption and luxury products, as well as for numerous industrial applications. While dry-food packaging is the most common application for today's composite cans, more and more retailers are seeing its value as a customizable option for vendable and non-food products.

When you look at the issues facing food packaging, which is the largest packaging market segment, safety and cost are at the top as shown in Table 6.1. When considering the composite can as a packaging option, it proves to be one of the most versatile packages in the marketplace, primarily because of its ability to safely deliver a product at a relatively low cost. In addition, it also satisfies basic marketing/brand functions. In general, it provides some general performance characteristics, such as containing the product and allowing it to be readily and easily dispensed. It must also deliver adequate shelf life for the type of food it contains. Finally, the can must fit the product and retail venue, and meet the needs of the brand.

Table 6.1 Top 10 issues impacting food packaging

Ranking	Packaging issue	Rating
1	Product safety	**4.07**
2	Cost of materials	**3.99**
3	Faster packaging line speeds	**3.75**
4	Improved packaging line automation	**3.74**
5	Consumer convenience	**3.73**
6	Product shelf life	**3.56**
7	Increased flexibility/changeover	**3.40**
8	New packaging materials	**3.32**
9	More customized packaging	**3.19**
10	New labelling and coding technology	**3.18**

Note: Readers were asked to rate the impact of the following packaging issues on their businesses in the next two years. (Based on an average rating on the 5-point scale where 5 is most important and 1 is least important.)
Source: Food Engineering's 2002 Packaging Trends Survey.

6.2 Composite can (container)

6.2.1 Definition

A composite can is a convolute-wound, spiral-wound, linear-draw or single-wrap rigid body with one or both end closures permanently affixed. While paper is the primary component of the canister body, the total construction of the package involves several layers of material, often including aluminum foil and plastic, Figure 6.1.

6.2.2 Manufacturing methods

There are several processes which can be used to manufacture composite cans.

6.2.2.1 Convolute winding

The convolute method of manufacture involves winding multiple layers of a single-ply of material around a rotating mandrel to form a round (or non-round) can body. The body material is coming in at a right angle to the mandrel, with all of the paper going in the same direction (Fig. 6.2a). A cutting operation sizes individual cans to customer specifications.

6.2.2.2 Spiral winding

The plies of a spiral can are wound around a stationary mandrel in a helical pattern, bonded with an adhesive in high volume, continuous production, Figure 6.3. Individual sizes are then cut to customer specifications. The spiral can is divided into five distinct parts (Fig. 6.2b):

- an inner liner
- paperboard body, separate plies (typically two-ply)
- label
- top closure
- bottom closure.

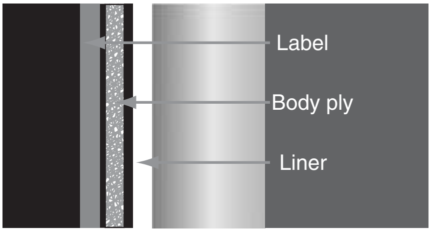

Figure 6.1 Composite-can construction. *Source*: Sonoco.

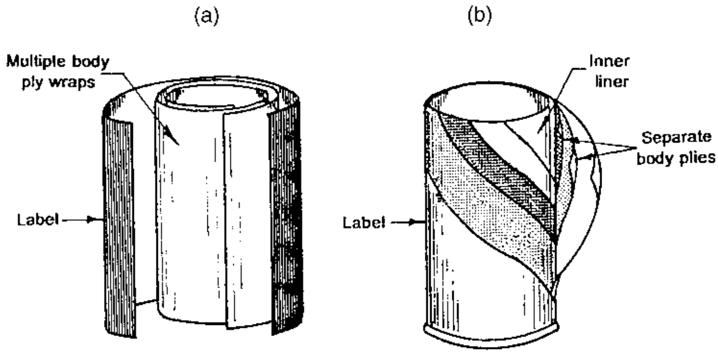

Figure 6.2 Construction of sidewalls of composite containers: (a) convolute construction and (b) spirally wound construction. (Reproduced, with permission, from the Institute of Packaging.)

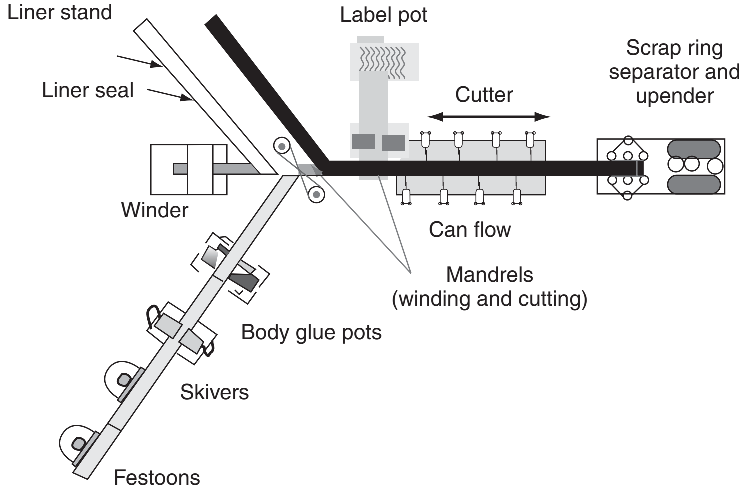

Figure 6.3 Basic can technology. *Source*: Sonoco.

6.2.2.3 Linear draw

Multiple plies are wound around a stationary mandrel in the same direction of the mandrel, Figure 6.4.

6.2.2.4 Single wrap

In this manufacturing process, composite cans are made one at a time. An already-sized, pre-printed, unglued blank is formed around a mandrel. Once heated, the can is positioned to receive the bottom-end closure which is heat sealed and

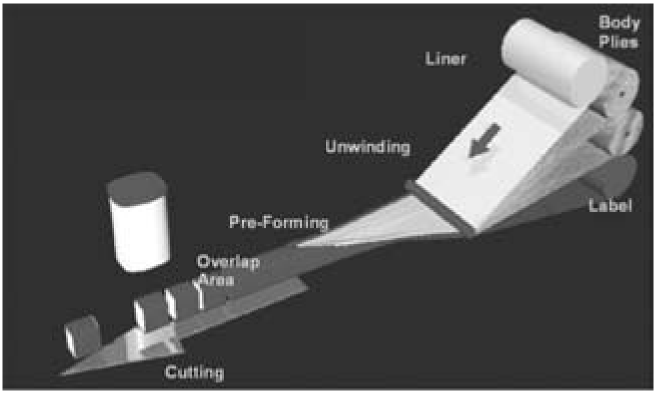

Figure 6.4 Multiple plies wound around a stationary mandrel. *Source*: Sonoco.

Figure 6.5 Single wrap can. *Source*: Sonoco.

clamped to the body. The top is then heated and curled. The single wrap can is available as straight wall or tapered to nest, or stack, one inside another, Figure 6.5.

6.3 Historical background

The composite can has a long history that dates back more than 100 years when packaging was in its infancy and packages were designed to hold and transport lightweight, easy-to-hold dry products. In its earliest beginnings, it was an offshoot of the paper tube. In the late 1800s, gunpowder, oatmeal and salt were commonly packaged in paper tubes with crimped ends. At some point, near the turn of the twentieth century, paper end plugs were added, and composite canisters were born.

While the early construction of these packages involved nothing more than unlined paper bodies with crimped paper or metal ends, interest in the composite can began to grow. Most commonly seen on the pharmacist's shelf, composite cans had become the package of choice for items like Epsom salts, sulfur and other powdered drugs.

Move ahead four or five decades, by the mid-twentieth century, the composite-can market had experienced rapid expansion. Now, the product was offered with lined or sprayed can bodies, coupled with the appearance of opening and pouring features. It was also during this tremendous growth period that manufacturing and distribution processes were becoming more complex. As production became more sophisticated, so did the demands placed on manufacturers. New, nationwide distribution channels led to high-volume, high-speed manufacturing. Package design began to focus on product protection, ease of handling and user convenience. The resulting versatility of the composite can made it the package of choice for many products, such as cleanser, caulks and frozen berries.

It was also during the 1950s, that makers of refrigerated dough began seeking an inexpensive, convenient package for their products. The composite can was selected because of its low cost, its ability to hold internal pressure and an opening feature that did not require the use of a can opener.

Due to the success of the composite can in the dough market, numerous technological advances were being implemented. These advances included the development of high-speed winding and cutting equipment, the use of improved liners, like aluminum foil, for enhanced product protection and special metal-end designs coupled with better seaming techniques.

Over the next decade, the composite can migrated from specialty markets to the more high-volume commodity-oriented segments. In the 1960s, the first commercial shipments of frozen citrus concentrate packaged in composite cans took place in Florida. Within a few short years, the composite can achieved package of choice status for 6 and 12 ounces, a position it still maintains in the twenty-first century.

Paralleling the growth of the concentrated juice market was the petroleum industry. During the 1960s and through the 1980s, the composite can was the package of choice for the quart-size container of motor oil. This success, coupled with some technical experimentation in coffee and solid shortenings, led to further successes over the next several decades.

In the 1970s, Procter & Gamble made headlines when the company introduced a brand new product in a brand new package. The Pringles® potato crisp, a uniquely shaped chip, was the first large-scale snack food to be packaged in a hermetically sealed composite can.

Major manufacturing companies seized the opportunity to develop the snack-food business and began, rapidly, establishing production systems and technical support groups to satisfy the needs of this emerging market. The success of the nitrogen-flushed, hermetically sealed composite can is well documented, and created numerous opportunities to use the composite can as a package for processed meat snacks, powdered infant formula, peanuts and specialty nuts, noodles and other food items.

6.4 Early applications

Many of the earliest composite can applications, as mentioned in Section 6.3, are still in use today. Table 6.2 illustrates some of the world's most famous brands and the length of time they have been marketed in composite cans.

Table 6.2 Leading brands packed in composite cans

Segment	Brand names	Time in market (years)
Snacks	Pringles/Planters	30
Refrigerated dough	Pillsbury	50
Concentrates	Minute Maid, Seneca	50
Adhesives/sealants	DAP, DOW, GE	≥30
Cleansers	Ajax/Comet	50

6.5 Applications today by market segmentation

The packaging industry, valued at more than $400 billion (including packaging machinery), is one of the world's largest and most diverse manufacturing sectors. Nearly 70% of all packaging is found in the food chain, primarily food and drink (Packworld, 2002).

More than half a decade after its introduction as a commodity package, the composite can still maintains an admirable position in the marketplace. Ernst & Young estimates that paper and paperboard remain the most important packaging material, Figure 6.6, accounting for nearly one third of the market (Packworld, 2002).

To summarize, the major markets for the composite can in the packaging industry include foods, non-food, beverage and adhesive/sealant products. Further segmentation of each market is listed in Table 6.3.

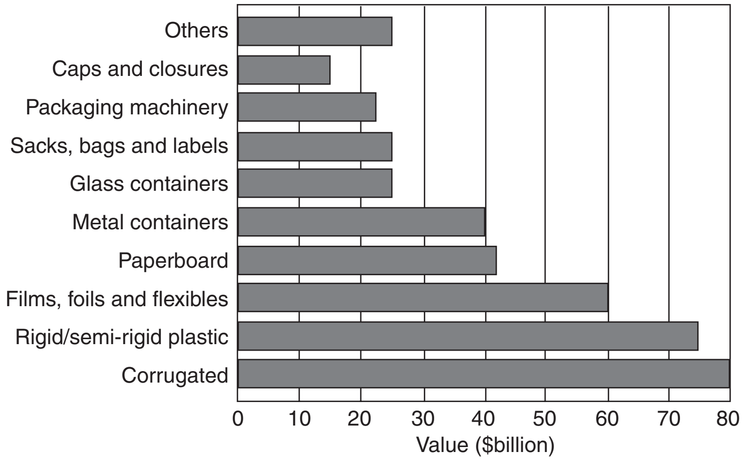

Figure 6.6 Global packaging analysis by value. *Source*: Ernst & Young.

Table 6.3 Products packed in composite cans

Foods	Misc. non-food	Beverage	Adhesives/Sealants
Refrigerated dough	Petroleum products	Frozen concentrates	Caulks
Snacks/nuts/chips	Agricultural products	Coffee	Adhesives
Frozen fruits	Household products	Powdered milk products	Sealants
Dried fruit	Pet products	Powdered beverages	
Salt/spices	Dish detergent		
Solid/liquid shortening	Cleansers		
Confectionery			
Nutraceutical products			
Cookies/crackers			
Powdered foods			
Dried meats			

6.6 Designs available

While the earliest composite cans were available with limited design options, technology has enabled a total redesign of the package. The composite can allows industrial and consumer companies to create packaging based on product attributes and customer preferences with different sizes and shapes with numerous opening-feature options.

6.6.1 *Shape*

Shaped containers are an ideal and proven way to establish product differentiation on the cluttered shelves of drug, grocery, specialty and retail stores. The traditionally round composite canister is now available in unique shapes – rectangular, triangular and oval. The ability to print high-impact graphics is an added bonus to other can features like stackability and delivering eye-catching billboarding opportunities.

6.6.2 *Size*

- *Diameter.* In the case of a round can the size is determined by the diameter. There is a difference between the way this is expressed in the US compared with Europe.

  In the US the dimension used is the diameter of the metal can end which is applied to the tube and in Europe the dimension used is the internal diameter of the tube itself.

  Popular diameters in the US expressed in inches and sixteenths of an inch are: 202, 211, 300, 401, 502 and 601.

  In Europe popular diameters expressed in mm (US measurements in brackets):

  65 (211), 73 (300), 84 (307), 93.7 (313), 99 (401), 155 (603).

  (The 73, 84 and 93.7 mm are also produced with other styles of closure, which are within the tube diameter. The 93.7 mm is used for powdered milk and drinking chocolate and the 73 and 84 mm are used for gravy powders and have paper bases.)
- *Height.* A wide variety of heights is available.

6.6.3 *Consumer preferences*

Manufacturers of consumer products are taking consumer preferences into consideration when determining composite can characteristics. For example, many conventional canned goods now offer an easy-open (EZO), closure feature to eliminate the need for any type of opening device, e.g. can opener, twist key. Certain demographics are also considered. For example, in the United States, where the population is aging, many can features are designed to make handling and opening easier.

6.6.4 *Clubstore/institutional*

With the explosion of clubstore and institutional buying opportunities for the general public, larger cans and combination packs are becoming more prevalent in the marketplace. Often multi-packs are bundled together with shrink-wrap packaging or labeling.

6.6.5 Other features

Because of the composite can's versatility, there are numerous ways to enhance the package based on particular customers' needs:

- *Twist can.* This exciting product is directed toward the tween (8–12) and younger market. The outer ply of the package is lightly scored, so that the resulting rings spin about the can body. The can becomes a re-usable toy, and is a great attention-grabbing device that can often result in impulse purchases.
- *Combination packs.* As manufacturers of consumer products continue to consolidate, more combo-packs are appearing on the shelf. One of the fastest growing markets is the pet-care industry. It is very common to see cans of pet treats sold in combination with other pet care products. In this type of scenario, multiple packaging options are combined for promotions.
- *Pressure-sensitive coupon application.* To increase shelf appeal and sales, many manufacturers apply a coupon directly to the end or body of the composite can prior to shipment. These immediately redeemable in-store money-off coupons or recipe ideas often influence consumers' purchasing decisions.
- *Insert-inside overcap.* Similar to the pressure-sensitive coupon application, an insert is attached to the inside of the overcap, and is not visible to the consumer prior to opening the product. In many instances, a coupon is included for cents off on subsequent purchases.

6.6.6 Opening/closing systems

In addition to strength and versatility, the composite canister is also known for its numerous options for opening and closing systems. Consumers prefer easy-opening and dispensing features that provide resealability to maximize freshness. Paper, aluminum, steel, plastic or membrane closures are fitted on cans by single or double seaming, gluing, pressure inserting or heat sealing.

Closure choice primarily depends on the product to be packaged, as well as the ease of use, protection needed, dispensing requirements, the opening and re-opening ability and the necessary hermetic properties. Choices include:

- glued or heat-sealed paper bottoms and/or lids
- steel and aluminum bottoms and/or EZO lids with single or double seaming
- lever system with or without pilfer-proof membrane
- seamed metal ring with a foil membrane and plastic overcap
- plastic lids and/or bottom with pour spouts
- rolled edge with flat membrane and plastic overcap
- sealed recessed foil membrane with pull-tab and plastic lid
- glued-in or sealed plastic closure with hinged lid and pilfer-proof membrane
- paper lid with or without flat membrane.

6.6.6.1 Top end closures

Top-end closures are often, but not always, differentiated from bottom-end closures by the presence of an opening feature. Various types of opening features are available in the market today due to the wide range of products packaged in composite cans. In today's economy, consumer preferences dictate the types of opening features which are most frequently used. Some of these opening features are also used with shaped and non-round composite cans. Details of various designs of opening are given below. For their features and benefits, see Table 6.4.

Table 6.4 Features and benefits of various opening ends for composite cans

Steel end options	
Type	• Full panel
Features	• Full panel easy open ring-pull end • Food and non-food applications • Double reduced steel available in select diameters • Safety fold available in select diameters
Benefits	• Easy open • Lithography, embossing available • Style, design options • Recloseable with overcap • Vacuum or nitrogen flush capable
Aluminum end options	
Features	• Full or partial-pour panel with easy open ring-pull end
Benefits	• Easy open • Folded edge or hot melt bead provides cut protection • Recloseable with overcap • Vacuum or nitrogen flush capable
Flexible membrane options	
Features	• Peelable, flexible multi-layer or foil membrane heat sealed to a tinplate ring or tinplate steel ring • Valve available for pressure applications • Ring-pull option for some diameters • Leveling feature
Benefits	• Easy open • Printing, embossing available • Recloseable with overcap or plastic plug • Pressure, vacuum or nitrogen flush capable
Plastic end options	
Features	• Resealable molded plastic overcap • Available in colors to complement label
Benefits	• Easy dispensing • Preserves freshness and integrity of product • Increases shelf life • Provides tamper resistance, deters pilferage • Is spill proof

Source: Sonoco Phoenix.

Steel ends
- Full panel
- Partial pour
- Mira strip (peelable and ring-pull options).

Aluminum easy-open ends
- Full panel
- Partial pour.

Flexible membrane
- Paper or aluminum foil
- Recessed membrane with plastic plug
- Flat membrane applied to curl-top can.

Plastic
- Full-panel easy-open end
- Rotor-tops
- Shake and pour
- Overcaps.

6.6.6.2 Bottom end closures

Bottom end closures are primarily coated with steel although plastic, paper and aluminum are used in some applications.

The strength of the steel end is generally correlated with basis weight and temper. Commonly used base weights range from 55 to 107 lb per basis box, with temper ranging from T-3 to T-5.

Coatings may also be applied to the end closure. This is done to protect the raw material from attack by the packaged product or other, environmental, elements. Examples of coatings include tinplate (the most common), vinyl, epoxy and phenolic. If maximum protection is needed, a sealing compound is applied to the end. The compound serves as a gasket to seal the can and protect the contents. The chosen compound is based on the properties of the product being packaged.

6.7 Materials and methods of construction

As mentioned in Section 6.2, the composite can is made from several layers of material, Figure 6.7, and is sealed with top and bottom ends. Material selection and the final can composition are based on customer needs and end-user preferences.

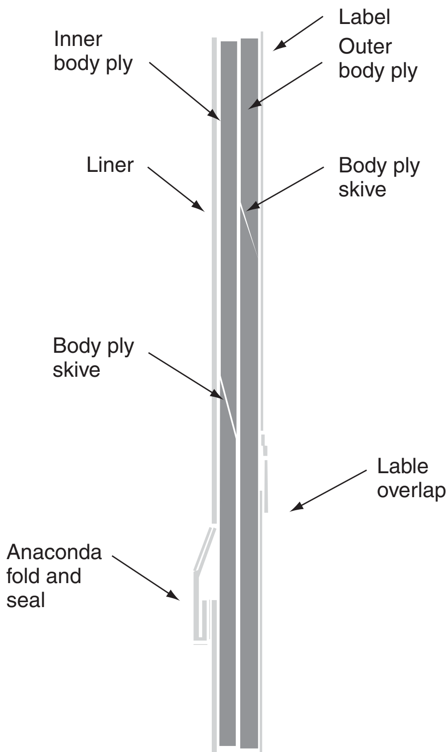

Figure 6.7 Cross section of composite can body. *Source*: Sonoco.

6.7.1 The liner

The function of the liner is to provide product protection. It must be impervious to attack by the product, and at the same time resist transmission of its own components into the product. The liner must also maintain its integrity under impact from external forces, particularly during shipping. In some applications, such as salty snacks, it must also resist abrasion and puncture from within. In some cases, the liner must also act as a barrier to oxygen and moisture, while in others, it serves only to prevent product leakage.

Depending on the product to be packaged, the liner is structured with two or more layers of material. Materials used on the product contact surface include polypropylene, polyethylene (PET), Surlyn®, metalized PET (MPET) and others. In order to maintain a complete barrier with spiral winding, the edge of one spiral winding overlaps the preceding winding, the edge is turned through 180° and heat sealed, face to face, with the preceding winding in the overlapped area. This is known as an 'Anaconda fold and seal' (see Figure 6.7). Aluminum foil is used under the contact surface where barrier and product protection are both required. A kraft (paper) layer completes the liner structure. It serves as a carrier through the converting process that produces the liner structure.

The ratings in terms of 'High', 'Medium' and 'Low' for moisture vapor transmission rate and oxygen permeability are shown in Table 6.5 and examples of typical liner structures, their barrier ratings and typical uses are shown in Table 6.6.

Table 6.5 Ratings for various levels of functional barrier

	Approximate barrier parameters	
	MVTR* Grams/24 hours/container 38 °C/90% RH	O_2 permeability cc/24 hours/container 25 °C/50% RH
High	<0.02	<0.01
Medium	<1.00	<0.50
Low	<5.00	<1.00

* Moisture vapor transmission rate.

Table 6.6 Barrier ratings for typical liner structures

Liner structures commonly used	Barrier properties	Typical uses
Kraft/foil/polypropylene	High	Hermetic food (coffee, nuts, snacks, shortening, peanut butter, infant formula, etc.) solvent- and latex-based paints
Kraft/foil/Surlyn®	High	Hermetically sealed packs for food, including nuts and snacks
Kraft/foil/High density polyethylene (HDPE)	High	Solid shortening, powder beverage, snacks
Kraft/MPET/Surlyn®	High	Hermetic snack foods
Kraft/PE/foil/Coex HD	High	Refrigerated dough
Kraft/foil/vinyl slipcoat	Medium	Refrigerated dough, adhesives, caulk, powder beverage, non-hermetic food
Kraft/PE/PET/Surlyn®	Medium	Pet food, paper-bottom can
Kraft/LDPE/OPP	Medium	Solid shortening
Kraft/LLDPE/White HDPE	Low	Hard to hold frozen concentrate
Kraft/Surlyn®/White HDPE	Low	Hard to hold frozen concentrate
Kraft/White HDPE	Low	Frozen citrus concentrate
Kraft/HDPE	Low	Motor oil

6.7.2 *The paperboard body*

The paperboard body of the composite can is its source of strength, Figure 6.8. The body must provide axial strength sufficient to withstand multi-pallet stacking of finished goods, and sidewall strength necessary to absorb impact during distribution.

There are generally two types of paperboard used in composite cans: unbleached (brown) kraft and recycled. Both provide similar axial and sidewall strength, but kraft may resist more shearing because of its longer fibers. Recycled board is an affordable alternative, and due to regulations in some geographic locations, is a required component of packaging.

In order to achieve a neat joining between adjacent spirally wound layers, the edges are 'skived'. This means that the edges are cut at an angle so that the adjacent edges mesh neatly together. This also adds strength to the composite can.

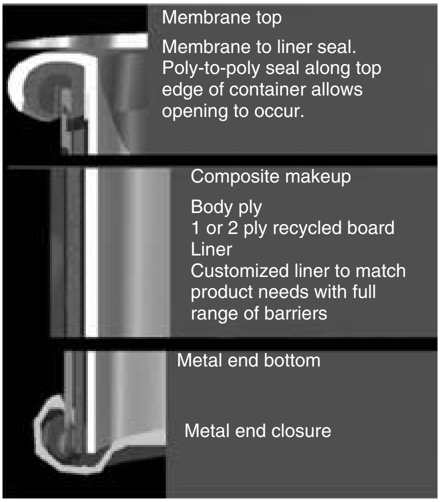

Figure 6.8 Composite-can construction. *Source*: Sonoco.

6.7.3 *Labels*

The label is the outer layer of the composite can that meets a variety of needs. It serves as a billboard for product information and attention-grabbing graphics, as well as providing additional barrier protection.

6.7.4 Nitrogen flushing

The materials and methods of constructing a composite can depend on its end use and desired performance characteristics. When composite cans were being developed for the snack industry, the concept involved creating an hermetically sealed container that could replace the vacuum-packed steel can. This process – known as nitrogen flushing – was developed to accomplish this, and it is still in use today to extend the shelf life of certain products, such as nuts, snacks and chips (potato crisps).

The most common way to remove oxygen is called flushing. It works on the principle of flooding the container with a non-reactive gas, such as nitrogen, just before it is filled.

The type of gas flush is generally determined by the nature of the product. For example, powders have a tendency to pack together, i.e. particles compact together, making it more desirable to purge in several stages. Firstly, to purge the can prior to filling; secondly, to purge the product in the filler; and finally, after filling, prior to seaming, to remove oxygen from the head-space. For snacks, it may be only necessary to flush the filled can prior to seaming.

6.8 Printing and labeling options

6.8.1 Introduction

The two most common label materials are aluminum foil and paper. Foil is most often used for aesthetics and barrier properties when packaging products such as cleanser and some food stuffs. An example is the Kraft® Parmesan Cheese canister. On paper, there is more of a matte, less glossy finish, such as the Pringles® Potato Crisps canister.

A thermoset or thermoplastic coating is applied over the foil or paper for print protection and added barrier properties, particularly moisture. These coatings also provide shelf-appeal, delivering a high-gloss appearance.

Ensuring proper registration on graphics is a complex process. Both aluminum foil and paper provide good offset litho, flexographic and rotogravure print surfaces. Paper is less expensive, but aluminum foil adds additional barrier protection.

It is important to remember that a package is a communication vehicle, which plays an important role in the purchasing process – both as a billboard for the brand and as a bearer of product information. Therefore, the impact the label has on the effectiveness of the composite can is paramount to the end-user, the consumer. It must be eye-catching and appealing.

There are several printing options for composite can labels. In the following sections, we will focus on the most common printing options: flexographic, rotogravure and off-set printing.

6.8.2 Flexographic

Flexographic printing is an efficient, cost-effective and versatile printing method, widely used for packaging products and envelopes. It provides high print quality on a wide variety of absorbent and non-absorbent substrates, including flexible materials, label stock, corrugated substrate, rigid plastics, envelopes, tissue paper and newsprint.

Flexography is a relief printing process, in that the image is pressed onto the label material. This printing process is so named for its flexible rubber plates, which are also the key to the method's versatility and increasing popularity. The increasing use of flexography also increases the demands on the print quality of the end product.

Flexography is the fastest growing printing process, due to:

- its ability to print on practically any substrate, absorbent or non-absorbent, including very thin extensible films
- the use of fast-drying inks, be they solvent-based, water-based or UV curable
- development of photopolymer plastic plates with good half-tone reproduction and low dot gain
- quick make-ready and changeover times make it profitable for short-run printing and
- its cost-effectiveness for many applications.

The European Flexographic Technical Association (EFTA) estimates nearly 40% of all packaging printed globally is through the flexo process with annual growth of 5%. Additionally, it is in label printing where the greatest growth has occurred; over 70% of new machine installations in Europe are believed to be flexo. The use of ultraviolet (UV) inks has contributed to the growth and popularity of this printing process (EFTA).

6.8.3 Rotogravure

Once an art form that has been totally digitized, rotogravure is a printing technique characterized by high print quality and large quantity runs – hundreds of thousands or even many millions. Tiny ink volumes are transferred from the steel-based gravure printing cylinder to printing dots on the label substrate. Millions of printing dots show up to the human eye as letters, text and images.

Material knowledge, papermaking competence and production facilities are the secrets to ensuring superior printing performance. Gravure is a quality printing process producing excellent quality and constant reproductions throughout the entire print run. The secret of the gravure process lies in the cylinder. Increased robotics and total plant computer control systems will bring many further advantages for gravure.

Gravure's environmentally friendly printing process allows the use of:

- papers with higher recycled-fiber content
- highly effective solvent-recovery installations
- industry-leading methods to save paper, ink and energy and
- less residual ink solvent content in gravure products.

In short, rotogravure is a very simple printing process that can produce millions of perfect copies at enormous speed. It also produces superb colors and good gloss on relatively low quality paper. Because the gravure process can guarantee consistent reproduction of high quality graphics, it suits the packaging market where buyers are greatly influenced by the quality of the printed image. The ideal substrates are generally smooth in finishing (clay-coated paper, films and foils) since effective ink transfer depends on thorough cell contact with the substrate to be printed. Presses for packaging gravure printing must meet different requirements due to the variety of substrate colors and finishing processes. Running at lower speeds enables the processing of difficult materials and drying of special inks. Packaging presses can combine in-line finishing processes including laminating, cutting, creasing, embossing, etc. (ERA).

6.8.4 Lithography (litho/offset) printing

Lithography is an 'offset' printing technique. Ink is not applied directly from the printing plate (or cylinder) to the substrate as it is in gravure or flexography. Ink is applied to the printing plate to form the image to be printed and then transferred or offset to a rubber blanket. The image on the blanket is then transferred to the substrate to produce the printed product.

Lithography is based on the principle that oil and water do not mix (hydrophilic and hydrophobic process). Lithographic plates undergo chemical treatment that renders the image area of the plate oleophilic (oil-loving) and therefore ink-receptive and the non-image area hydrophilic (water-loving). Since the ink and water essentially do not mix, the fountain solution prevents ink from migrating to the non-image areas of the plate.

The structure of the label substrate has a strong influence on print quality and ink drying, making this a field of high priority for research and development. Properties such as the base paper's formation and topography and the surface's porosity and smoothness must be optimized for the end-use and printing method.

6.8.5 *Labeling options*

- Spiral labels roll fed
  - printed using rotogravure or flexographic printing processes
- Convolute (strip) labels – roll fed
  - more cost-effective
  - printed using rotogravure or flexographic printing processes
- Convolute (strip) labels – sheet fed
  - can only be printed off-set/lithographic
- Single wrap
  - pre-printed on the body blanks
  - liner, body and graphics are all together as one piece – wrapped to make the body
- Post-filling labeling techniques
- No label; no printed surface
  - customer applies labels

While many improvements can be readily made, there has to be a balance between cost and market demand. For the future, efforts will be focused to enhance label appearance with a more glossy finish. The differences between rotogravure and flexographic processes are narrowing as printers have made tremendous strides to improve the quality of the latter. Rotogravure printers are working toward reductions in pre-press costs.

6.9 Environment and waste management issues

6.9.1 *Introduction*

During the latter part of the twentieth century, the composite can received extensive scrutiny in terms of meeting current environmental initiatives underway at that time. The package's body plies are made from recovered and recycled fiber and can have a post-consumer recovered waste content of over 50%. In many communities, this qualifies the composite can for placement in the material flow streams of curbside recycling programs. In addition to the body, the metal ends of the can are also recyclable.

Today, the composite canister continues to fit into the majority of environmental initiatives demanded by the marketplace, and continues to be recognized for its environmentally friendly attributes. These attributes include the introduction and use of a paper bottom end, which can increase the amount of recycled post-consumer content up to 70%, reduction of material into the waste stream and other efforts to enhance the can's ability to be recycled.

6.9.2 Local recycling considerations

When selecting packages, manufacturers and co-packers take a close look at local and regional recycling laws. In the US, some states require that certain types of packaging are recyclable and use a minimum of recycled content while still meeting Food and Drug Administration (FDA) food contact standards. The wide availability of paper and plastic recycling resources in the US make composite cans an excellent package for a variety of products. While there is a preference for foil composites in Europe, there is also a good deal of aluminum can packaging due to its easy recyclability.

6.10 Future trends in design and application

6.10.1 Introduction

The ongoing development of new materials, sizes, shapes and technologies indicates that market applications for the composite canister will continue to grow. Packaging engineers are focusing on ways to increase performance and convenience by:

- enhancing existing features and materials
- identifying ways to reduce costs associated with materials and processes and
- redesigning closure systems.

Some of the more interesting opportunities include research into the use of sorbent materials in liners, the recent commercialization of a valved-membrane end and the delivery of improved closing features, specifically the plastic overcap.

6.10.2 Sorbents

Sorbents provide high moisture and odor absorbing capability. Generally included in the product mix as a non-edible packet consisting of silica gel, clay or other compound, there is promising new research underway focusing on ways to build sorbents into the liner structure. By continuing to absorb oxygen, the product inside the can will remain fresher before and after opening, Figure 6.9.

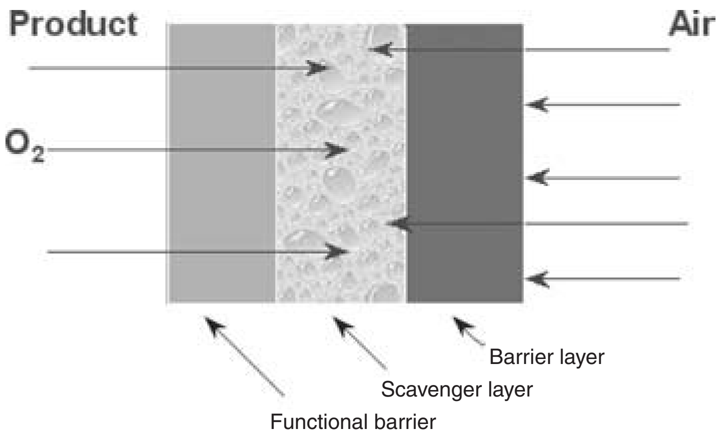

Figure 6.9 Oxygen scavenging. *Source*: Sonoco.

6.10.3 Valved membrane end

Designed for coffee, this one-way release valve allows for packing and sealing immediately after roasting. This eliminates the need for extended hold times for degassing, and at the same time maximizes flavor and aroma. A vacuum is no longer necessary. Because the end is a peelable foil membrane, a can opener is not needed.

6.10.4 Resealable plastic overcap

In another effort to increase product life span, the resealable plastic overcap offers great promise for providing increased shelf life after opening. Redesign of the typical overcap to increase performance levels can be accomplished through the addition of a gasket that will snap to the opening of the composite can.

6.11 Glossary of composite can related terms

Anaconda seal – In order to maintain a complete barrier where the edge of one spiral winding overlaps the preceding winding, the edge is turned through 180° and heat sealed, face to face, with the preceding winding in the overlapped area.

Body stock – A term used to identify the inner plies of a composite can body – excludes the liner or label.

Caliper – Thickness of a sheet of paper or paperboard, measured under certain specifically stated conditions, expressed in thousandths of an inch. Units are called ‘mils’, when referring to paper, and ‘points’ when referring to paperboard.

Canboard – A generic name for the board used in composite cans. It is generally a medium-strength board with good surface smoothness.

Can dimensions – Can diameter and height measurements are expressed in inches and sixteenths of an inch. The standard 12-ounce juice can measures 211×414, which translates to $2^{11}/_{16}$ in. in diameter by $4^{14}/_{16}$ in. in finished can height. The diameter of the can is given first. In Europe, dimensions are measured in millimetres (mm), which refer to the internal diameter of the can.

Composite can – A term used to describe a can made from more than one type of material. The tops and bottoms can be made of metal, plastic, paper or a combination of materials.

Convolute can – A laminated fiber can made by winding material around a form with the material fed at right angles to the axis of the form.

Finished can height – The overall height of a finished can with one end seamed on. Often referred to as 'one end on height'.

Gas retention – The measured ability of a can to retain gas during a specified time.

Gassing – The act of removing air from a can and replacing it with a non-reactive gas, such as nitrogen or carbon dioxide.

Hermetic can – Air or gas-tight canister.

Hermetic seal – The bonding of two parts together so that it is air or gas-tight.

Kraft – A term meaning strength applied to pulp, paper or paperboard having a minimum of 85% virgin wood fibers and produced by the sulfate process.

Label – The outermost ply of a composite can. This layer may be printed. Even if it is not, it is still called the label.

Liner – The innermost ply of a composite can, constituting the can body's principal barrier to moisture or gas transmission.

Linerboard – Solid bleached or unbleached kraft paperboard, either fourdrinier or cylinder, combination paperboard produced from a furnish containing less than 80% virgin kraft wood pulp.

Mira strip tape – Plastic strip adhered to the top of a can-opening feature, which is used with crimp seams (such as frozen concentrate cans).

Nitrogen flushing – During the filling process, the can is filled with a nitrogen gas before inserting the product. The nitrogen gas displaces oxygen allowing for longer shelf life.

Overcap – A cap fitting over another closure that will allow resealing once the can is opened. An overcap must be slightly larger than the end on the can for a proper fit.

Paperboard – A broad classification of materials made from fibrous matter on board machines, encompassing linerboard and corrugating medium. Most commonly made from wood pulp or paper stock.

Ply – The layers of paper used to form the can body. The paper on a can is usually described by the number of plies wound into the can: two-ply versus one-ply can.

Reclosure – A term used to identify or classify the type of end, plug or cap which can be replaced after opening a container.

Recycled stock paper – A paper made from pulp consisting of reclaimed paper waste materials.

Shelf life – The length of time a composite can, or material in a container, remains in a saleable or acceptable condition under specified conditions of storage.

Spiral can – Any composite can which has been formed by winding material around a mandrel at an angle to the axis (less than 90°).

Self-opening can – A method of construction that allows a refrigerated dough can to open when the label is removed, the body ply joint is exposed, allowing the liner heat seal to release and dough pressure pops the can to open.

Skive – In order to achieve a neat joining between adjacent spirally wound layers, the edges are 'skived'. This means that the edges are cut at an angle so that the adjacent edges mesh neatly together. This also increases the strength of the composite can.

Wicking – The tendency of liquid to be absorbed by osmosis through a sheet of paper.

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7 Fibre drums

Fibrestar Drums Ltd

7.1 Introduction

A fibre drum is a cylindrical container with a sidewall made of paper or paperboard having ends and components made of similar or other materials such as metal, plastics, plywood or composite materials. The sidewall of drums used for industrial applications is made up of several layers of paper laminated together by convolute winding.

Fibre drums are used globally and offer a strong, cost-effective means for the packaging of solid, granular, powder, paste, semi-liquid and liquid products. They are widely used by the chemical, pharmaceutical and food industries as well as for special applications in other industries, such as the packing and dispensing of wire, cable and metal foil, adhesives, rolled sheet materials, dyestuffs and colourants. A US survey indicated that fibre drums comprised 30% of the industrial containers (drums) market (Hanlon *et al.*, 1998).

A comprehensive range of open-top fibre drums is produced in sizes from 10 l up to 270 l capacity (2–60 imp. gal) and in a wide range of designs with respect to diameter, height, cross section, type of closure and lid/base construction (Fig. 7.1).

Fibre drums are strong and protect their contents during transportation and under compression whilst in storage. In general terms, they are capable of holding up to 250 kg (550 lb) of dry or semi-liquid product, but with today's Health and Safety legislation, typical pack weights are 25 kg (55 lb) or 50 kg (110 lb).

Fibre drums were originally introduced as an alternative to the metal drum and therefore had a circular cross section. In recent years, drums with a square cross section with rounded corners have become available (Fig. 7.2).

Figure 7.1 Various designs of fibre drum.

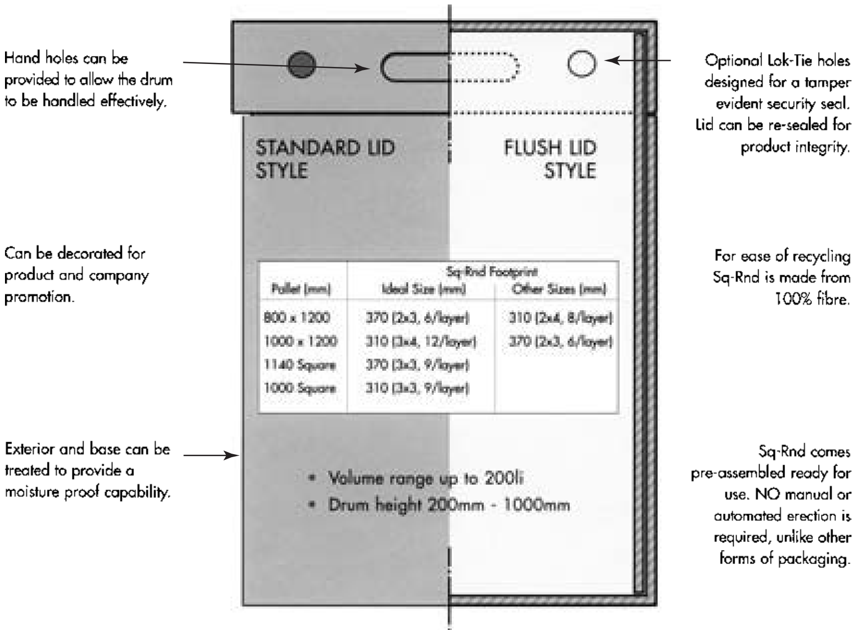

Figure 7.2 Square-round all-fibre drum with rounded corners.

The square cross-section drums enable customers to make use of the space saving attributes when such a pack is palletised for storage and distribution.

Fibre drums are made primarily, and in some designs exclusively, from fibrous materials, namely paper and paperboard, as in Figure 7.3. Figure 7.5 shows a fibre drum with a strengthened fibre top rim or chimb. This all fibre drum has a metal closure band and options with respect to a plastic lid and base collar. Several designs, however, incorporate metal components, plastic liners and coatings to meet specific application needs.

One of the most important characteristics of the fibre drum is that manufacturers are able to supply users with a bespoke, fully customised drum, to match their packaging requirements exactly. Fibre drums are therefore not over specified and hence follow the European Packaging Waste Directive for optimised packaging. They are lighter than metal drums and, additionally, fibre drums are easily recovered and their component parts recycled.

7.2 Raw material

The sidewalls are constructed using virgin unbleached kraft or a recycled paper alternative, for example coreboard. A typical grammage would be 280 g/m^2. The strength of the drum is strongly influenced by the type of paper and the number of plies

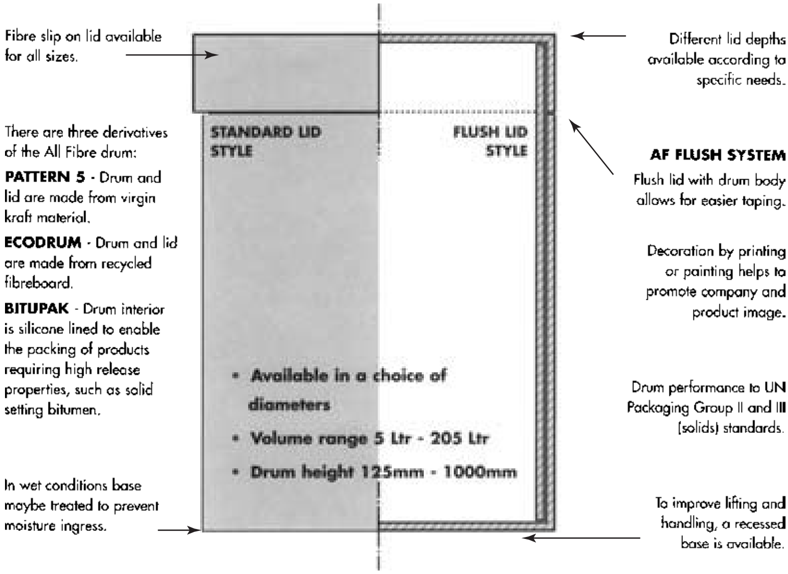

Figure 7.3 All-fibre drum with circular cross section and slip on lid.

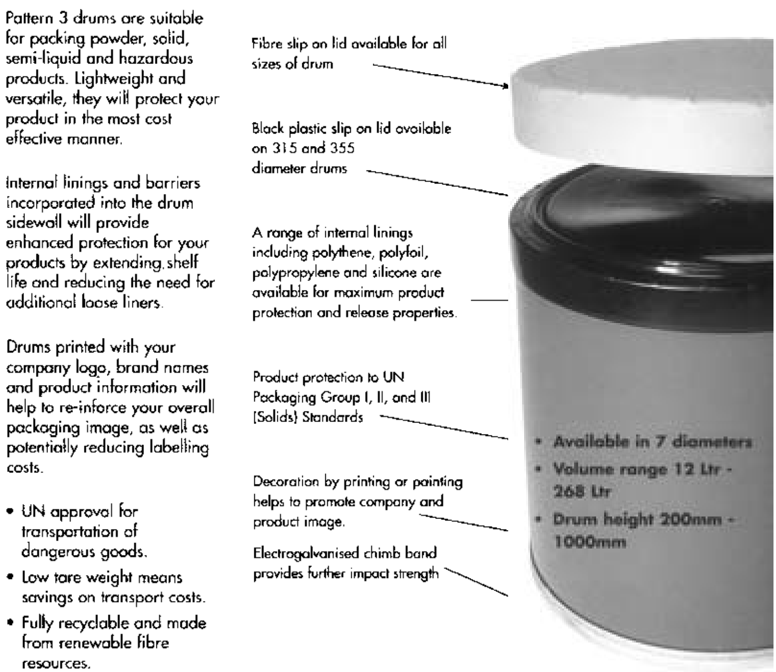

Figure 7.4 Drum with fibre body, steel chimb on bottom, slip on lid.

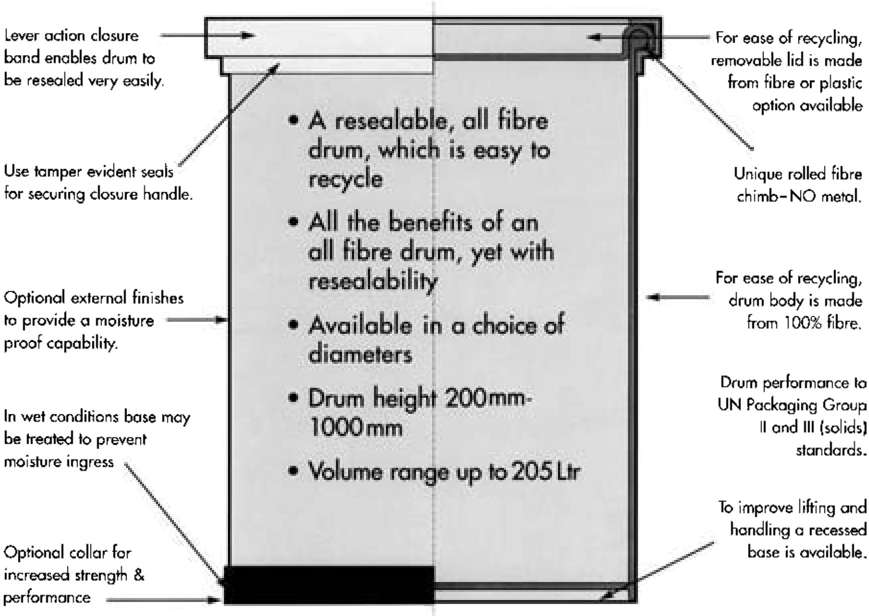

Figure 7.5 All-fibre drum with fibre bead.

wrapped around the mandrel. End boards used in the base construction typically start at 1275 gsm and can be as high as 1800 gsm.

Laminates based on these materials with, for example, aluminium foil, polyethylene or other materials are used for additional functional properties, such as moisture barrier. The additional barrier material may be ‘sandwiched’ within the sidewall construction.

7.3 Production

7.3.1 Sidewall

The usual method for constructing the sidewall is by convolute or straight winding of paper around a mandrel, or forming tool, from a reel, i.e. continuous length. Adhesive is applied to the paper by an applicator roll rotating in an adhesive tray prior to wrapping around the mandrel. A number of plies are built up on the mandrel, for example 6 plies. The finished cylinder is then removed from the mandrel. In this convolute winding, the diameter of the cylinder is the same as the diameter of the mandrel on which it was wound and its length is the same as the width of the paper from which it was wound.

After removal from the mandrel, the cylinder is left to stand for from 1 to 8 hours to allow the adhesive to dry. It is then cut to the required drum length, any waste generated being recovered for recycling.

Winding on to the mandrel in this way means that the cross direction of the paper becomes parallel to the axis of the newly wound cylinder with the machine direction running around the circumference. This is an advantage as far as the strength of the drum is concerned. There will be enough plies of paper to give the required vertical stacking strength, and the body of the drum will have a greater resistance to sideways impacts.

Paper laminates with additional functional properties are applied to the cylinder in sheet form. Depending on the required position of the barrier material in the drum construction, the material may either be wrapped around the mandrel prior to or after the winding of the sidewall.

It should be noted that there are other methods of winding paper around a mandrel, but they do not have the strength required for industrial drums. The use of these methods, such as spiral and single-wall winding, is confined to the manufacture of small retail size drums, decorative drums and hat boxes.

The industry standard, and most commonly used, adhesive is sodium silicate. This adhesive is cost effective and efficient in the winding process, and contributes to the strength of the drum.

For drums requiring moisture proof capability, polyvinyl acetate (PVA) is used. There is also some use of polyvinyl alcohol and dextrine. The main requirements for the adhesive are good wet tack and a quick setting speed. It is important to use an adhesive with a high solids content to ensure that the amount of water added, as a consequence of using the adhesive, is kept to a minimum.

7.3.2 Drum base

The fibreboard discs are die-cut from larger parent sheets; this is usually done in-house for low-volume requirements, and higher-volume requirements are bought in from specialist suppliers. For the all-fibre drum, the base is fixed in place by sandwiching it between a turned over flange and an outer thinner disc.

A galvanised steel chimb on the bottom rim of the sidewall may be used to apply a plastic (PE) or steel base by crimping. This will make it easier for one person to move the drum by rolling it along on the base rim.

Caulking is used to seal the chimb ‘joint’, hence producing a liquid-carrying capability if required. A typical caulking compound is a moisture-curing polyurethane, which is applied as an extruded bead into the joint before it is crimped.

The chimb adds strength and enables the drum to meet the United Nations (UN) performance standards. The incorporation of a chimb to the edges of both the top and bottom ends is a global standard produced by all manufacturers in one form or another.

7.3.3 Lid

Fibre drums are known as 'open' top drums. This means that they have a lid which matches the diameter of the drum. The lid can be made from wood, plastic, steel or fibreboard. The lid is held in place with a metal band, normally steel, Figure 7.6. (Readers should note that there is another type of drum, having a different design, known as a 'tight head' drum where the top is permanently fixed to the body. These drums are made only from plastic or steel. Tight-head drums are used to carry liquid or semi-liquid products, with two 2-in. diameter apertures in the top which are closed by bungs.)

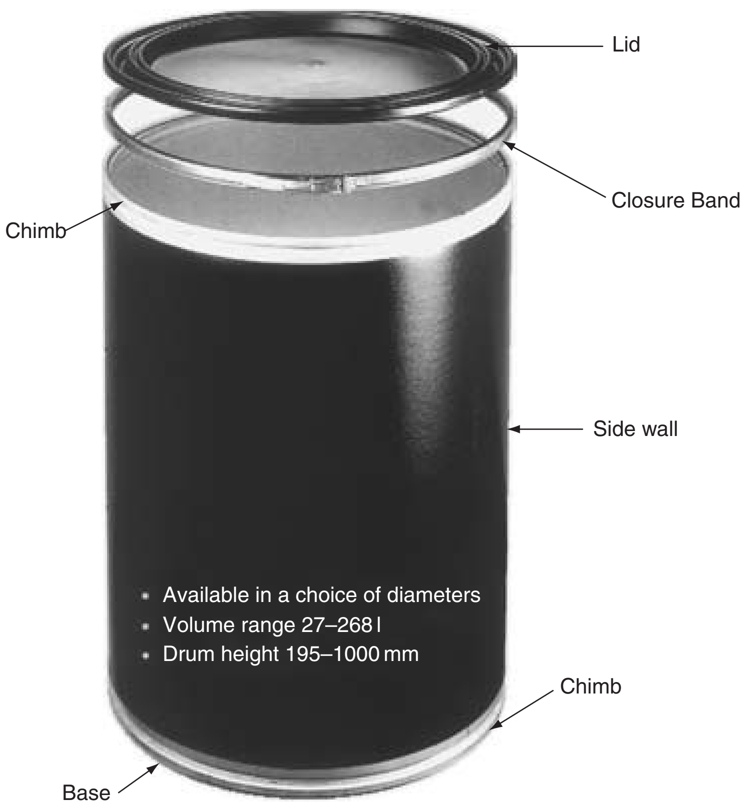

Figure 7.6 Fibre/steel fibre drum with fibre body, steel chimb top and bottom, lid and closure band.

Depending on the global manufacturing location, there is a preference for the lid material. In the UK, the most popular choice is plastic, both HDPE and LDPE. Steel lids are used in high-performance specifications. Within the USA, choice of the lid material is split approximately, evenly between plastic and fibreboard lids. Steel is used where required. In mainland Europe, a wider variety of lid is used, including plywood, steel, fibreboard and plastic.

Where a plastic lid is used, as in Figure 7.6, a 2″ aperture bung can be incorporated which can take a bung closure. This is used for filling, using a lance or pipe, and dispensing liquid and semi-liquid products, such as PVA adhesives. An option for easily dispensing the product with the drum on its side is to fit a large tap in the bung housing.

Steel lids can be either varnished, galvanised or hot-dip galvanised for corrosion/weather protection.

In order to assist the stacking of drums, and the stability of a stack of drums, it is usual for the lids to be designed in such a way that they locate within the base chimbs of the drums on the next layer. For drum specifications that require an air-tight seal, a gasket is incorporated into the plastic or steel lid. Gasket material varies between manufacturers, but the most common is a polyurethane foam gasket flowed into the lid, or a rubber gasket ring bonded to the lid.

The choice of the lid material comes down to cost and performance requirements, all the materials quoted being accepted around the world.

There are several ways of securing the lid to a drum:

- For the design of drum shown in Figure 7.6, with a metal chimb at both ends, for example Fibrestar 'Leverpak', the lid is secured in place by a metal closure band or closure ring. The ring is normally made of steel and galvanised for anti-corrosion protection. The locking-handle design varies around the world. There are two basic designs: one incorporates a locking latch, while the other incorporates a one-piece handle with the provision for a security seal.
- The majority of closure-band designs allow for the use of a tamper evident security seal. There are many designs of standard industry seals, but one of the most popular is known as the 'fir tree' or 'Christmas tree' seal.
- For drum styles that have slip on lids, such as those shown in Figures 7.3 and 7.4, the end-user would usually tape it in place with wide self-adhesive tape.
- The square cross-section all-fibre drum, Figure 7.2, has a provision for securing the lid by means of plastic tie straps, which are inserted through a set of holes in its corners.

7.4 Performance

Fibre drums are used for the carriage of dry powders, granules, pastes and semi-liquid products and other materials. As already noted, the main industrial sectors that use fibre drums are the chemical, pharmaceutical and foodstuff sectors.

Fibre drums which conform with UN Packaging Group I, II or III Standards are often used to transport hazardous products in dry/solid form. Fibre drums cannot be used to transport or pack hazardous liquids. Tests are clearly laid down in the UN *Orange Book*, which defines the drum specifications that can be used for specific products.

Every country has its own national testing authority to undertake and/or validate testing carried out in other testing facilities. This testing may be carried out in facilities owned by drum manufacturers, provided such facilities have been approved by the national testing authority. The national testing authority issues certificates when test data is submitted to it in the required manner.

The tests themselves are clearly laid down by the UN. They incorporate a variety of drop tests at different angles of drum impact, along with a stacking test, at 23 °C, 50% RH.

Stacking performance, due to the very nature of the fibre drum being a bespoke designed container for a specific, vertically stacked application, means that the stacking performance or capability will vary as between the various sizes, design and specification of drum. As a guideline, a drum for packing 25 kg (55 lb) of product could be designed to allow a maximum of 10-high stacking. Whereas a drum for packing 200 kg (440 lb) of product could be designed to allow a maximum of 3 high stacking.

Handling of fibre drums can be undertaken manually, but above 50 kg (110 lb) handling would typically be by means of vacuum lifting, mechanical drum-handling equipment or forklift truck. Fibre drums can be handled by all these methods.

When fibre drums are used to pack moisture sensitive and flavour or aroma sensitive, semi-liquid and liquid products, the interior of the drum is integrally lined with a polyethylene-lined paper or a PE aluminium foil lined paper, thus stopping the product from penetrating the fibre sidewall body. Such barrier lining protects the product from losing moisture, flavour or aroma and prevents contaminating odours, flavours and aromas from affecting the product. The base joint is also normally sealed with a caulking compound to prevent the liquid from leaking through the joint, whilst the lid will include a gasket. When required for a liquid, or semi-liquid product, a PE strip is heat sealed over the lap join on the inside of the straight wound drum to ensure that the product is not absorbed by the otherwise exposed (raw) edge of paper.

The use of an integral barrier material plus caulking allows drums to be used without the need for a separate loose polythene liner where the product requires that type of protection. Hot-molten products which solidify on cooling can be packed in fibre drums which have silicone-coated paper as the inside liner of the drum. Removal of the product is usually facilitated by cutting away the container or by the use of special drum heating equipment.

Fibre drums which are required to be suitable for external storage – the exterior surface of the sidewall body is likely to be exposed to the natural elements such as rain, snow, frost and sun – will incorporate a weatherproof barrier or coating and the lid will include a gasket for improved sealing. Fibre drums can be externally varnished to provide moisture protection.

The vast majority of fibre drum users, when packing, for example dry powders, would use a separate plastic bag, usually polyethylene (PE), as the first level of protection, Figure 7.7. Other higher specification coextrusions can also be used. The bags can be inserted by the drum manufacturer. Bags can be fixed to the drum base by heat sealing or with the use of a semi-permanent adhesive. This has several advantages:

- drums are ready to use when delivered to the end-user
- end-user stock control and labour costs are lower
- fixed bags speed up product discharge and prevent them, accidentally, entering reactors and blenders
- semi-permanently fixed bags are easily removed from the drum for reuse or disposal.

If the highest barrier/moisture protection is required the drum would, depending on the product, have a PE/aluminium foil lining or PE barrier built into the drum sidewall, with a gasket seal added to the lid.

Fibre drums incorporating a bag with high barrier properties can be used for aseptic, hot-fill packaging.

Fibre drums with recessed ends provide edge protection for reels of materials such as plastic film, aluminium foil and rolls of plastic sheeting and floor coverings.

The wire-manufacturing industry uses a special design of fibre drum, which incorporates an additional core secured into the base of the drum. There is a choice of design. The core may be glued around a stapled-in locating disc, or it may be glued into a hole formed by a ‘donut’ shaped base disc. Wire and cable products are packed in the void between the inner core and the drum sidewall. Drums such as these are used for long duration feeding of welding wire and other similar products, thereby reducing the number of changeovers for manufacturers.

Figure 7.7 Inserted plastic bag.

Cleanliness of the drums is an important feature and some customers, such as those in the pharmaceutical/fine chemicals sector, require packs that have passed through an air-wash system which removes fibrous debris from the inside of the drum, as shown in Figure 7.8.

7.5 Decoration, stacking and handling

The standard brown/beige fibre drum can be roller coated either with a colour or clear varnish, to provide a wipe-clean surface, corporate image ('house' or brand colour) and, as noted above, a moisture-resistant surface. Water-based inks and varnishes also can be used.

The body can also be silk screen printed, normally up to a maximum of three colours. Printing can include product/user instructions, safety and hazard-warning data. If the design required and volume required are cost effective, a pre-printed outer wrap can be applied when the cylinder is manufactured, hence allowing multi-colour complex designs to be added to the fibre drum.

Labels can also be applied to the drum body if required, and these labels, including the adhesive, are usually application specific, for example for internal or external storage. Where the label is to be applied by the filler the fibre drum manufacturer can print a label location guide on the drum surface to enable the filler to position the labels correctly.

Pigmented plastic lids are available to complement drum sidewall decoration.

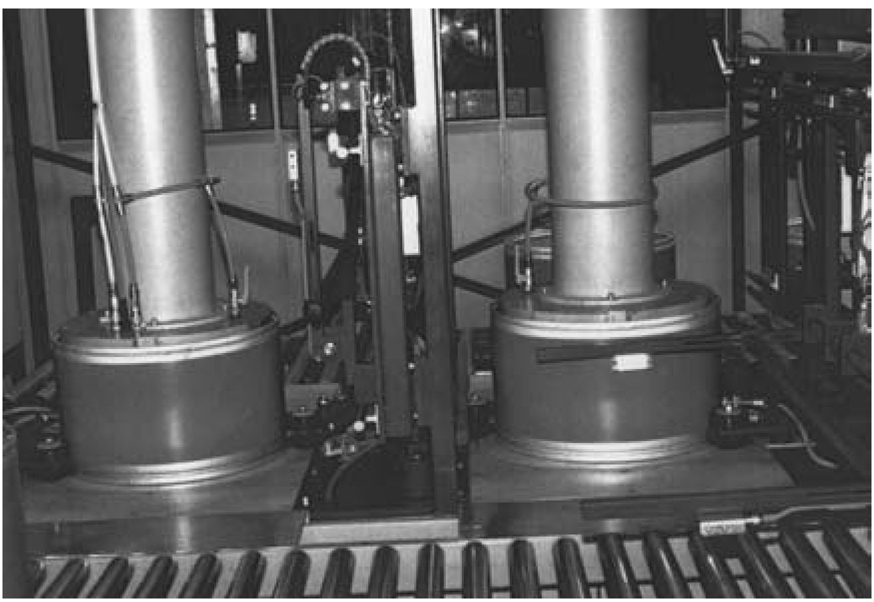

Figure 7.8 Drums in air-cleaning facility.

7.6 Waste management

Fibre drums can either be reused, the component materials recovered and recycled, or disposed of in energy-to-waste systems. Internationally agreed identification code data and a recyling logo can be applied to drum sidewalls and bases which indicate their composition (SEFFI, 2004). This information is used as a guide to recycling. Fibre drum manufacturers can provide information and support on all environmental and waste management issues. This can include advice with respect to drum recycling companies and equipment to assist recycling.

7.7 Summary of the advantages of fibre drums

- Bespoke designed pack, matching customers' specific requirements
- Cost effective compared with metal alternatives
- Available globally in a wide range of diameters, heights and styles
- The fibre is naturally renewable and both the fibre and the other components are easily recoverable and recyclable
- Fibre drums can incorporate linings and barriers, increasing their performance and range of applications
- Approved for the packing and transportation of hazardous solids
- Used predominantly by the chemical, pharmaceutical and food industries.

7.8 Specifications and standards

A British Standard for fibreboard drums, BS 1596:1992, provides a minimum specification, a series of definitions and the normal size/capacity range. BS 1133-7.4: 1989 Packaging Code describing paper and board wrappers and containers including fibreboard drums is also a current standard.

European standard BS EN 12710:2000 covers the construction requirements of fibre drums in the 15–2501 range.

Hazardous products which are allowed to be packed in fibre drums are listed in the UN *Orange Book*, with its proper title being, *Recommendations on the Transport of Dangerous Goods: Model Regulations*.

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Edited by Mark J. Kirwan

8 Multiwall paper sacks

The Environmental and Technical Association for the Paper Sack Industry

8.1 Introduction

Multiwall paper sacks are concentric tubes of 2–6 layers (or plies) of paper with a choice in the type of end closure. Many different designs of paper sack will be described in this chapter. The designs differ mainly in respect of whether the sack is to be filled through an open mouth or a valve, which in turn depends on the product and the volume to be handled. Valve designs are closed automatically as a consequence of their design and there are various methods, including sewing and tying with wire, for closing the open mouth paper sack.

Other key features of the specification are the number of plies and the types of paper and other materials used by way of paper coatings, impregnations, laminations or whether separate liners are incorporated depending on the product, protection and performance required.

Paper sacks were developed in the late 1800s and became a major type of packaging from the 1920s. Their traditional uses from the early days were building materials, chiefly cement, foods such as flour, dried milk, sugar and potatoes, animal feed, chemicals and fertilisers. Today, it is claimed that over 2000 different products are packed in paper sacks in the USA. Advantages for paper sacks include easy bulk palletisation, stacking and handling and the fact that plain paper sacks, as for instance are used for cement, are permeable to air allowing the products to 'breathe'.

Paper sacks have been used to pack up to 50 kg of products but this weight has been reduced to ease handling and meet health and safety requirements. Furthermore with a wide use of paper sacks in the retail sector today, where there are customer convenience needs, the weights range from 25 down to 10 and 5 kg. Products packed for the retail trade include cement and similar materials in DIY, together with gardening products, pet food and pet litter. The retail trade also requires a higher quality of printing and features such as carrying handles.

Over four billion paper sacks are used per annum (pa) in Europe and over three billion pa in the USA. The typical end-use range is shown in Table 8.1.

8.2 Sack designs

There is a wide range of sack designs from which users may choose to meet their requirements. When making the choice, account will need to be taken of the

Table 8.1 End-uses of paper sacks (in Euro)

European end-uses for 2001		
Product end-use	Quantity used in 2001 (in million units)	%
Building materials	2204	50.1
Mineral products	158	3.6
Food products	704	16.0
Animal feed	496	11.3
Chemicals and fertilisers	448	10.2
Refuse sacks	88	2.0
Seeds	104	2.4
Miscellaneous	195	4.4
Total	4397	100.0

Source: Eurosac.

properties of the product to be packaged, the requirement of the filling, closing and distribution systems and the needs of the final user.

8.2.1 Types of sacks

The first basic division of paper sack types is *open mouth* and *valved* designs. Each of these may be subdivided into *pasted* or *sewn* closure types and into further subdivisions by the sack body being either *gusseted* or *flat*. Further minor variations can also arise from the inclusion of certain other design features.

Not all the possible combinations of design features are practicable due to the restrictions in manufacturing machinery or sack design geometry.

A schematic range of multiwall sack designs are shown in Figures 8.1 and 8.2. Each design will now be discussed briefly outlining the important features, advantages and limitations, etc.

8.2.1.1 Open mouth sacks

There are four basic open-mouth sack designs depending on the type of closure types, namely sewn, pasted, pinched and double-folded closures (Fig. 8.1).

Open mouth, sewn, flat sack

This is the simplest form of multiwall paper sack (Fig. 8.1a). It may be directly compared with the traditional jute and cotton sacks that have been used for centuries to pack granular and powdered products. The name 'pillow sack' is sometimes used to describe this design, which has an inherent disadvantage in that, when filled, corners tend to jut out. These can give rise to difficulties after palletising, by snagging against objects to cause tearing and leakage.

There are certain considerations that may dictate the use of these sacks. For instance, it is possible to include a layflat seamless polyethylene film tube as the

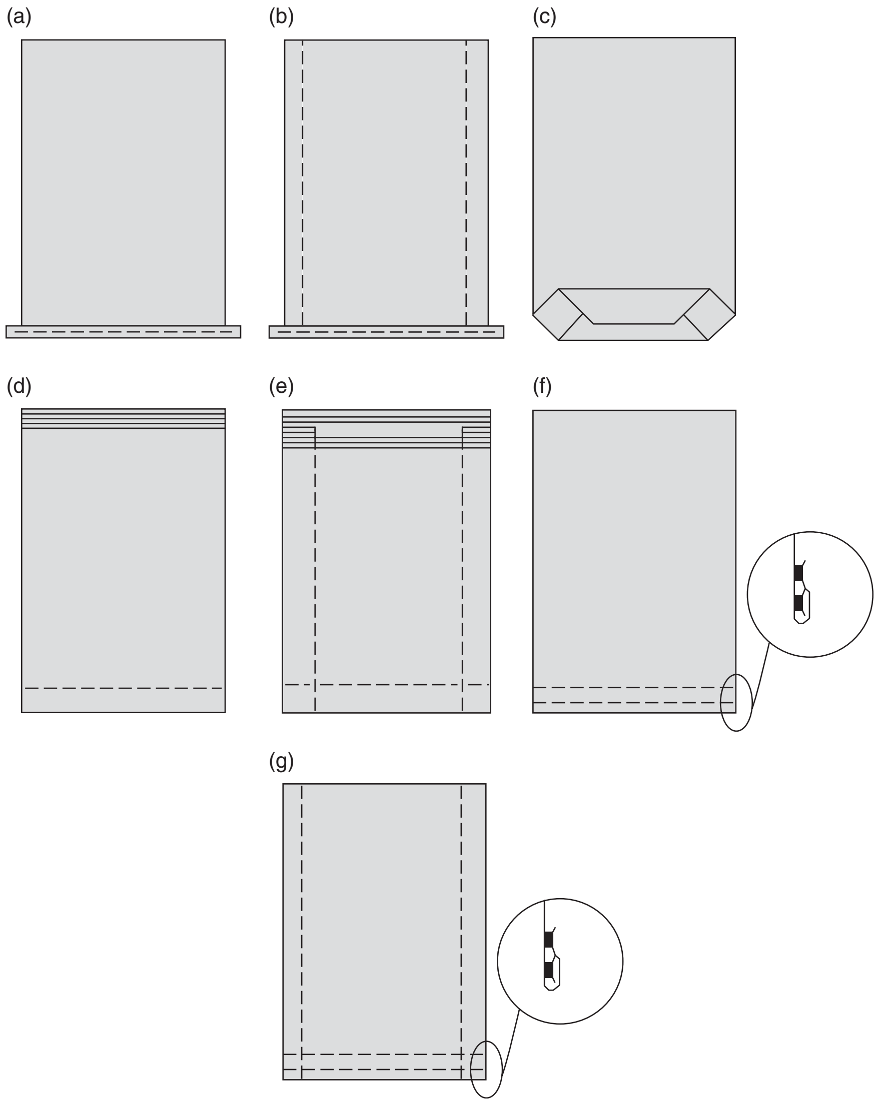

Figure 8.1 A schematic range of open mouth multiwall sack designs: (a) sewn, flat; (b) sewn, gusseted; (c) pasted, flat; (d) pinch closed, flat; (e) pinch closed, gusseted; (f) pasted, double-folded, flat; and (g) pasted, double-folded, gusseted.

innermost ply. Such a sack may be heat-sealed within the line of the sewing to give an hermetic closure. These layflat film tubes may also be made longer than the paper plies by including a Z-fold section in the tube length. This enables it to be pulled out, filled and closed as a separate operation prior to the closure of the paper plies.

Open mouth, sewn, gusseted sack

By having gussets inserted at the sides of the sack, the user is ensured of a rectangular block shape after filling (Fig. 8.1b). The choice of face width, gusset depth and sack length will be governed by factors mainly associated with the volume of contents and palletising requirements.

Because of the gusset folds, it is not possible to include an internal polyethylene layflat film liner contiguous with the paper plies. In certain circumstances, it is feasible to include an edge-folded layflat tube of polyethylene film, which is inserted into one sidefold of each gusset. A Z-fold may also be included in this construction, as with the open mouth, sewn, flat sack.

The most popular gusset sizes are 75 mm, 100 mm, 125 mm and 200 mm. Larger gussets than these are possible but the filled shape of the sack becomes less rectangular.

Open mouth, pasted, flat sack

The pasted bottom closure (Fig. 8.1c) will automatically give filled sacks a rectangular end, and a sewn closure at the top will allow them to be either butted or overlapped when stacked onto pallets. A layflat polyethylene film liner can be incorporated into this sack during manufacture, which may be made longer than the sack plies by the inclusion of a Z-fold.

The open mouth, pasted, flat sack may be designed as a baler bag. Here the sack is a preformed wrapper for packing single items, quantities of small containers, trays of eggs, etc. Baler bags can be made with bottom widths up to approximately 350 mm. The top of a baler bag is generally folded down and sealed by either tape or adhesive.

Open mouth, pinch closed, flat sack

The pinch closed sack (Fig. 8.1d) is one with an envelope-type closure, as the design uses an extended flap at each end, which is folded over and glued down. This allows a fully sealed barrier sack to be made using a thermoplastic-coated aluminium foil to paper laminate as the innermost ply. This may be sealed at the side seam and at each closure to encapsulate the contents.

Pre-applied hotmelt adhesive may be employed on the open mouth flap of the sack for the user to close by re-activating with hot air.

Performance figures for pinch closed sacks compared with the same size of sewn sacks show the design makes a stronger sack, which effectively means that they may be of lighter construction to give equal performance.

If a barrier ply is present next to the sack contents, it is generally important for the sack closure to include an effective seal of the barrier ply. With pinch closed sacks, a heat seal may be included above the fold line of the flap so that, after closure, no stress is put on the heat seal by the contents. By using a layflat tube of polyethylene film for the innermost ply, which is heat sealed at both closures, the product can be very effectively encapsulated.

There is a variation to this design in which the open mouth flap is trimmed away during the final stage of manufacture to allow the user to make a normal sewn closure. A tear string may be incorporated into the closed flap, during manufacture, as an easy-opening device.

Open mouth, pinch closed, gusseted sack

The inclusion of gussets overcomes the problem of sharp corners and the filled sack can assume an almost perfect rectangular block shape (Fig. 8.1e). As with sewn sacks, the gussets prevent the incorporation of a contiguous polyethylene film tube but a side-folded layflat film tube inserted into one side of each gusset is possible. The design variation, in which the top flap is trimmed off to allow closure by sewing, is also available, as is the easy-opening tear string.

Open mouth, pasted, double folded, flat sack

A pasted bottom closure may be achieved on a flush-cut multiwall paper tube by simply folding the bottom edge over twice and gluing (Fig. 8.1f). To ensure a strong closure, and to resist any tendency for the bottom to unfold, the outer ply is slit on the edges to form a flap which is adhered to the body of the sack above the folding. These sacks are also known as 'double fold' and 'roll bottom' sacks. The user closure is normally made by sewing. A layflat polyethylene film may be incorporated as the innermost ply at the tubing stage of manufacture.

Open mouth, pasted, double folded, gusseted sack

The presence of gussets results in a rectangular shape after filling, and the packer/filler closure is normally made by sewing (Fig. 8.1g). A contiguous layflat tube cannot be incorporated into the construction but it is possible to include an edge-folded layflat polyethylene film tube into one side of each gusset.

8.2.1.2 Valved sacks

A valved sack is closed at both ends during manufacture and includes an opening for filling purposes in one corner. Valved sack designs may be divided in a similar manner to open mouth sacks; first into sewn and pasted types and then into the gusseted and flat varieties (Fig. 8.2). There is a further subdivision of the valved, pasted, flat sacks into those made from either stepped-end or flush-cut multiwall tubes.

Valved, sewn, flat sack

The valve of this sack can be inserted only by a complex manual operation during manufacture and the filled sack has the disadvantage of protruding corners (Fig. 8.2a). The valved, pasted, flat sack has superseded it almost totally.

Valved, sewn, gusseted sack

This design of sack also requires complex manual corner folding for the valve insertion stage of manufacture (Fig. 8.2b). Although the presence of the gussets overcomes the protruding corners problem, the demand for this type of sack is negligible and it has largely been replaced by valved, pasted sack designs.

Valved, pasted, flush-cut, flat sack

In the manufacture of paper sacks, the paper is drawn from the reels and formed into a flattened tube which is then separated into the required length needed for the

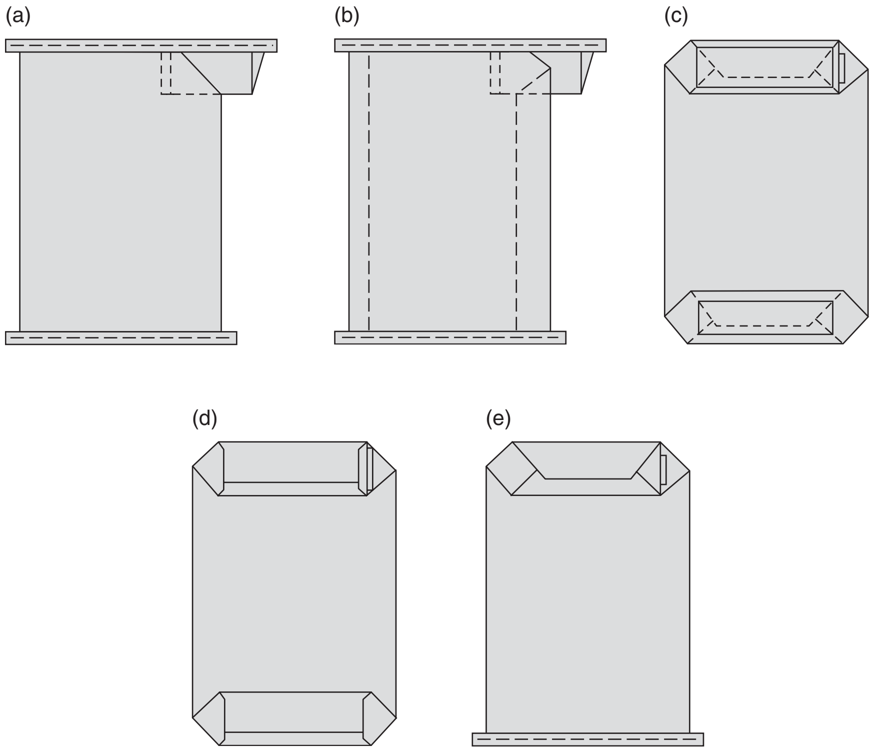

Figure 8.2 A schematic range of valved multiwall sack designs: (a) sewn, flat; (b) sewn, gusseted; (c) pasted, flush-cut, flat; (d) pasted, stepped-end, flat; and (e) pasted and sewn, flat.

sacks. With flush-cut sacks, the preformed tube is cut into lengths with a guillotine or chop knife (Fig. 8.2c).

The use of a flush-cut tube is the simplest way to achieve a folded and pasted closure. Sacks made in this way are usually given an additional paper-capping strip on each end to strengthen the closure and resist sifting. Alternatively, longitudinal slits may be made in the ends, down to the diagonal fold, to form rectangular flaps for pasting down.

Valved, pasted, stepped-end, flat sack

The multi-ply tubes for stepped-end sacks are made in similar manner to those for flush-cut sacks, but the individual plies are perforated before the tube is formed (Fig. 8.2d). The tube is separated into sack lengths by pulling apart the perforations. By this means the ply ends may be stepped relative to each other, and by perforating in a different pattern for each ply, it is possible to substantially increase the area that is available for folding in and pasting. The stepping also allows the individual ends of the plies to be pasted and incorporated directly into the closure. Stepped-end sacks do not generally require caps and may be made from multiwall tubes of two to six plies.

Valved, pasted and sewn, flat sack
This design of sack enables a pasted valve to be used for filling and allows the final customer easier access to contents through the sewing line (Fig. 8.2e). Carrying handles may also be included with the sewing line.

8.2.2 Valve design

Valves used in paper sacks are held closed after filling, either by the pressure of the contents of the sack or by the folding down of an external sleeve. These are termed ‘internal’ and ‘external’ valves respectively and either design may be incorporated into sewn or pasted types of sacks. There are many possible combinations of the various valve design features, especially with pasted valves, and it is not possible to illustrate all of these in this guide. (Users are advised to consult paper sack suppliers for more specific information.)

8.2.2.1 Valve designs for sewn sacks
Sewn sack valves are made by folding in one corner of the sack prior to sewing the closure. An extended corner or ‘notch’ may be employed in the multi-ply tube to allow a greater length of paper to be folded in to form the valve.

The simplest valve is made without the use of any additional paper, but generally a folded paper patch is inserted and sewn in as the internal or external component. Figure 8.3 shows the three basic sewn valves.

8.2.2.2 Valve designs for pasted sacks
The simplest type of filling valve is for one corner of a capped flush-cut pasted sack to be left unglued. Such a design is weak and a strengthening patch of paper is usually included under the corner fold.

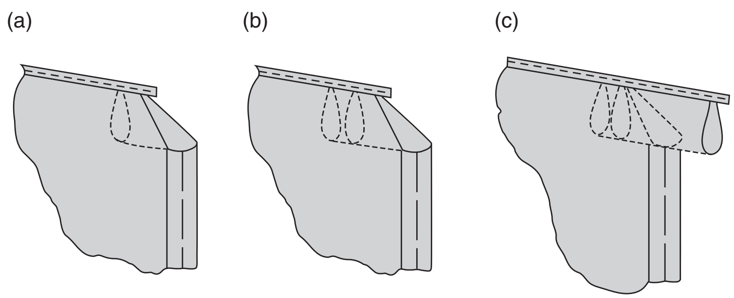

Figure 8.3 Valve designs for sewn sacks: (a) plain sewn valve; (b) internal sewn valve; and (c) exterior sewn valve.

An improved type of valve is achieved by the inclusion of a flattened tube of paper or plastic film into one corner to form either an internal or an external valve. In addition to the tubular component of the valve, it is possible to insert other paper or plastic components to produce a whole variety of designs to improve the efficiency of the valve or to tailor the valve design to the filling requirements.

It is not possible to illustrate all the combinations of design features, but Figure 8.4 shows the six basic types of valve design used in pasted sacks.

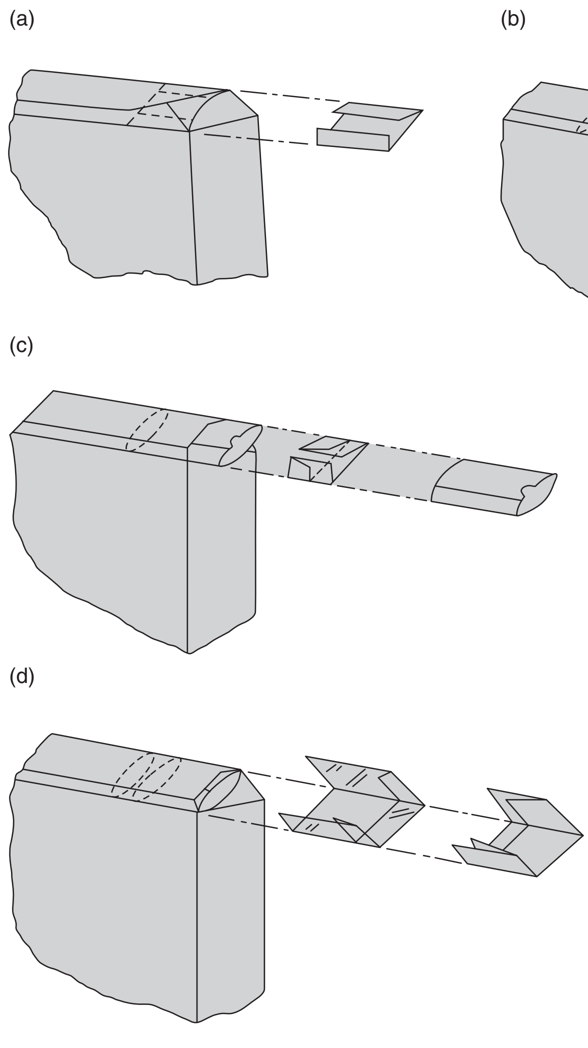

Figure 8.4 Valve designs for pasted sacks: (a) patch valve; (b) internal sleeve valve; (c) external sleeve valve; (d) small valve in larger bottom; (e) polyethylene film valve; and (f) polyethylene tubular sleeve valve.

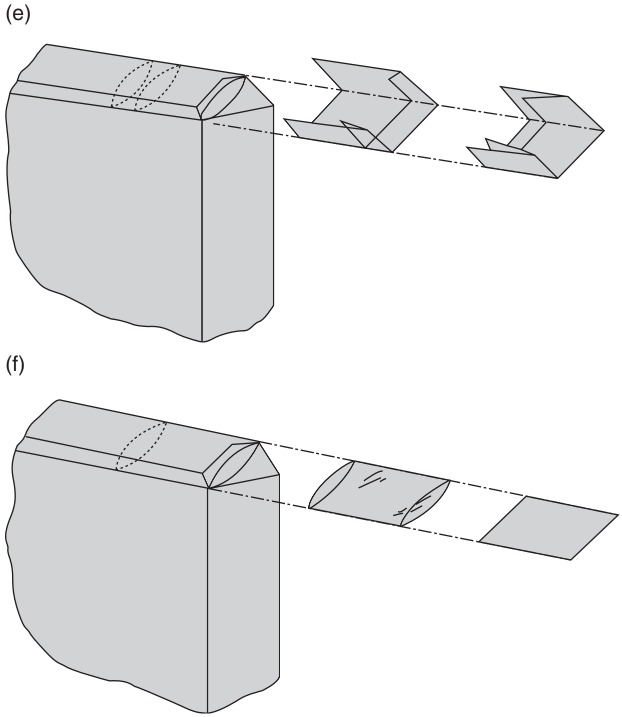

Figure 8.4 (Continued).

Patch valve
A single ply of folded paper is positioned in the valve opening to give strength and rigidity (Fig. 8.4a).

Internal sleeve valve
A tubular paper sleeve is positioned in the valve opening and protruding into the sack (Fig. 8.4b).

External sleeve valve
This type comprises a tubular sleeve extending out of the valve opening, often with an internal pocket formed by a folded paper patch (Fig. 8.4c). This sleeve can be supplied with a thumb notch to facilitate easy opening.

Small valve in larger bottom
This is similar in formation to the external sleeve valve but includes a preformed valve sleeve smaller than the bottom width (Fig. 8.4d).

Polyethylene film valve
This valve is comprised of two sheets, one paper and one polyethylene, generally slightly offset from each other (Fig. 8.4e). They are inserted together, folded and positioned in the sack aperture to form an internal valve.

Polyethylene tubular sleeve valve
A paper strip is attached to a tubular polyethylene sleeve and positioned in the sack aperture (Fig. 8.4f). The width of the sleeve may be less than or equal to the width of the bottom.

8.2.3 Sewn closures

There is a choice for the user of the type of sewing and the materials used in sewn closures. Stitching can be with either one or two sewing threads and may be in combination with other ancillary crepe paper tape and cords.

8.2.3.1 Single sewing or chain stitch
Single sewing, Figure 8.5, can be readily unravelled and is a feature that may be used effectively as an easy-opening device by incorporating a ripcord.

8.2.3.2 Double sewing
With double sewing, Figure 8.6, a second thread loops through and round the stitches on the underside during the sewing process and is very effective in increasing resistance to unravelling. This stitch is not used for easy opening.

8.2.3.3 Sewn closure constructions
In addition to sewing threads, a number of other materials may be used in forming the sewn closure.

Crepe tape may be folded over the end of the flattened multi-ply tube and sewn through. This has the effect of cushioning the stitching and assisting in preventing the sifting out of fine powdery contents. Different colours of crepe tape may be used for product identification.

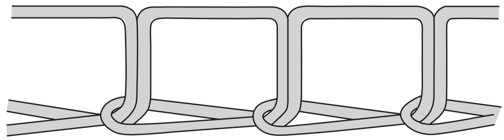

Figure 8.5 Single sewing or chain stitch.

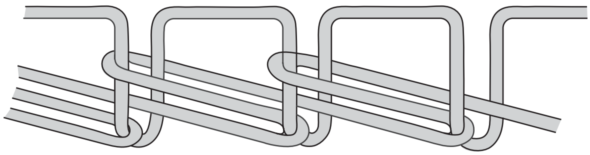

Figure 8.6 Double sewing.

In addition to the crepe tape, sewing may be made through a jute string generally called a filler cord, a soft cotton string called a filter cord, or a double-folded paper tape. These cushion and reinforce the stitches and will also tend to block up the sewing holes and resist sifting.

An additional crepe tape may be applied over the stitching and adhered with a quick-setting latex adhesive to fully seal the sewing holes. Latexed closures are used as a means of preventing the entry of contamination and sifting of contents.

For users who require a carry-home pack, it is possible to incorporate a carrying handle into the manufacturer's sewing line. One design uses a thick polypropylene string, in a similar manner to the jute filler cord, which is left unsewn at the centre portion of the face. An alternative is a pre-made plastic handle, generally of low density polyethylene (LDPE), which is inserted under the sewing tape and sewn in.

8.3 Sack materials

The materials used in multiwall paper sacks are most easily divided into those of the sack body and the ancillary materials employed elsewhere.

8.3.1 Sack body material

The construction of a multiwall paper sack is based on the use of sack kraft – a strong, durable and versatile paper that can be coated, laminated with other materials, modified to give it additional strength properties, printed, glued and sewn in the converting operations to produce a product of high strength and quality.

8.3.1.1 Sack krafts

The word 'kraft' means 'strong' in a number of languages and sack kraft is so named as it is one of the strongest papers made. It is manufactured using woodpulp fibres made by the sulphate papermaking process. This uses sodium sulphate as the main chemical, which produces strong, undegraded cellulose fibres.

The sheet is formed by flowing a suspension of wood-pulp fibres in water onto a moving wire mesh. Most of the water drains away through the wire to leave a consolidated layer of intermeshed fibres. This is then pressed by mechanical presses, dried by steam-heated rolls and then wound into reels.

This mode of manufacture imparts different properties to the paper in the direction of movement, compared to the properties across the sheet. For example, sack kraft has higher tensile and lower stretch properties in the machine direction (MD) compared with those in the cross direction (CD). This arises from the random lattice-work orientation of the fibres as they form a sheet on the moving wire in the papermaking process. Both the tensile and the stretch properties contribute to strength, and the overall effect is high sheet toughness in both directions.

Paper produced from cellulose fibres will readily absorb water unless the sheet is treated by 'sizing' with an additive to inhibit ingress of water into the dry sheet.

All standard sack kraft is sized on the paper machine, generally with rosin. The degree of sizing is measured by the Cobb test (ISO 535: 1991).

Sizing does not impart strength-when-wet properties to the sheet because it only slows down the rate at which the paper absorbs water. Wet strength is achieved by the addition of a liquid resin during the papermaking process. This locks the fibres together at their points of contact so that they are not readily pulled apart when the sheet is soaking wet. Normal wet-strength treatment will allow approximately 20–30% of the strength of the dry sheet to be retained after the sheet has been thoroughly soaked in water.

The natural colour of sack kraft varies from dark to light brown, a shade which is suitable for many applications. By bleaching the wood-pulp fibres during manufacture, a pure white sack kraft can be made. When used on the outside of a paper sack, the white appearance enhances presentation and provides an improved surface for printing. In addition to the natural and bleached colours, a range of coloured sack krafts can be made by the addition of dyes during the papermaking process or by surface-colouring the paper after it has been manufactured. The range of colours available is normally restricted to a number of standard shades with any one manufacturer, and users should consult sack supplier to obtain details and samples.

8.3.1.2 Extensible sack krafts

The term 'extensible' is used to describe those sack krafts which have been given enhanced MD stretch properties, either in the papermaking process or as a subsequent operation. This increase of stretch is generally associated with a slightly lower corresponding tensile but the overall effect is for most extensible krafts to be tougher than normal sack kraft. All are available in normal and wet-strength grades, either natural or bleached.

Low-stretch creped (LSC) krafts

These are sack krafts that have been subjected to a wet-creping process, usually on the papermaking machine, to give a greater MD stretch. The creping process permanently wrinkles the sheet so it is rougher in appearance, more porous and more flexible than normal kraft.

Microcreped krafts

These sheets are mechanically crimped, or compacted, with a barely visible creping in the MD during papermaking, to give greater MD stretch. Typical of a number of systems for producing such paper is the 'Clupak' process.

8.3.1.3 Coated sack krafts

Certain commodities packaged in paper sacks require some form of barrier protection to restrict either the ingress or the egress of vapours or liquids. For this purpose, sack krafts can be coated with a range of materials to give strong, flexible barrier sheets for inclusion in paper-sack constructions.

Protection of the packaged material from the water vapour in the atmosphere is a common user requirement, and the barrier generally used is polyethylene coated sack kraft. This is readily available in a range of grades to suit most requirements.

8.3.1.4 Laminated sack krafts

For greater strength or barrier protection of sensitive commodities, laminates of sack kraft with foil, film, woven or non-woven plastics maybe utilised. These materials are relatively more expensive than normal and coated sack krafts, and the choice would depend on the barrier requirements and/or the hazard level of the distribution system.

8.3.1.5 Non-paper materials

A number of non-paper materials, such as plastic film, layflat plastic-film tubing, woven or non-woven plastics, may be included in paper-sack constructions where high barrier or high strength is a prime requirement. The use of thermoplastic film can make it possible to include a heat seal in the closure of some types of sack. There are limitations to the use of these materials in the manufacture of certain types of paper sacks. For example, it may not be possible to include some of the reinforced and high-strength materials into stepped-end sacks, as these are not compatible with the normal manufacturing process.

8.3.1.6 Special purpose sack krafts

Although the majority of user requirements can be met by paper-sack constructions using combinations of materials described in the previous subsections, there is occasionally a need for a special material for a specific requirement. A number of such special purpose materials which meet particular requirements are discussed in Section 8.3.1.7. Any such need should be discussed with sack manufacturers for advice on the most appropriate material that can be used in specific situations.

8.3.1.7 Summary of sack body materials

The following notes give information on most sack-body materials in general use, but are not intended to be fully comprehensive. Where applicable, abbreviations in general use have been included in brackets after the name of the material. There is no international agreement on names and abbreviations, and where there is more than one alternative in general use, all are included.

Natural sack kraft (NK or K)

Generally in grammages (substances) of 70 g/m^2, 80 g/m^2, 90 g/m^2 and 100 g/m^2. Higher, lower and intermediate grammages are obtainable but not usually held as stock by sack manufacturers. It may be used generally throughout a sack in all plies.

Wet-strength kraft (WIS or WS)

The most generally used grammages are 70 g/m^2, 80 g/m^2 and 100 g/m^2 but other grammages are available, although not as normal stock items. Widely used for the outer plies of sacks which maybe exposed to rain.

Bleached kraft (BK or BIK or FB)
Available mainly in 80 g/m^2 and 90 g/m^2 grades, but other grammages are available if required. Mainly used as the outside ply to enhance presentation.

Wet-strength bleached kraft (B/WS or FBWS)
The general trade standard is 80 g/m^2 but higher and lower grammages can be obtained if required. Used for the outside plies of sacks which are liable to become exposed to rain.

Coloured krafts
Generally available in the 80 g/m^2 grade with or without wet-strength additive. The colour required should be written in full to prevent confusion with paper grade abbreviations. Bleached or natural kraft may be used as the base paper, each of which will give a distinctly different shade to the imparted colour.

Low-stretch crepe (LSC)
Available as natural or bleached, and generally as the 80 g/m^2 grade, with or without wet-strength additive. The normal level of creping is between 5 and 9% for MD stretch. The creping process also imparts higher air porosity to the sheet.

Microcreped fully extensible kraft (EK or ExtK)
Such krafts are defined as having an MD stretch greater than 7%. It is a tough paper that can be very similar in appearance to standard sack kraft as the microcreping is barely apparent. It is available in both natural and bleached grades with or without wet strength, and in the same range of grammages as normal kraft.

Microcreped semi-extensible kraft (S/EK or SExtK)
The shortened name in general usage for this material is ‘semi-extensible kraft’. It is defined as having the MD stretch within the range 4–7%. The same grades are available as for fully extensible kraft. The stiffness of semi-extensible kraft allows good runnability on converting machinery, similar to normal sack kraft, and high field performance in the finished sacks, making it an ideal material for many applications.

Polyethylene-coated kraft (polykraft or PEK)
Low density polyethylene has reasonable moisture and water vapour barrier properties, but its grease and odour barrier properties are not good. It is generally available with 80 g/m^2 natural kraft as the base paper and 15 g/m^2, 23 g/m^2 or 34 g/m^2 of coated polyethylene. The most popular and the most general purpose coating weight is 23 g/m^2. A coating weight of 34 g/m^2 is one which is relatively free from pinholes and film rupture caused by surface fibres. The 15 g/m^2 coating weight is not a good barrier to water vapour but does resist the ingress of liquid moisture and may also be used as a means of preventing paper fibre contamination of the packaged product.

Coating weights above 34 g/m^2 cause the paper to curl and give serious problems in the converting operation and are not normally recommended.

Silicone coated kraft
The silicone coating is not a barrier ply for liquids or vapours. It is a release coating used on the inner surface of the innermost ply to enable sack kraft to be easily stripped away from sticky or mastic contents.

Waxed kraft
The wax coating will partially or totally impregnate the sheet. It is used only to a small extent, mainly as a grease or odour barrier. Although it has some moisture and moisture vapour barrier properties, these are inferior to those of other materials available.

Polyvinylidene dichloride coated kraft
Polyvinylidene dichloride is an excellent barrier for moisture, moisture vapour, grease, solvents, oil and odours. It is appreciably more costly than polyethylene coated kraft and its use is justified where a good odour or grease barrier is a requirement.

Foil laminated kraft
Aluminium foil is virtually a complete barrier for odours, grease and water vapour. In paper sacks, it is generally used at thicknesses between 15 and 25 μ as a laminate with sack kraft. At 25 μ thickness, it is virtually pinhole-free. Below this thickness, the effect of the presence of pinholes is virtually eliminated by the use of a plastic coating, usually polyethylene or ionomer. Either of these two materials may also be used to laminate the foil to the sack kraft. The plastic coating will also allow a sack closure to include a heat seal with certain designs of sacks.

Bitumen laminates
Coatings of bitumen on sack kraft and laminates of two krafts or LSC kraft sheets, using bitumen as a laminant, have been used in paper sack manufacture since the early years. It is a general purpose barrier against moisture and water vapour, but has been largely superseded by polyethylene coated kraft. It is not a high performance barrier because a totally continuous coating of bitumen is not easy to achieve in practice. This barrier is also not resistant to creasing and the fold lines in a paper sack are weak areas of the barrier.

Vegetable parchment
This is a traditional grease-resistant material but its use has been largely superseded by plastic film or coated kraft.

Scrim and cloth laminates
Scrim laminates, comprising an open mesh woven cloth adhered to a single layer of sack kraft or sandwiched between two layers of sack kraft, will give a very high resistance to sack burstage and tear propagation. The degree of toughness of the laminate will be governed by the quality of the scrim cloth used; very open mesh cloth mainly giving resistance to tear propagation, and closer mesh, resistance to burstage.

Woven plastics/sack kraft laminates
Laminates of sack kraft and woven plastics are very tough and resistant to tear, burst and puncture. Sack kraft contributes stiffness to the laminate and the sack.

8.3.2 Ancillary materials

In addition to the materials comprising the plies of the sack, other ancillary materials are also included, being either necessary to the construction or optional, at the request of the user.

8.3.2.1 Sewing tapes
The most important requirements for sewing tapes are softness and bulk to assist the blocking of the sewing holes, and strength, flexibility and extensibility to suit the intermittent action of the sewing head. Sewing tapes are most generally made from crepe paper, with a creping level of the order of 10–12%.

Overtaping the stitching in the same operation as sewing is generally made using a wider version of the same crepe tape in conjunction with a quick-setting latex or hotmelt adhesive. Overtaping with a polyethylene coated kraft tape, either creped or non-creped, may also be used in conjunction with a heat sealing unit. This is most generally undertaken as an additional operation.

8.3.2.2 Sewing threads
Sewing threads are either made of natural cotton, synthetic filaments or a mixture of the two. Each thread is comprised of a number of strands or plies. Three and four ply threads are used for sacks containing up to five plies of paper and five-ply threads for sack constructions of six plies.

8.3.2.3 Filler (filter) cords
A cord of jute, double folded crepe tape or fibrillated plastic string may be used in the sewing line to cushion the stitches and block the sewing holes to resist the sifting of fine powders, etc. Jute and cotton cords may be applied on one or both sides of the sewing line.

A single cord or double folded crepe tape may be used in conjunction with single sewing for use as an easy-opening device.

8.3.2.4 Plastic handles
Injection-moulded LDPE carrying handles may be included in the manufacturer's sewn closure. These are inserted under the tape and sewn through during the closing operation and are available in a range of colours.

A simple carrying handle may be made using a heavy-duty polypropylene string, which is not sewn at the centre of the sack face.

8.3.2.5 Adhesives
Starch and modified starch-based adhesives are generally used for the side seams, cross pasting and end closures, generally with a wet-strength additive included. When special coatings or laminates are employed in the sack construction, synthetic emulsion adhesives may be necessary. Hotmelt adhesives may also be used with certain designs of sacks as a quick acting adhesive or as a pre-applied hotmelt adhesive which can be reactivated for the user's closure.

8.3.2.6 Printing inks
Paper sacks are generally printed with flexographic water-based printing inks which are formulations of pigments, resins and other additives for colour fastness, printing opacity, etc. Lead pigments are no longer used in these formulations. Over-varnishes are also available to give an enhanced finish.

8.3.2.7 Slip-resistant agents
There are a number of proprietary materials which may be applied to the outside of paper sacks to impart resistance to slipping during transportation. These are generally colloidal suspensions of a finely divided solid material, such as silica, in water. Such applications are reasonably effective but operators will need to exercise care in handling such sacks, as skin irritation may occur. High application levels may also give difficulties with the sliding of sacks in chutes.

8.4 Testing and test methods

In present-day papermaking, automatic controls are incorporated to check sheet properties and adjust the machine settings to ensure consistent and high quality. In addition, all finished paper coming from the machine is sampled and tested on a frequent and regular basis for quality control and quality assurance purposes. Sack manufacturers may also test the incoming consignments of sack kraft and the other materials used in their production.

Specialist equipment is required for paper testing, which must be undertaken in an atmosphere which is controlled for temperature and humidity. Paper testing is not normally undertaken by users, but a sufficient knowledge of testing and quality is needed when changing specification levels or establishing new sack specifications.

Testing encompasses the two broad areas of the materials and the finished sacks, each of which requires the application of quite different techniques and principles.

8.4.1 Sack materials

A multiwall paper sack is a flexible form of packaging and is required to resist the stresses arising from the contents as well as those of the filling, handling and distribution systems. Testing should measure properties which best relate to sack performance in these areas.

Sack kraft is made from natural fibres which will readily take up or lose moisture, depending on the ambient temperature and humidity of the air. If there is no control of this, the absorbed moisture can vary widely and will have an appreciable affect on the physical properties and test results. For this reason, it is necessary to keep sack kraft for 24 h in a controlled standard atmosphere of temperature and relative humidity (RH) before any physical testing is undertaken.

In the United Kingdom and Ireland, the standard atmosphere used in the paper-sack industry is 23 °C and 50% RH, which gives an equilibrium moisture content of approximately 9.5% to sack kraft.

Sack kraft, like all other paper materials, is composed of a mass of intermeshed fibres and any testing will show a degree of variation of properties both across and along the sheet, i.e. in the CD and MD. Because of this, it is always necessary to undertake a number of replicate tests on each sample of paper and sufficient samples to be taken from each consignment, for meaningful average results to be obtained.

There are a number of ISO, EN and British Standards (BS) on sampling, conditioning and testing, details of which are given in Table 8.5.

8.4.1.1 Strength tests

The more important of the tests for strength are those which measure the resistance to breaking or the energy needed to cause rupture.

Tensile strength

The tensile strength of paper is the maximum pulling force that a narrow strip will stand before it breaks. Generally sack kraft has a higher tensile strength in the MD compared with the CD.

It is measured by an instrument in which a strip of sack kraft is clamped between two jaws which are gradually moved apart until the strip breaks. The machine records the final force before breakage as well as the amount of stretch that has occurred.

Stretch

This is determined at the same time as the tensile strength, and is a measure of the elongation that will occur before a sheet is ruptured. The product of the tensile and stretch is an indication of the energy-absorbing ability or toughness of the sheet and may be used for comparison between materials.

Tensile energy absorption (TEA)

As the name implies, this is a test which gives a direct measurement of the energy needed to rupture a sheet. A special type of tensile tester is used, which not only measures the tensile and stretch but will integrate the two results and work out the total energy the paper strip absorbs before rupture occurs.

It is a test which is regarded as giving a better relationship to performance of finished sacks than all other tests and may therefore be used as an index when adjusting sack constructions or drawing up specifications. It is normally performed on two sets of sample strips, cut in the MD and in the CD of the sheet. The average between the two directions is normally used for comparing two or more materials.

Wet strength

Wet strength is defined as the level of strength that is retained by a paper sheet after it has become thoroughly wet, i.e. after a sample has been immersed in water for at least half an hour.

Traditionally the pneumatic burst test was used to establish the wet strength of sack kraft but tensile testers based on load cells are now used more generally for this purpose.

Normal sack kraft will possess little or no strength after immersing for half an hour in water, but wet-strength sack kraft should retain an agreed percentage of its dry strength after soaking. Approximately 30% wet-strength retention is the level most generally used within the paper sack industry.

Burst strength

The burst test is one that has largely gone out of favour, mainly because of the extreme variability of the results. In the test, a sample of paper is clamped above a rubber diaphragm covering an orifice of approximately 30 mm diameter. Air or hydraulic pressure is gradually increased under the diaphragm which expands until the paper sheet becomes ruptured. Hydraulic burst testers are not sufficiently sensitive for sack-kraft testing, and pneumatic instruments are more generally employed.

Although it is regarded as an unsuitable test for assessing paper quality, the test may be used as a quick check for wet strength by burst testing a conditioned sample and another that has been soaked in water for half an hour. It may also be used as a quick check for confirming weakness in a paper sheet, such as that caused by over-creasing, abrasion, etc.

Tear strength

The tear strength is a measure of the resistance to tear propagation after puncture or rupture has occurred. In the test, a partially slit rectangular sample is held by two adjacent clamps, on either side of the slit, and the force to tear the sample fully apart is measured.

There is an inverse relationship between tear strength and tensile strength over which the paper-maker can exert a large degree of control. To obtain maximum tensile strength would result in a paper which possesses a relatively low tear strength. Good tear strength and good tensile strength are important in sack kraft, and the paper-maker will aim for a reasonable balance between the two.

8.4.1.2 Other physical properties/tests

There are a number of generally accepted testing methods for assessing other physical properties in addition to those for strength.

Grammage

The term 'grammage' is replacing the traditional terms of 'substance' and 'basis weight'. It is the weight in grammes of one square metre of paper, after conditioning in the standard atmosphere of 23 °C and 50% RH for 24 h. The cutting of the sample to a suitably sized area for weighing must be done after the paper is conditioned.

In North America, the term 'basis weight' relates to the weight in pounds (lb) of a ream of paper, usually 500 sheets, with each sheet measuring 24 × 36 in. This amounts to 3000 sq ft so that the most common basis weights for paper sacks are between 40 and 60 lb (equivalent to roughly 65–100 g/m^2).

Thickness (caliper)

Thickness is not normally measured on sack kraft as it has very little relevance to quality, performance or defining the grade. When required, it is measured by means of a dead-weight caliper micrometer and the result quoted in microns (thousandths of a millimetre) or thousandths of an inch.

Moisture content

The moisture content of paper is the loss in weight of a sample after oven-drying at a constant temperature of 105 °C. A sheet of paper will rapidly lose or gain moisture when exposed to the atmosphere and samples for moisture testing must be taken and placed immediately into a weighed container which should then be tightly closed.

Sack kraft, when freshly made, will have a moisture content of between 6 and 9%, and after conditioning for 24 h in the standard atmosphere of 23 °C and 50% RH, the moisture content will be approximately 9.5%.

Air permeability (porosity)

The rate at which air can pass through sack kraft is important for the filling operation, particularly for valved sacks and for any sack to be filled with an aerated powdered product. This air permeability may be measured in a number of ways, the most general method being the Gurley test (ISO 5636/5 1987). In this test, the time is measured for 100 ml of air, under a fixed pressure head, to pass through a 6.5 cm^2 area of sample. The porosity of most sack krafts will generally be between 5 and 35 s.

Water absorption

It is important for sack kraft to resist the absorption of water into the sheet in order to maintain as much of the dry strength as possible. Sack kraft is treated, or sized, during manufacture for this purpose. The degree of sizing is normally measured by the Cobb test (ISO 535 1991) which determines the weight of water absorbed by a given area of the paper surface after being held under 1 cm of water for one minute. The Cobb value for most sack krafts is normally between 20 and 30 g/m^2.

Friction

Friction is the resistance to movement of two surfaces in contact, to either start or continue movement over one another. Sack krafts are normally fairly resistant to slippage, and it is generally some form of surface contamination that causes low friction to occur.

There are a number of methods for measuring friction. In one, a weighted sample of paper is pulled over another and resistance to movement is measured. Another method is for two samples to be held together on a level surface by a weight, and the surface gradually inclined until slippage between the samples occurs. The angle with the horizontal when slippage first starts is a measure of the surface friction.

The measurement of friction is a most unreliable test as there are many factors which can affect the result. Strict care is necessary when taking and preparing samples, as even the touching of either surface by an operator is sufficient to appreciably affect the results.

Water vapour transmission rate (WVTR)

The rate at which water vapour can migrate through a barrier is dependent on the type of barrier material, its thickness and factors such as temperature and the humidity levels on either side of the barrier layer. It is measured by containing a quantity of a chemical that readily absorbs water in a metal can under a sealed-in sample of the barrier. The can is then left in a controlled atmosphere of temperature and humidity and weighed daily until the rate of increase in weight reaches a stable level. An atmosphere of 75% RH and 25 °C is most generally used for testing barrier materials used in paper sacks.

The water vapour transmission rate is always quoted in grammes per square metre per 24 h together with the thickness of the barrier and the testing conditions. It is a time-consuming test which tends to give results with a degree of variability. A number of quicker, alternative non-gravimetric methods have been published, but with little information on comparison with this method.

8.4.2 Sack testing

There are two types of tests which may be undertaken on finished sacks, and these concern the quality of the finished sacks and sack performance.

8.4.2.1 Quality of finished sacks

To assess a consignment, sacks should be checked against the sack specification which includes:

- dimensions
- sack construction, including quality of materials and number of plies
- printing, including print design, layout, register and colour
- supplementary features such as the use and positioning of adhesives.

All manufacture dimensions are subject to the normally accepted trade tolerances, which are given in Table 8.6. Repeat measurements should always be made from sacks sampled throughout the consignment.

One of the main criteria for the quality of the materials is that of grammage, which must be measured only after conditioning in the manner detailed in Section 8.4.1.2.

The type of material is generally visually apparent but checks, such as those for stretch or wet strength, may need to be made on certain materials.

The printing, especially with first consignments, should be compared for position and colour against the agreed design and layout specification.

8.4.2.2 Performance tests

There are two types of performance tests that may be undertaken on finished sacks, namely drop testing and field trials.

Drop testing

Drop testing consists of dropping filled sacks, generally until breakage occurs. By this means, different constructions or materials may be compared for performance in the same size of sacks. The sacks can be filled with either the normal or the dummy contents. Drops may be onto the faces (flat drops) or the ends (butt drops) or a sequence of different types of drops. Drop testing is not an absolute assessment of sack strength. It must always be comparative, i.e. between two or more sets of sacks; one of which should be a control set of a sack construction that has given satisfactory performance.

Ideally, sacks used for drop testing should be conditioned immediately prior to the testing and, if possible, the drop testing should be undertaken in a conditioned atmosphere. This latter aspect is normally not possible, and it is therefore necessary that care to be exercised when planning testing to ensure that it is not undertaken in extreme conditions of temperature and humidity.

The main factors which influence drop test results are:

- weight of the contents
- type of the contents
- sack construction
- sack type
- degree of filling.

But dropping, consisting of dropping the filled sacks repeatedly onto one end until burstage occurs, will test the girth of the sack but puts no strain on the end closures. The results will indicate differences in body strength only.

Flat dropping will stress the whole sack, i.e. the body and the end closures. Such testing may be used to show differences in performance between different types of sacks as well as different constructions.

There are three ways in which sacks may be compared by drop tests:

Static drop height method. Here a height is chosen at which a set of sacks will survive a reasonable number of drops before bursting. The set under test is dropped from the same height and the average number of drops to breakage determined.

Elevator drop height method. The first drop is made from a height of 0.85 m and the height of each subsequent drop is increased by 150 mm until breakage occurs. If sacks reach the maximum height of the drop tester without breaking, usually about 4 m, drops are continued at the maximum height until burstage occurs. In practice, this approach is better than that of the static drop height method, which can be extremely protracted if the sack constructions are appreciably different in strength.

Drop sequence method. A drop test sequence, comprising drops from a predetermined height onto face, butt and side in sequence, has been proposed as an international means of establishing a minimum standard for sacks, and other forms of packaging, for containing goods classified as dangerous. Users should be aware that whilst this test establishes a minimum standard, it does not establish that a particular construction is suitable for any specific distribution system. The hazards and journey lengths in distribution systems vary widely and a user should always think in terms of a preliminary limited field trial, if there is no prior experience of a particular distribution system. ISO 7965 1984 currently applies.

Field trials

Field trials are advisable with distribution systems involving multiple handling stages. Such a trial need only consist of a small initial consignment which is checked at despatch and upon arrival at the destination. Field trials in which consignments are monitored at various points within a distribution system can require a large number of observers and can be expensive to undertake.

This latter type of trial is only justified for complex or lengthy distribution systems in which initial trial consignments have shown unacceptable levels of performance or damage. The final analysis of the findings of such a trial should be aimed at the determination of sources of any damage and whether the need is for improvement in sack strength or the elimination of particular distribution hazards.

8.5 Weighing, filling and closing systems

The choice of filling and closing equipment is governed by a number of factors which include the nature of the product, the desired speed of operation and the type of sack.

Flow characteristics and bulk density of the product may determine the easiest method by which a sack can be filled. The particle size may also determine whether a satisfactory pack can only be achieved by either an open mouth or a valved sack system.

High-speed, fully automatic packing lines, in which the whole output of a mill or factory is funnelled through one packing line, will ensure labour is kept to a minimum. On the other hand, a number of simple packing lines will give flexibility in operation where various grades of one product are produced in the same factory.

The various systems available are most easily subdivided into those for open mouth sacks and those for valved sacks.

8.5.1 Open mouth sacks

Open mouth sacks are widely used for animal feed, seed, milk powder, etc. in the UK and Ireland. The equipment available for the filling, closing, conveying and palletising of these sacks may be chosen from a range of automatic, semi-automatic and manual units.

8.5.1.1 Weighing

All sacks containing products for sale must be filled within defined limits of weight accuracy. This can be done by gross or net weighing. The gross weighing is a slow operation and is usually linked to a simple packing line where operators are involved in both the weighing and the sewing operation. The net weigher can be used with either manual or automatic installations.

With gross weighing, the product being packed is weighed as the sack is filled; the flow of material being stopped once the correct weight is obtained. In net weighing, the product is pre-weighed into a weigh bucket after which it is discharged into the sack. Both types require a feeding system suited to the flow characteristics of the product and a device for reducing and finally cutting off the flow at the correct weight.

Weighers for free-flowing, granular products usually rely on either gravity or belt feeders. For other products vibratory, screw or fluidised feeders may be required.

The control systems for gross weighers are normally manual or semi-automatic. With semi-automatic systems, the flow of product is cut off just below the correct weight and the operator controls the final amount of material to enter the sack. Outputs of up to four sacks per minute are possible according to the nature of the product and the weight to be packed. The advantages of gross weighers are their relatively low cost, reduced headroom requirement and a low risk of inaccurate weighing due to the build-up of difficult materials on the machine components.

Net weighers, which always operate automatically, offer much higher speeds than gross weighers due to the separation of the weighing and filling operation. This means that whilst one sack is being filled, the next weighment is being prepared in the weigh bucket of the machine. The system also enables two or more weighers to deliver in turn through a common hopper to the filling spout where very fast packing is required. Typical outputs of free-flowing products, from a single weigher, range from 8 to 14 discharges per minute.

8.5.1.2 Sack applicators

The operation of placing and clamping empty open mouth sacks onto a filling spout may be manual or automatic. By using a net weigher, this can be linked to an automatic sack applicator where sacks are withdrawn from a magazine, opened by suction cups and lifted by pick-up arms onto the filling spout. Sack-detecting switches are used on the spout so that the weigher will only discharge if the sacks are correctly positioned.

8.5.1.3 Filling

The filling spout can be either a bird-beak type, which opens inside the sack, or an elliptical body, where the gripping jaws secure the sack from the outside. The elliptical units allow a dust-tight seal to be achieved during the filling operation. When the sack is correctly placed on the spout, the filling cycle is automatically started, the weigher discharges and the filled sack is released after a timed interval.

To assist light and aerated products to settle during filling, the sack may be mechanically agitated by a ‘posser’. Two types are commonly used, one causing the filling spout to oscillate vertically and the other applying a vibration or oscillation to the base of the sack.

The transfer of the filled sacks to a closing unit is achieved by using a conveyor which receives the sacks directly from the filling spout. This avoids manual handling and distortion of the sack mouth.

8.5.1.4 Summary of weighing equipment for open mouth sack filling

Table 8.2 summarises the details of the filling/weighing systems available for open mouth sacks. The list of typical products is by no means complete and is provided for guidance only.

Table 8.2 Filling/weighing systems

Products				Weighments per minute	
Type of feeder	General description	Typical examples	Unit weight (kg)	Gross	Net
Gravity	Free-flowing, granular	Pellets, cubes	25	3–4	9–12
		Plastic granules	25	3–4	10–14
		Grain	50	3–4	6–8
		Fertiliser	50	2	10–12
		Sugar	50	2	8–10
Belt	Free-flowing, granular and coarse powder	Meals	25	3	8–12
		Pellets, cubes	25	4	10–14
Screw	Fine powders	Flour	50	3	6–8
		Fine chemicals	25	3	5–6
Fluidising	Fine powders	Flour	50	—	8–10
		Fine chemical	25	—	6–8
Vibrator	Coarse with lumps	Solid fuels	50	—	4
		Jumbo nuts	25	—	6
		Coarse flakes	25	—	5

8.5.1.5 Closing

Open mouth sacks may be closed by sewing, bunch tying or, with certain types, by folding and gluing.

Sewing

Most open mouth paper sacks are closed by sewing. This gives a neat secure closure with a minimum requirement of ullage, or free space, at the top of the sack. Stitching equipment range from hand-held or suspended portable sewing machines to high-speed, automatic heavy-duty machines used in conjunction with conveyors. Either single or double thread stitching may be carried out, with or without kraft paper string or jute filler cord and may be sewn through crepe tape folded over the sack top.

Portable machines, which normally apply a single-thread stitch, are suitable for low or intermittent outputs, for example up to two sacks per minute. These should not be used on sacks with more than four plies. For low outputs in conditions requiring robust equipment, a heavy-duty pillar–mounted sewing machine may be used with a bogie on rails to carry the sacks.

The most widely used sack closing equipment comprises a heavy-duty sewing head mounted on a pillar over a conveyor. The sewing head is fitted with automatic knife-and-switch mechanism so that it starts when a sack is entered, sews, cuts the trailing sewing chain and stops again as the sack clears.

Sewing and conveyor speeds range from 6 to 15 m/min. At higher speeds, one sewing machine can close up to 20 sacks per minute.

Given adequate weighing and filling capacity, under typical conditions, one operator can fill and sew up to 6 sacks per minute. Two operators, one filling and one sewing, can handle from 12 to 16 sacks per minute. With sacks of heavy construction or if sewn-through-tape closure is in use, lower rates will apply or an extra operator may be required to fold the sack top before sewing. Table 8.3 shows the output of sacks per minute with respect to the type of equipment used.

For high-speed packing lines serving continuous production processes, double-head sewing machine units are recommended. If it is necessary to replace the closing materials or carry out adjustments, the operator simply rotates the unit to bring the reserve head into action.

Automatic sewing equipment eliminates the operation of forming and entering the sack top into the sewing machine. The sack may be fed forward by vertically mounted shaping rollers on either side of the conveyor or from a sack top stretching and forming system. Converging belts will then enter the sack into the sewing head. Guide boards, or a troughed conveyor, ensure that the sack remains upright during the closing operation. For tape closure, the sack top is trimmed flush before entering the sewing unit.

Automatic open mouth sack packing systems are available as either a combination of sack applicators and stitching units or self-contained integral filling and closing machines. These installations not only eliminate manual labour normally associated with sack packaging but have built-in safeguards against malfunctions, enabling

Table 8.3 Sewing closure – equipment options and outputs

Type of equipment			Sacks per minute with number of operators		
Scale	Filling	Sewing	1 operator	2 operators	3 operators
Platform	Hand spout	Portable	1–2		
Semi-auto gross	Hand spout	Pillar and bogie	2–3		
Standard net	Auto spout	Pillar and conveyor (low speed)	4–6	8–10	
High-speed net	Auto spout	Pillar and conveyor (high speed)	5–8	10–15	
Twin net	Auto spout	Pillar and conveyor (high speed)		12–16	18–24
High-speed net	Auto spout	Automatic	8–14		
High-speed net	Auto sack placer and spout	Pillar and conveyor (high speed)	8–14		
High-speed net	Auto sack placer and spout	Automatic	8–14*		
High-speed net	Integrated auto filling and sewing machine		8–14*		

* One operator in attendance but free to perform other duties in vicinity.

the operator to perform other duties in the vicinity. The relative rigidity and handling qualities of a paper sack make it most suitable for use with automatic equipment.

Equipment is available to close sacks of specialised construction. For instance, sacks containing a sealable inner ply for containing finely powdered, toxic or hygroscopic materials may be closed by heat sealing and sewing. Successively sewing and heat sealing the inner liner below the sewing line achieves a closure. Any of these operations may be achieved by the inclusion of individual units in the closing line or by an integral machine which combines all operations. Other extras, such as a unit to clean the surfaces of the sack mouth, may also be incorporated in the packing line.

Closures other than sewing

Pinch-closed sacks, which contain a pre-applied line of hotmelt adhesive at the mouth flap, are closed by a unit which reactivates the adhesive and then folds the flap over the mouth to form an instant closure. These units are built around a conveyor for moving the sacks and may also include a heat-sealing position and compression rollers to ensure complete adhesion and consolidation of the bonds.

There is also a unit to close open mouth sacks with the double-folded closure. It has a built-in conveyor and uses hot melt adhesive which is applied to the top of the filled sack during the folding operation to give instant adhesion to the closure.

8.5.2 Valved sacks

By eliminating the need for the sewing operation, valved sacks can give faster packing speeds, together with automatic filling and weighing systems.

8.5.2.1 Applicators

A number of designs of sack applicator are available which automatically place valved sacks onto filling spouts. These generally rely on suction cups for handling the sacks and for opening the valves. Whilst most valved sack placers are designed to work with single or twin spout packers, they are also offered to serve up to four closely spaced filling spouts. In addition, applicators are also available for high-speed rotary packers. The majority of designs make use of magazines for holding the empty sacks which may be replenished with fresh sacks either manually or automatically. Other designs are available, which present the sacks to the applicator by means of pre-made rolls of shingled sacks.

8.5.2.2 Weighing and filling

For the filling of valved sacks, several different types of packing equipment are available, the choice depending on the nature of the product. The method by which the product is accelerated to fill the sacks serves to classify the various packing machines. These may be further divided into those which operate below a pre-weigher and those which weigh the product in the sack and arrange for the flow of material to be cut off at the correct weight.

The filling machines cover a wide range of outputs from simple units to high-speed multiple installations. With the systems which automatically weigh and discharge the filled sacks, an operator has only to place sacks onto the filling spout or into the magazine of an applicator.

Gravity packers

The simplest type of valve packer employs gravity filling and is suitable for free-flowing, granular products (Fig. 8.7). For low outputs, the equipment takes the form of an inclined chute terminating in a filling tube above a sack chair, all mounted on a platform scale. Weight is controlled manually or by means of an automatic cut-off gate at the base of the overhead feed hopper.

A high output 'free fall' gravity packer operates in conjunction with a pre-weighing scale and consists of a vertical accelerating tube and filling spout, with automatic sack clamps. These packers require considerable headroom but may be grouped close together for operation by one person. They are particularly recommended for dense and free-flowing products.

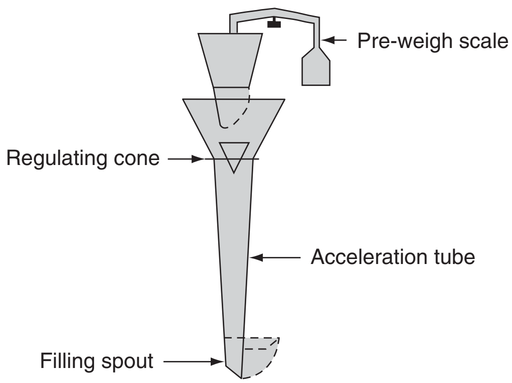

Figure 8.7 Gravity packers.

Belt packers

The high-speed packing of granular material of any density is best undertaken with a grooved wheel or belt packer (Fig. 8.8). A pre-weighed amount of the product is fed vertically into the annular space between a continuously running belt in contact with the grooved wheel. This travels through 90° and delivers the product horizontally at high speed, through a throat and filling spout, into the sack. During filling, the chair supporting the sack may oscillate to settle the product. The chair may be tipped manually or automatically to discharge the filled sack. Grooved wheel packers are available in single or twin spout versions and may be grouped for one operator.

Some products, such as beet sugar pulp nuts, although free-flowing, would bridge if discharged directly into the narrow feed chute of a belt packer. This is

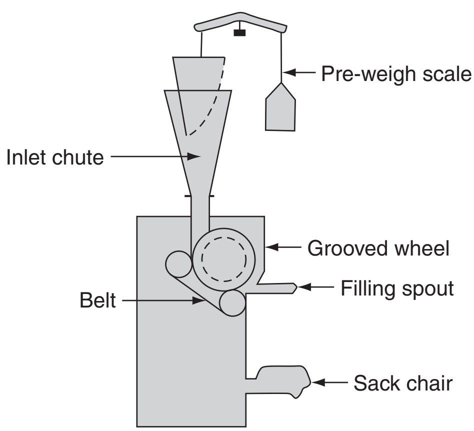

Figure 8.8 Belt packers.

overcome by inserting a belt feeder between the pre-weigher and the packer, which regulates the delivery rate of the material.

Impeller packers
For packing a range of ground rock–type products, the impeller packer is recommended (Fig. 8.9). A continuously running impeller feeds the product, through a cut-off valve gate and a flexible connection, to the filling spout and into the sack. A saddle on a weigh beam supports this, and, once the correct weight is obtained, the cut-off gate is actuated and the sack discharged. Impeller packers are available with weighing systems based on load cell controls.

They are also supplied with up to four spouts for high-speed packing of cement and similar products. For low outputs, a simple impeller packer is available in which the filling spout and chair assembly is mounted on a platform scale, the cut-off gate being manually controlled.

Fluidising packers
Fine and very fine powders may be made to flow readily by passing air through them. With valve packers based on this property, the fluidising is achieved by admitting low-pressure air through a porous pad in the base of a chamber. The fluidised product flows out by gravity, through a cut-off gate and the filling spout, into the sack. In the 'pressure flow' version of this machine, applying air pressure above the product in the chamber increases the packing rate. The control of weighing is similar to that of an impeller packer.

Fluidising packers can handle a wider range of products than any other type but are most suitable for material with a sufficiently high proportion of fine powder to hold the fluidising air (Fig. 8.10). They are particularly recommended for fine powders with difficult handling characteristics. By increasing the fluidising air considerably, some granular products may also be packed. Since the product delivered by a fluidising packer will be aerated, provision for the escape of entrained air may be needed. A vent may be incorporated in the filling spout, and if the sacks include a barrier ply, some perforations may also be necessary.

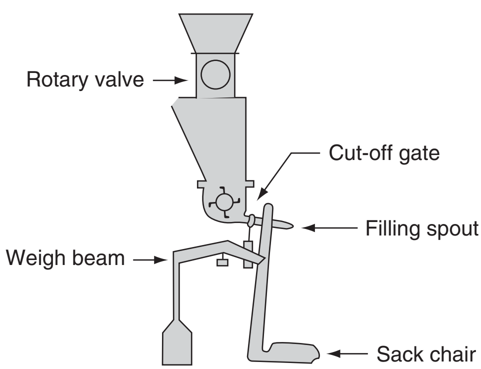

Figure 8.9 Impeller packers.

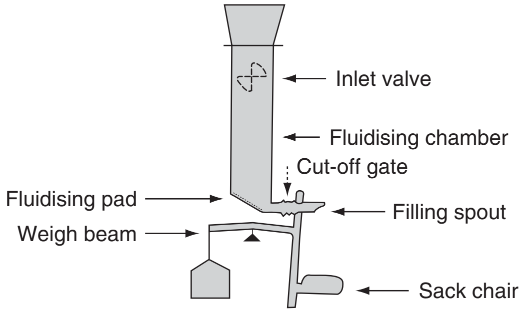

Figure 8.10 Fluidising packers.

Screw packers

For powder products which do not flow freely, a screw packer may be used, either in connection with a pre-weigh scale or as a hand-controlled unit mounted on a platform scale (Fig. 8.11). The material is delivered from a small hopper fitted with an agitator, through a screw feed in the filling tube. Provision to assist settling of the product can be made during filling with net weighing.

8.5.2.3 Rotary packing system

For industries which pack one unvarying product at a constant high rate, rotary packing machines have been developed. These consist of a number of individual packing units which are mounted on a slowly rotating structure. Empty sacks are placed either manually or automatically on each of the filling spouts at one point. Filling takes place as they travel round to the automatic discharge point. The advantage of these machines is that the output is no longer governed by the time taken to complete the weighing and filling of each sack. Rotary packers are available for both valved and open mouth sacks. They are used mainly for filling cement,

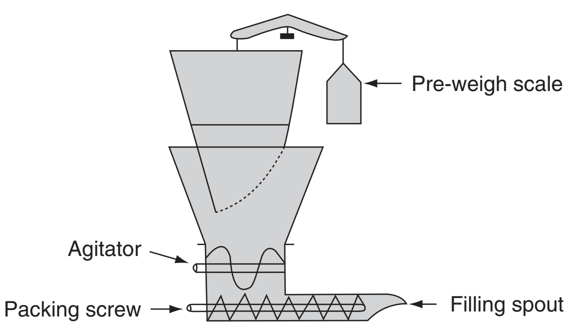

Figure 8.11 Screw packers.

plaster or chemicals into valved sacks at rates up to 120 tonnes per hour. A fully automated rotary system requires sacks to be presented to the spouts as flat as possible and free from sticking together, using one of three types of magazine as follows:

- horizontal sack-holding magazine with capacity of 600 sacks
- vertical magazine with storage capacity of up to 6000 sacks
- roll system (sacks on reel) which serves as a magazine holding approximately 3000 sacks shingled together to form a reel with a maximum diameter of 160 cm held in place by two plastic tapes.

In machines for filling open mouth sacks, it is more usual to employ two or three fixed pre-weighing scales, each serving several filling spouts. After filling, the sacks are led off tangentially onto a conventional sewing line or for heat sealing. If the operation is automatic, only one person is required to place empty sacks into a cassette magazine. If the operation is manual, up to three operators could be involved.

8.5.2.4 Output levels of valved sack systems

Table 8.4 summarises the output levels of available valved sack packing systems for various products. The list of products is not intended to be comprehensive and is provided for guidance only.

If sacks with tuck-in sleeves are used with valve packers having automatic discharge, an arresting device may be provided to hold the sack temporarily at a convenient angle.

8.5.3 Sack identification

It is often necessary to add information or a batch identification mark to sacks during the packing operation. This may be done by simple printing devices or by attaching pre-printed tickets.

On open mouth sacks, printing may be added by a rotating contact roller mounted beside the sewing head, applying a code or batch number close to the sewing line. Alternatively, for any type of sack, the printing may be done after filling, by an ink-jet printer or a roller device as it passes along a conveyor. Special printing devices are available for valved sacks which are either incorporated into the clamp which secures them to the packing machine spout, or are an addition to certain sack applicators.

If printed tickets are required, these may be manually or automatically inserted into the sewing line or open mouth sacks. Automatic ticket dispensers either take the tickets from a reel or will feed them from a magazine. Self-adhesive tickets may also be applied to either valved or open mouth sacks after they have been filled.

Table 8.4 Valve sack output levels for various products and packing systems

Type of packer	Products		kg	Output in sacks per minute with one operator weight for given number of spouts			
	General description	Typical examples		1	2	3	4
Gravity with platform scale (semi-auto weigh)	Granular, free-flowing	Plastic pellets	25	2	4		
		Dry sand	50	2	4		
Gravity free fall with pre-weigh scale	Granular, free-flowing	Plastic pellets	25	5–6	12–14		
		Granular fertiliser	50	6	12–16	—	—
Belt, grooved wheel with pre-weigh scale	Granular, free-flowing	Granular fertiliser	50	6–7	14–15	20	20
		Granular sugar	50	4–5	8–10	—	—
		Plastic pellets	25	6–7	14–15	20	20
		Provender pellets	25	6–7	14–15	20	20
		Grain	50	5	10	15	20
		D.V. Salt	50	6–7	14–15	20	20
Belt, grooved wheel with pre-weigh scale and belt feeder	Large cubes	Beet pulp nuts	50	3	6	9	12
		Cattle cubes	25	4–5	10	15	20
	Light fine flake	Provender meals	25	4–5	8–10	12–15	16–20
		Soya meal	50	4	8	12	16
		Shredded beet pulp	40	2½	5	7½	10
Impeller on platform scale	Pure ground rock	Portland cement	50	2–3			
		Gypsum	50	2			
		Hydrated lime	25	1–2			
		China clay	25	1–2			
		Fly ash	25	2			
Impeller with automatic weighing and sack discharge	Pure ground rock	Portland cement	50	5–6	10–12	15–18	20–24
		Gypsum	50	3–4	7	10	14
		Hydrated lime	25	3	6	10	14
		China clay	25	3	6	9	12
		Fly ash	25	4–5	8–10	12–15	16–20
Fluidising pressure flow	Powder	PVC resin	25	5–6	12		
	Powder/ fine-granule mixture	Carbon black	25	3–5	8–10		
		Starch	50	4–5	8–10		
		Refractory powders	50	5–6	12		
		Flour	50	4–5	8–10		
Screw with screw feeder, mounted on platform scale, hand control	Fine and very fine, non-free-flowing, powder	Resin powder	25	1			
		Starch	50	1			
Screw with pre-weigh scale	Fine and very fine, non-free-flowing, powder	Resin powder	25	2	4		
		Starch	50	1½	3		
		Flour	50	1–2	4–5		
		Provender meal	25	2–3	4–6		

8.5.4 Sack flattening and shaping

To gain the maximum advantage from paper sacks as a means of storing and transporting materials, it is often desirable to flatten or shape them after filling. This provides firm, uniform packs, offering substantial savings in storage and transport costs, together with safer stacking or palletising.

The choice of equipment depends on the nature of the product and the type of sack. For light and medium density free-flowing products, a twin-roller sack-shaping machine, which serves to distribute the product evenly along the length of the sack, is adequate. For denser products which pack more solidly, the compression flattener, in which the whole length of the sack is subjected to uniform pressure as it passes between belts, is recommended. If the product is sensitive to excessive pressure or is of a coarse lumpy nature, a vibratory flattener should be used.

There is generally a greater benefit to be obtained from flattening sewn open mouth sacks than pasted valved sacks. Open mouth sacks should always be fed bottom first into roller or belt flatteners.

The flattening of sacks with barrier piles containing highly aerated products must be done very slowly, to avoid burstage, even if they are specially perforated. It is preferable to reduce aeration as much as possible by mechanically settling or 'possing' during filling and to allow time for further de-aeration before sealing the sack.

8.5.5 Baling systems

Baler packing equipment ranges from simple devices, which aid manual loading of baler sacks, to fully automatic power-operated machines. The method of functioning will depend on whether the goods to be packed are *fully compressible*, such as woollen articles, *semi-compressible*, such as small bags of flour, or *rigid*, such as boxes or cans.

A typical hand baler consists of a short chute, shaped to receive and clamp the mouth of the sack and support it in an inclined position. Articles are simply pushed through the chute into the sack. In another version, suitable for rigid articles only, the goods are loaded into a horizontal open trough, over which the baler sack is drawn. On releasing a catch, the trough tilts forward so that the goods and sack slide clear.

Semi-automatic baling machines include a receiving hopper into which the items are manually loaded. The sack is manually applied to the 'duck bill'-type jaws which grip it tightly. On closing the hopper, the charge is first subjected to alignment or pressure, by inward movement of one side of the hopper, and then pushed through a throat into the sack by a longitudinal ram. At the end of its travel, the ram pushes the loaded sack off the jaws. If the items are compressible, the side plate applies sufficient pressure to reduce the volume of the charge slightly; if they are rigid, it merely serves to line them up firmly.

In fully automatic baling machines, automatic collation of the articles forming the complete pack may take place directly in the hopper from above, or by forming the load alongside the machine and transferring it sideways into the hopper. The placement of the baler sacks on the sack jaws may be by hand or by mechanical means using suction cups.

Baling machines can be incorporated into continuous production lines, the completed packs being discharged through a sealing station to a conveyor.

8.6 Standards and manufacturing tolerances

The paper sack industry participates actively on national and international standards committees, ISO, etc. These committees are concerned with the elaboration of standards dealing with terminology, dimensions, capacities, marking and test methods in the fields of packaging and unit loads. (ETAPS participates in this work.)

8.6.1 Standards

In some instances, there are separate standards for the three Standards groups mentioned in Section 8.6 but there is an increasing tendency towards common standards either internationally or across Europe.

Although many standards are not mandatory, they may become so. A standard on manufacturing tolerances for paper sacks has not yet been ratified, but ETAPS has discussed the subject with a number of user bodies and is able to set down guidelines for the area of the UK and Ireland.

Table 8.5 includes relevant standards for plastic film which is now a common constituent of the paper sack. Also detailed are those standards of a more general nature which may be of interest to both manufacturers and users of paper sacks.

Table 8.6 indicates current manufacturing tolerances being observed by ETAPS members in the absence of a specific agreement on tolerances with a sack user or another trade association.

In recent years, much attention has been paid to the suitability of paper sacks and other containers for the packaging and distribution of food products for human consumption. The question of possible migration of hazardous substances from paper, board and plastic film is under active consideration at national and international levels. Food manufacturers are now concerned about the condition of the manufacturing plants and the distribution methods of their packaging suppliers.

United Nations approved specifications are becoming common in relation to the packaging of hazardous chemicals. In the United Kingdom, the Food Safety Act 1990 is relevant as well as the following statutory instruments: SI 1523:1987 and SI 3145:1992.

Table 8.5 List of Standards (ISO, EN and BS)

International or European Standard	British Standard	Title
ISO 1924/2 1986	BS 4415/2	Determination of tensile properties of paper/board
ISO 2206 1987	BS 4826/1 1988	Complete filled transport packages
ISO 2233 1986	BS 4826/2 1986	Complete filled transport packages
ISO 3676 1983	BS 6884 1987	Plan dimension of unit loads
ISO 6780	BS 2629	Pallets for materials handling through transit specifications for principal dimensions and tolerances (NB: ISO and BS are not similar but are related.) Packaging – sacks – vocabulary and types • Part 1 – Paper sacks • Part 2 – Sacks made from thermoplastic film
ISO 6591/1 1984	BS EN 26591/1 & 2 1993	Packaging – sacks – description and method of measurement • Part 1 – Paper sacks • Part 2 – Sacks made from thermoplastic film
ISO 7023 1983	BS EN 27023 1993	Packaging – sacks – method of sampling empty sacks for testing
ISO 7965 1984	BS EN 27965/11993	Packaging – sacks – drop test
ISO 8351 1994	BS ISO 8351-1 1994	Packaging – method of specification for sacks • Part 1 – Paper sacks
ISO 8367/1&2 1993	BS ISO 8367/1&2 1993	Packaging – dimensional tolerances for general purpose sacks • Part 1 – Paper sacks • Part 2 – Sacks made from thermoplastic film
EN 277 1989	BS 7303/1 1990	Sacks for transport of food aid (polypropylene fabric)
pr EN 1086 1993		Sacks for transport of food aid – selection recommendations for type of sack and liner (provisional recommendations)
	BS EN 770 1994	Sacks for transport of food aid (paper sacks)
ISO 535	BS 2644 1985	Sizing properties of paper – methods of detecting the degree of water resistance (Cobb method)
ISO 3689	BS 2922 Part 1 1985	Methods of testing paper and board after
ISO 3781	BS 2922 Part 2 1985	immersion in water
	BS 2987 1958	Notes on application of statistics to paper testing
ISO 2758/9	BS 3137 1972	Methods of determining bursting strength of paper and board
ISO 187 1993	BS EN 20187 1990	Methods for the conditioning of papers and boards for testing
ISO 536 1976	BS 3432	Method of determining grammage (basis weight) of paper and board
ISO 1974 1990	BS 4468	Method of determining internal tearing resistance of paper and board

Table 8.5 (Continued)

International or European Standard	British Standard	Title
ISO 5636/5 1987	BS 6538/3	Determination of air permeability (Gurley) of paper and board
ISO 6599	BS EN 26599/1 1993	Method of conditioning paper sacks
	BS 6563 1985 (1990)	Surface roughness determination (Bendtsen)
	BS 3725 1984	Non-returnable paper sacks for loose potatoes
	BS 3755 1964 (71)	Methods of test for assessment of odour from packaging materials used for foodstuffs
	BS EN 645 1994	Foodstuffs contact – cold-water extract preparation
	BS EN 646 1994	Foodstuffs contact – colour fastness determination
	BS EN 647 1994	Foodstuffs contact – hot-water extract preparation
	BS EN 648 1994	Foodstuffs contact – fastness of fluorescence determination
	BS EN 643 1994	List of European Standard qualities of waste paper
ISO 2875	BS 3110 1959 (85)	Method of measuring rub resistance of print
ISO 9001/1/2/3 1987		Water spray test
ISO R 181, 174, 307, 8618	BS 2782	Methods of testing plastics
ISO 291, 3205	BS 2782:Part 0:1982	Introduction
	BS 2782:Part 2	Antistatic behaviour of film
	Method 250A 1976(83)	Charge decay method
	Method 250C 1976(83)	Field window method
ISO 1184	BS 2782:Part 3 Methods 326A to 326C:1977	Determination of tensile strength and elongation of plastic film
	BS 2782:Part 3 Method 332A:1976(83)	Stiffness of plastic film
	BS 2782:Part 3 Method352D:1979	Determination of falling weight impact resistance of thin flexible sheet (film)
	BS 2782:Part 3 Method 353A:1991	Determination of multi-axial impact behaviour by the falling dart method
	BS 2782:Part3 Method 360A:1991	Determination of tear resistance of plastic film by Elmendorf method
	BS 2782:Part 6 Method 630A:1982	Determination of thickness by mechanical scanning of flexible sheet
ISO 1183 1987	BS 2782:Part 6 Method 620D:1991	Determination of density and relative humidity of non-cellular plastic
ISO 1133	BS2782:Part 7 Method 720A:1979	Determination of melt flow rate of thermoplastics

Table 8.5 (Continued)

International or European Standard	British Standard	Title
ISO 255	BS 2782 Part 8 Method 821A:1979	Determination of gas transmission rate of plastic film
	BS 2782:Part 8 Method 822A:1992	Determination of water vapour transmission rate of plastic film
	BS 2782:Part 8 Method 824A:1984(90)	Determination of coefficients of friction of plastic film
	BNS 3130 Part 8 1987	Packaging terms – plastic sacks
	BS 7344 1990	Specification for reeled low density polyethylene for general purposes
	BS 3177 1959	Permeability of water vapour into flexible sheet material
	BS EN 9001/1/2/3	Quality systems (formerly BS 5750)
	BS EN 7750 1994	Environmental management systems
	BS 7850 1992	Total quality management
	BS 6143 Part 2 1990	Guide to the economics of quality prevention, appraisal and failure model • Part 1 – Process Cost Model not yet published
ISO 10011/1/2/3 1993	BS EN 30011–1/2/3 1993	Guide to quality systems auditing
	BS 8750 1993	Environmental health
Proposed new work items		
ISO TC122/SC2/N292		Friction of filled sacks
ISO TC122/SC/N293		Method for testing the strength of seams. Determination of the peel resistance of glued seams in a pasted sack bottom
ISO 3852-1 ISO/TC122/SC2/N162 ISO 8352-2 ISO/TC122/SC2/N163 ISO 8352-3 ISO/TC122/SC2/N164		Packaging paper sacks – method of testing the strength of a single glued seam Part 1 – Strength of a single glued seam under normal climatic conditions Part 2 – Strength after immersion in water Part 3 – Determination of the water resistance by immersion in water
Food contact		
The Food Safety Act 1990		
SI 1523:1987 – Food		The materials and articles in contact with Food Regulations 1957
SI 3145:1992 – Food		The plastic materials and articles in contact with Food

8.6.2 Manufacturing tolerances

A paper sack is a pre-made form of packaging manufactured to the user's requirements of size and construction. During the manufacture, a small degree of variation can occur, which good manufacturing practice will keep to an absolute minimum. Table 8.6 summarises the tolerances which apply in sack manufacture

Table 8.6 Generally accepted multiwall sack manufacturing tolerances

	Tolerances		
Item	Plus	Minus	Notes
Sack kraft grammage	4%	4%	
Sack length	10 mm	10 mm	
Face width	3 mm	3 mm	
Circumference (girth)		10 mm	The upper limit controlled by upper limits on the face width and gussets
Gusset width	3 mm	3 mm	
Bottom widths	5 mm	5 mm	
Valve width	3 mm	0	
Valve sleeve position	5 mm	5 mm	
Seam overlap of 20 mm		3 mm	
Stitchline position	Not less than 12 mm from sack transverse edge		

Note: This table conforms largely to ISO 8367/1 but the ISO standard has a face width tolerance of plus 5 mm and minus 5 mm.

and which are generally accepted throughout the industry, although ETAPS has agreed more stringent tolerances for some of the measurements with the Chemical Industries Association (CIA).

8.7 Environmental position

The paper sack is a product invented and developed in the twentieth century. It continues to be a significant form of packaging. From its humble origin as a sheet of paper, rolled and tied at one end, filled with product and tied again at the other end, it has developed into one of today's leading packaging products. It is ideal for handling and containing a wide range of products in a packed weight ranging from 10 to 50 kg.

The essential element in all paper sacks has to be virgin fibre. Their strength, handling and efficient manufacture depend mainly upon raw material derived from sustainable temperate forests in North America and Europe, including Scandinavia and the Russian Federation. Secondary or recycled fibre at the moment is not an option as such material can result in an inconsistent pack which is weaker and is unsuitable for automated filling and in handling systems. The sacks would be more costly to produce and in many cases would be unacceptable for direct contact with food products.

As a result of continuing research and development there have been substantial reductions in the average construction weight of a paper sack. In conjunction with paper mills and machinery manufacturers, this work has enabled the industry to maintain an edge against competition from new materials and systems. Subsequent contribution to the overall reduction of packaging and packaging waste has largely not been recognised by governmental interests and also by those involved in the environmental lobby.

Recovered sacks can be recycled. The high quality long fibre they contain should be suitable to paper makers, provided economical recovery conditions prevail. The paper sack industry is willing and keen to participate in any viable scheme or schemes of recovery.

In Europe, intensive discussions are underway on implications of the EU Packaging and Packaging Waste Directive, involving legislators, affected authorities and trade associations. There are indications that a lack of awareness exists about the paper sack industry and the unique position it has within the overall packaging industry.

It is being suggested that buyers and specifiers should revise their specifications and maximise the content of secondary fibre. A levy on virgin fibre has been proposed. In the opinion of the paper-sack industry, these views indicate a lack of understanding that some virgin fibre in any mix of pulp is, and has to remain, an essential component in the paper making chain.

To summarise:

- paper sacks are made from renewable raw materials
- paper sacks are lightweight materials
- the inherent energy of paper sacks can be recycled in energy from waste systems
- paper sacks are biodegradable.

And, finally, the paper-sack manufacturing industry accepts its responsibility to contribute to the reduction of the overall volume of packaging.

Useful contacts

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Paper Shipping Sack Manufacturers' Association, Inc.
505, White Plains Road, Suite 206
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Environmental and Technical Association for the Paper-Sack Industry (ETAPS)
64, High Street, Kirkintilloch, Glasgow G66 1PR
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Websites

Environmental and Technical Association for the Paper Sack Industry at: www.natpack.org.uk
European Federation of Multiwall Paper Sack Manufacturers at: www.eurosac.org
Paper Shipping Sack Manufacturers' Association, Inc. at: www.pssma.com

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9 Rigid boxes

Michael Jukes

9.1 Overview

A rigid box is a box set-up ready for use without further fixing when received from the box manufacturer (BS 1986). The origins of the rigid box and its use go back centuries but its appeal today is largely based upon perceived quality and its ability to handle weighty contents – often of high value – and to afford physical protection.

With the dominant position of cartons and corrugated cases within the paper packaging industry, it may appear that rigid box use is in steep decline. However, for numerous boxmakers, both large and small, the market niches that rigid boxes and their derivatives serve is actually widening. While it is a long time since the rigid box was the packaging container of choice for the myriad of products which are now not even in cartons but in cellophane wrappers, for example, there are probably two major factors which underpin the appeal of the rigid box – quality and perceived luxury.

The range of the rigid box is not simply comprised of lift-off-lid (LOL) boxes. We should consider the wide range of products made by boxmakers and their box-making machinery in order to get a full appreciation of the market appeal of the rigid box. All products have their strengths and weaknesses/limitations but, in a world where packaging waste is an international environmental issue, the ‘greenness’ of the rigid box, together with its versatility, answers many of our present concerns.

Strengths

- structural strength and ability to provide protection for its contents
- perceived luxury by the ability to combine materials such as board, fabric, metal, plastics, etc.
- wide range of styles, sizes and covering materials and accessories, for example hinges, etc.
- design freedom – combination of rigid jackets, boxes, slipcases
- wider range of print and surface finishes compared with carton board
- compatibility with on-counter display of retail products
- ability to make ‘small quantity’ production runs
- second and alternative use when empty
- typically >80% of material content is recyclable and recycled.

Weaknesses and limitations

- large ‘empty size’ compared to the fold flat carton type offerings
- relative higher cost compared with cartons

- unsuitability for automated processing in volume applications
- volume restrictions – production rates limited to around 2500 per hour.

9.2 Rigid box styles (design freedom)

A defining characteristic of the rigid box is the freedom it allows with respect to shape, materials, use of accessories and overall presentation. Rigid boxes may be large or small, square, rectangular, round or elliptical in shape. The simplest rigid box forms are based upon the basic lift-off-lid (LOL) box as shown in Figure 9.1.

The shell and slide, book style and flip top, as indicated in Figure 9.2, show other distinctive closure designs. The shell and slide has been expanded into a case with drawers to hold, for example, assortments of chocolates or surgical instruments.

Combining trays (box bases) with different lid constructions results in hinged and shouldered (jewel) boxes as shown in Figure 9.3.

Turning trays on their sides results in slip cases with a variety of shapes and design features as shown in Figure 9.4.

Rigid board jacket with pockets and plastic fitments are used to pack digital video discs (DVDs) (Fig. 9.5).

The addition of accessories in the form of ribbons, bows, clasps and hinges can provide 'special' appeal as shown in Figure 9.6. Plastic and rigid board fitments are also used.

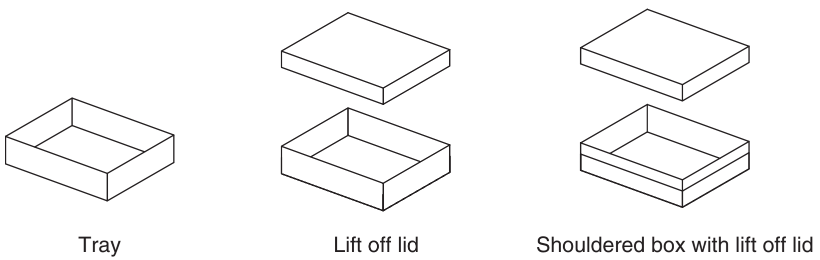

Figure 9.1 Basic lift-off-lid (LOL) boxes.

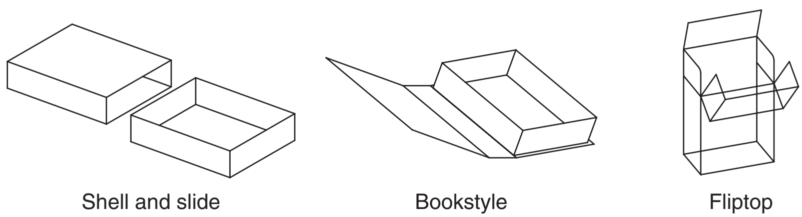

Figure 9.2 Examples of distinctive box styles.

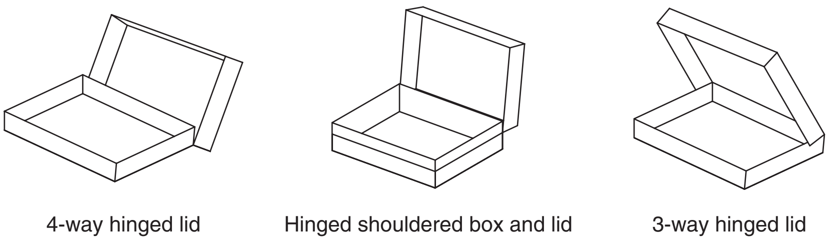

Figure 9.3 Hinged and shouldered boxes.

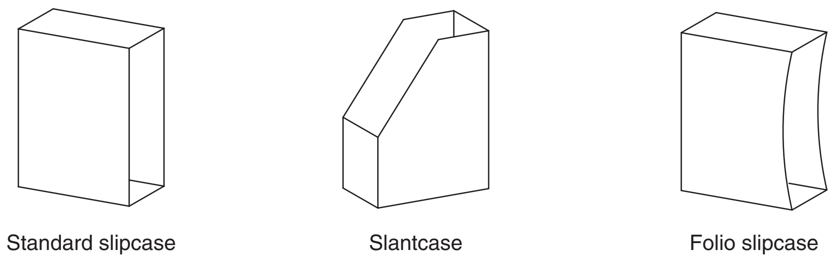

Figure 9.4 Slip cases.

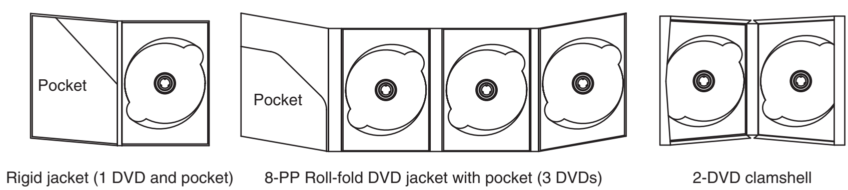

Figure 9.5 Rigid jacket with pockets for DVD.

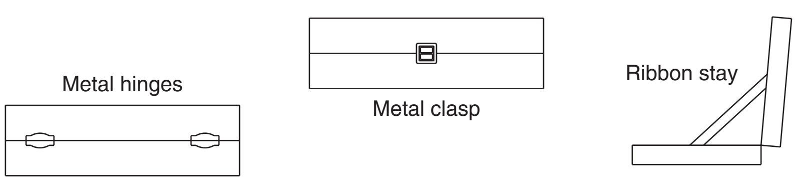

Figure 9.6 Incorporation of accessories in box design.

9.3 Markets for rigid boxes

The UK market sectors that are the largest users of rigid box packaging include:

- tableware – ceramics, pottery, glassware and cutlery
- jewellery and watches
- perfumes and cosmetics
- music, video and games
- stationery and office storage
- luxury drinks
- publishing
- chocolate confectionery and gifts
- boxed greeting cards
- photographic trade products
- engineering and DIY hand tools
- medical equipment.

At current price levels, the UK market, including imports, is in the region of £80 million. Exports from the UK mostly into near continental markets is low, probably in the region of <10% of home production. The proportion exported is low because it is relatively expensive to transport empty rigid, or 'set-up' boxes, over long distances because of the space required. Exported rigid boxes are usually those with more complex design where there is a high added-value component.

Within many of these sectors, the luxury 'gifting' nature of the contents of the box brings a large seasonal element into play. Typically the run up to Christmas, which may last four to five months, gives the boxmaker huge challenges as it is necessary to increase production dramatically. The typical box-making factory is both machine and labour intensive. Many of the box finishing processes utilise hand skills, whereas the setting, operating and maintenance of wrapping, laminating and material preparation machinery demands the highest level of expertise and skill.

In value terms, the use of one-off special boxes probably exceeds that of standard, repeated products. With short delivery lead-times (10 days would be usual in the music sector), the rigid boxmaker generally works directly with the client throughout the design stage, i.e. the use of sales agents is rare. Clearly the use of Computer Aided Design (CAD), communication through broadband lines, the digitisation of print and other 'modern' processes and systems are key tools in the boxmaker's range of competencies.

9.4 Materials

9.4.1 Board and paper

The main raw materials for paper and board are cellulose fibres, water and energy. The cellulose fibres mostly come from softwoods, but esparto grass and cotton fibres are also used for the finest papers. Boards are principally made from recycled fibres to give maximum humidity-related stability. Board thicknesses are typically in the range of 1000–2500 microns with weights of 400–1600 g/m^2. In 'composite boxes', where folding box board (FBB) is used in conjunction with recycled chipboard, lower weights in the range of 270–400 g/m^2 are used. As well as boards made from recycled fibre, solid bleached boards (SBB) and solid unbleached (brown) boards (SUB) are also used; they may be lined or unlined depending on their role in the box construction.

9.4.2 Adhesives

The rigid-box industry usually affixes printed paper to recycled board and generally, depending on the paper, uses glues of both gelatine and polyvinyl acetate (PVA) varieties for finishing. In all cases, both the paper and the board absorb moisture to differing degrees and the 'wet expansion' of each material is a key consideration, not only in material selection but also in design and construction. The absolute level of humidity in each adjacent material is not the issue, but rather the differential between each material.

Gelatine glues are almost always preferred but their inability to adhere to laminated paper surfaces is where the PVA type comes into play. Adhesion may be equal but gelatine provides a cleaner surface not only to the box but also to the production machinery. Precise glue selection is also dependant on the box construction with open times being an important consideration. Clearly, glue temperature and the dispersion of the solid adhesive are features which the boxmaker must take into account.

9.4.3 Print

Typically rigid boxmakers are not printers; they buy print in, often from local printers, who are familiar with printing on flat sheets. This is quite different from the carton-making industry that generally specialises in printing and then adds extra value by cutting, creasing and gluing to the final carton shape.

Standard sheet–fed printing presses are used with the majority of paper sizes in the B2 (520 mm × 720 mm) range. With the largest production volumes, often associated with the music industry, B1 (720 mm × 520 mm) size sheets are also used. Both 'standard' finishes and UV printing techniques are employed, all driven by the application, with print cost also being a major driving force in the print-finish selection.

Other embellishments are then added in the box-finishing processes, for example foil blocking, embossing, debossing and selective lamination or UV varnishing (where the free areas allow for subsequent gluing).

9.5 Design principles

The most obvious need for any form of packaging, including the rigid box, is the need to offer protection for its contents. Depending on the market use, probably a close second is the need to present, in marketing terms, the packaged product to its best advantage. This is sometimes achieved by making the product visible whilst in the box, especially where display at the point of purchase is important, but more usually it is achieved by the use of arresting graphics and print techniques. Other display techniques might include window patching and the use of transparent plastic lids.

Two examples, at opposite ends of the spectrum, might be packaging for the industrial use of acetate films (OHP slides) and the packaging of luxury cosmetics or chocolates. In both cases, the contents may have significant mass, both need protection prior to use or consumption, but their presentation is critical in the eyes of the customer. A simple lift off lid box with good print may suffice for the A4-sized box of film but a luxury appearance as, for example, may be provided by a round, oval or heart-shaped box is required for the beauty preparation or assortment of Belgian chocolates.

Boxmaking through the use of machinery (as opposed to hand-making techniques) imposes design limitations. The first is that boxes start as flat sheets of board and paper, and subsequent operations to form the box generally require right angles, i.e. 90° bends. They are usually rectilinear in shape although some polygonal shapes can be partially made on machines, for example hexagonal, etc.

From the examples shown earlier in this chapter, more elaboration may be achieved by the combining together of trays and lids, with or without platforms to hold the contents in position. The platforms can have complicated shapes and contours which are achieved by using vacuum formings, or expanded polystyrene, tailored to hold the contents securely. Transit testing, including drop testing, can be onerous on rigid boxes so each element of the design has to be carefully analysed to ensure structural rigidity and provide protection.

Rigid box construction uses a variety of glues and base materials, varying from recycled board through to covering papers, fabrics, etc., which must be 'stuck' together. The widely differing material/moisture expansion issues have to be borne in mind. Not only can glue/adhesive viscosity have a significant effect on the overall box dimensional sizing, but also the climatic conditions within the box-making factory can affect the wet expansion of paper, etc. This in turn can, in its simplest form, affect the clearances and tolerances of the box and lid. The rigid box is not, and cannot be considered, a precision product and tolerances of 0.5 mm are not unusual.

The main characteristic of the rigid box is its appearance. It is the variety of covering materials, including foils, papers, flock or fabric linings, leather – in fact any material that can be stuck to cardboard and take and hold its shape after the adhesive is dry – and a wide array of printed effects that give the rigid box its unique appeal. Lids may be flanged, domed or padded. Box corners can be metal edged. Component parts can be hinged together using paper, fabric, metal or plastic; fastened using many techniques; decorated with bows, ribbons, handles, etc. All these attributes can combine to make the finished pack suitable for gracing the most prestigious point-of-sale display, and frequently providing a second use (often in the home) after the contents are consumed or used.

Boxmakers, like carton producers, generally provide their customers and their design teams templates that show where the graphics are to appear on the sheet of print. These are essential as they show the relationship between those visible faces, flaps, turn-ins, etc. and the parts of the box that are not visible after construction. The addition of printed platforms, sleeves, drawers, etc. all add to the print complexity but all must be considered during the design stage.

9.6 Material preparation

Rigid boxes typically start as flat sheets that are cut to a predetermined shape before the box assembly process. ‘Preparation’ machinery and equipment can be as simple as scissors, continuing through a range of machinery up to computer-controlled guillotines and continuous cutting machines utilising a stamping-type process.

In the latter case, cutting dies are typically made from steel rule and plywood. They are often very complicated, including the use of make-readies, and not only prepare the board for box assembly but also make the scrap/unwanted board easy to handle and recycle. There are also simple platen dies with different heights of rule depending on whether a cutting or scoring action is required. (Scoring in this context means a knife cut in the surface, which penetrates about 50% of the way through the board.)

Additional equipment is used to cut large boards into manageable sizes for subsequent cutting operations and the forming of grooves and creases on rotary equipment. The boxmaker is always trying to optimise material usage, i.e. minimise the scrap cut to waste. This may be by the simple expedient of cutting boards in half or, more usually, by specifying specific board sheet sizes which the mill then produces to order.

Covering papers use similar processes but as they are generally printed, the boxmaker often performs embossing, debossing and foil-blocking operations, all of which may be vital ingredients of the finished box’s design appeal.

The most simple, covered lift-off-lid box has four main components, each with its own profile, comprising box card, lid card, box cover and lid cover. Typically the box and the lid cards will be cut together using a ‘one set-on cutting die’. Simple cutters for such a construction are relatively inexpensive at around £100 each. This makes short runs affordable for an extremely wide range of applications.

Modern boxmakers make extensive use of CAD systems for samples and limited production runs which are often cut on computer-driven plotter tables. The component parts are then hand-assembled. This obviously eliminates the need to buy unique cutters for each box type, size, etc.

Whilst small tooling, jigs and fixtures are generally produced locally, box wrapping, gluing, spotting and material preparation machinery is available internationally. Special purpose machinery, i.e. custom designed and built, also provides equipment manufacturers with unique challenges!

9.7 Construction

At its most simple level, prepared paper is coated with a thin film of adhesive and applied to the board, with the paper itself wrapped around the corner flaps to secure them. The next level of complexity is to first ‘stay-up’ the corners of the board (the box or lid sides) using a heat-activated tape, appropriately called stay tape, before the covering paper is applied.

Adhesive application may be by hand, simply by passing the paper over a glue-covered roller, and the paper then being wrapped around the box: this is suitable for samples, very limited production runs or complex packs/components which cannot be made by machine. For volume runs, the staying-up of the box is carried out automatically on a machine. This is then conveyed under a wrapping head to which the glued-out paper is presented, and through a complex series of rollers and brushes, the paper wrap is pressed to the back and sides, both on the outer surface and a turn-in on the inside.

Ideally, two wrapping lines are placed side by side, one producing the box and the other the lid, with the two parts being put together (lidded-up) by hand or by machine. Where a book-style box is required, these box-wrapping lines can be linked to laminating lines (adhering paper sheets to flat boards, grooved or multi-pieced) to produce a jacket which can then be fixed to the box base. Wrapping lines are complex and one modern line combined with a staying-up machine costs in the region of £250 000.

A typical high-volume production line is synchronised to perform box staying, gluing, spotting and then cover-wrapping. A typical machine layout producing both box and lid is shown in plan elevation in Figure 9.7.

The addition of platforms, both cardboard and vacuum formed, often requires long conveyorised production lines and throughput levels of 1500–2500 per hour. The boxmaker is often also called upon to pack the customer’s contents/product. Box making factories are capital-intensive with the best being air-conditioned or, at the very least, humidity controlled. Cleanliness and overall pest control are as necessary for rigid boxes as for any other paper based packaging.

Also the wide variety of box styles inevitably also means that boxmakers are employers of proportionately more semi-skilled employees than many other manufacturing industries. Multi-skilling and a flexible working schedule in manufacture is essential because of the seasonal variability of the sales of many luxury, gifted, products.

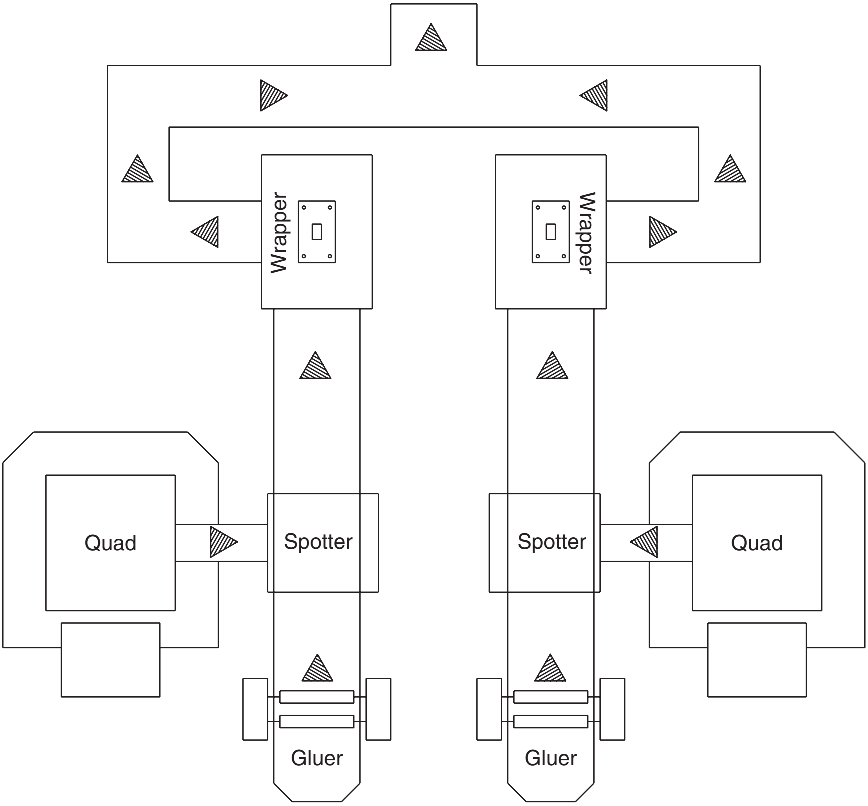

Figure 9.7 Machine layout for producing rigid box and lid.

Surrounding the main wrapping lines are special purpose machines for miscellaneous operations, such as hinging, stitching, labelling, sealing, hot-melt fixing, corner cutting and many more.

An alternative method of box covering is known as envelope or loose wrapping. This uses a cover paper which is not preshaped but is folded and pleated around the box with only the edge of the paper being secured to the board by adhesive.

9.7.1 4-Drawer box

The construction of a 4-drawer rigid box demonstrates the range of operations which may be necessary in order to meet a specific design for a luxury or novelty pack. The example is taken, with permission, from 'The Packaging Designer's Book of Patterns' (Lászlo Roth and George L. Wybenga, 1991).

Step 1: The first set of operations, Figure 9.8, result in the preparation of an outer sleeve and four inner sleeves, which form the drawer guides. Adhesive tape is used to make the various joins.

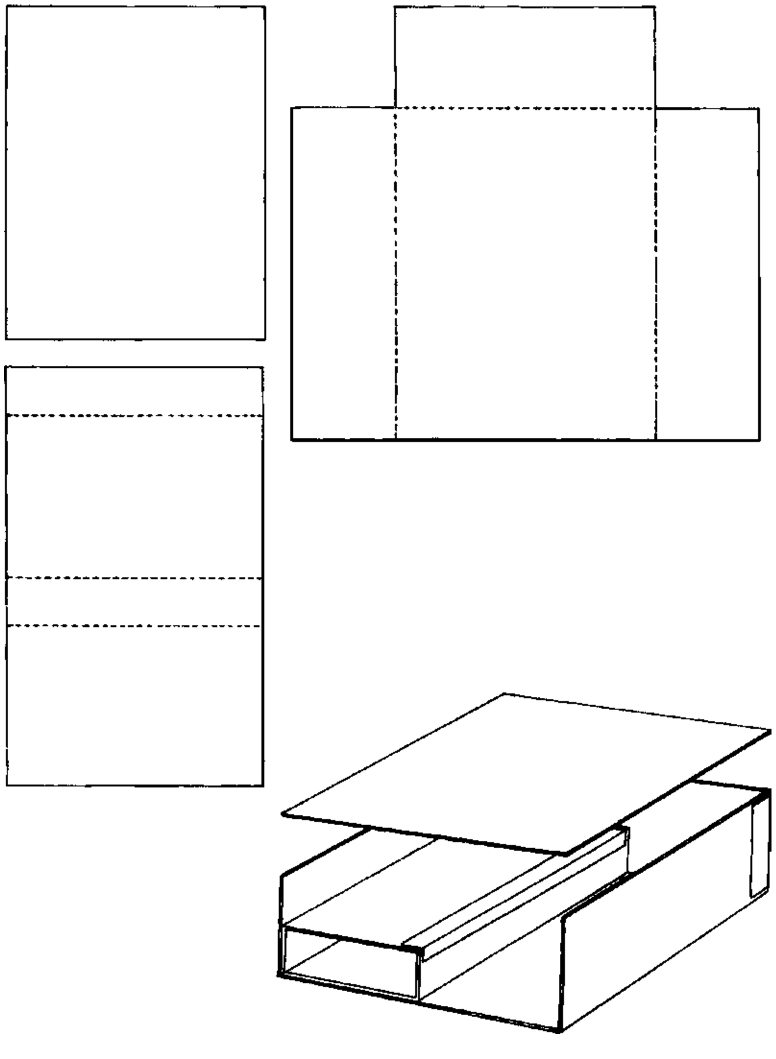

Figure 9.8 Preparation of outer and inner sleeves. (Reproduced, with permission, from John Wiley & Sons, Inc.)

Step 2: Then the face of the drawer guides and the outer sleeve are covered with decorative materials, Figure 9.9.

Step 3: The drawers are cut, scored and corner-stayed. Finally, the drawer pulls are applied, and the assembly checked for a snug fit. The complete assembly is shown in Figure 9.10.

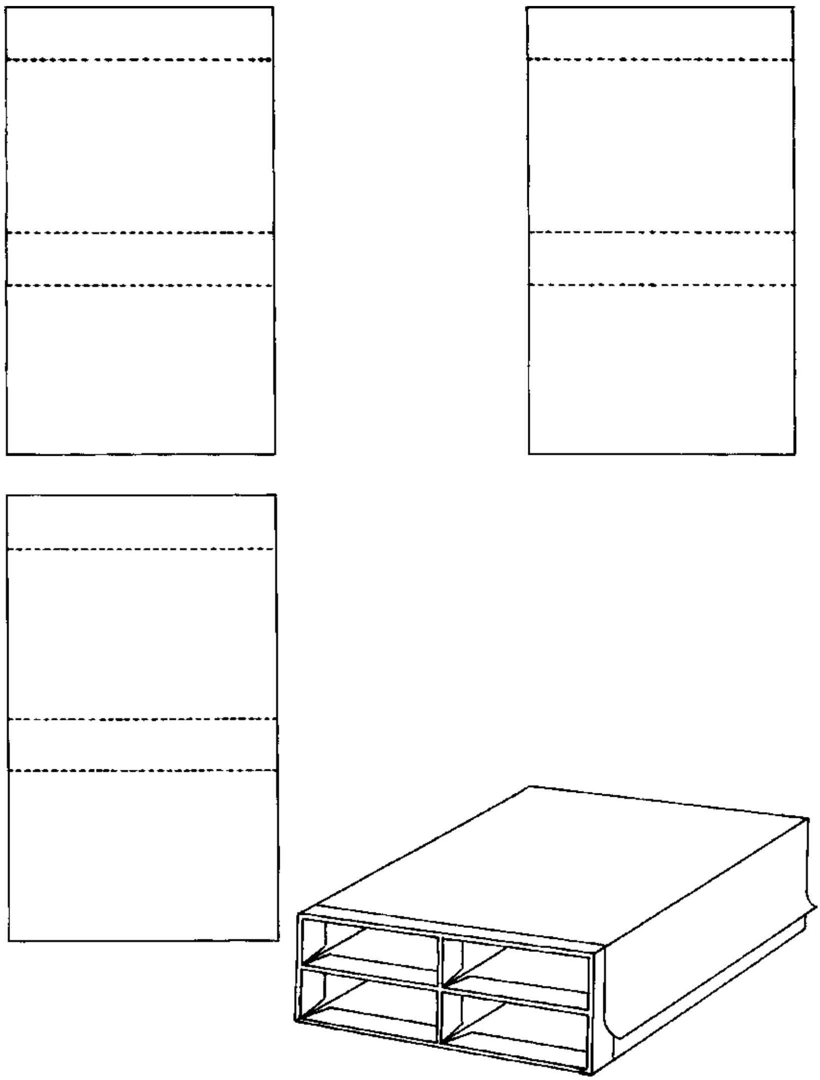

Figure 9.9 Covering of outer sleeve and face of drawer guides. (Reproduced, with permission, from John Wiley & Sons, Inc.)

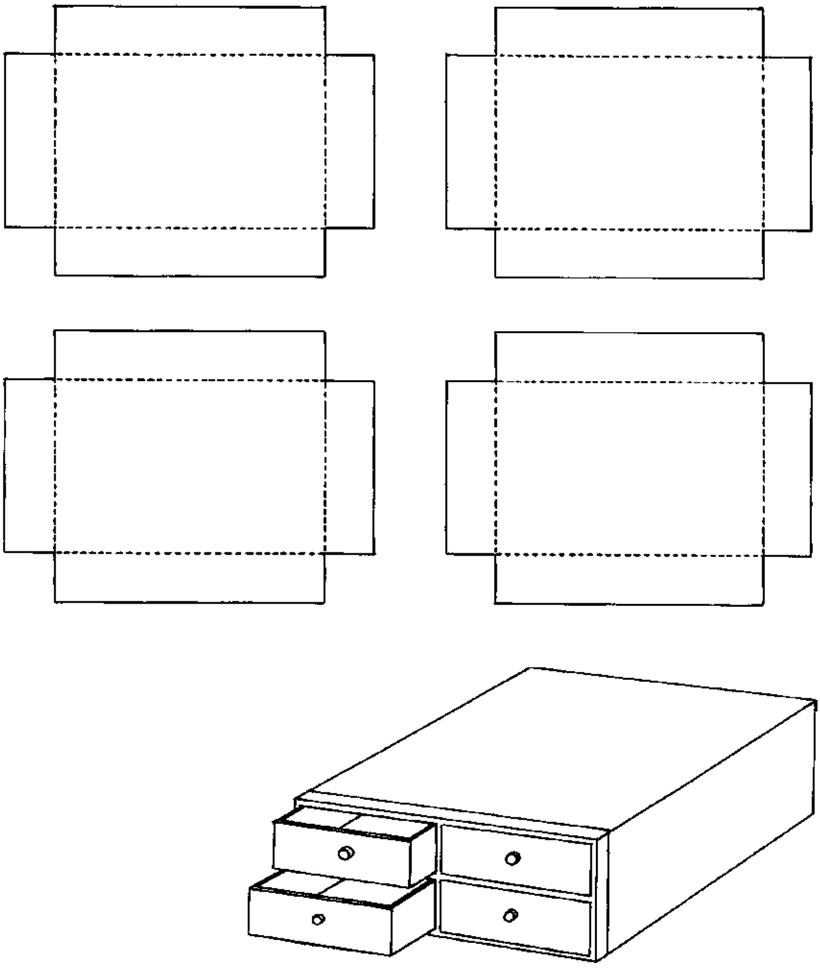

Figure 9.10 Production of drawers and final assembly. (Reproduced, with permission, from John Wiley & Sons, Inc.)

9.8 Conclusion

Use of the rigid box continues to compete and find a multitude of uses in the packaging world of today. Its raison d'être remains the need to engender the feeling of quality whilst providing physical protection for its contents. Design versatility, the use of accessories and widely varying print finishes provide a unique packaging proposition that continues to delight its users and consumers.

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10 Folding cartons

Mark J. Kirwan

10.1 Introduction

Cartons are small to medium sized boxes made from paperboard ('cardboard'). They comprise a significant proportion of the packaging found in the retail sector, i.e. in supermarkets and shops of all kinds, in mail order, in vending machines, in the service sector (hospitals, schools, catering, etc.) and in the dispensing of medicines.

Cartons meet packaging needs cost-effectively by providing product protection and information, visual impact and convenience appropriate for the product concerned and its method of distribution and consumer use.

Folding cartons are delivered to the packer in a flat form. This may be either as a flat printed and profiled blank, or as a side seam glued carton which is folded flat. The carton packer erects, fills and closes the carton either manually, mechanically or by a combination of manual and mechanical means. The flatness of the folding carton prior to the packaging operation is a major space-saving benefit in distribution and storage before use and distinguishes folding cartons from *rigid* cartons, which are 'set-up', ready for use at the point of manufacture.

Cartons increased in popularity with the pattern in retailing, whereby the shopkeeper trading locally, apportioning the product on demand from bulk, was replaced by manufacturers marketing brands and trading nationally and internationally. This was facilitated by the development of machinery to apportion the product and to erect, fill and close cartons.

Folding cartons are made from paperboard, often referred to as 'cardboard' or 'cartonboard'. There are several different types of paperboard differing in the types of pulp used in their construction. The main types of pulp, as has already been discussed in Chapter 1, are chemical bleached, chemical unbleached, mechanical and recycled. Paperboard is usually multilayered and may comprise layers of more than one type of pulp. Surfaces are usually, but not always, coated with a mineral-pigmented coating to enhance appearance and printability.

The properties of paperboard can be extended by the use of other materials, plastic extrusion coatings and other functional coatings and treatments.

Paperboard is characterised by its thickness and weight per unit area. Packaging trade and national and international standards organisations give different guidances as regards the thickness range for defining paperboard. The upper limit for practical purposes would, however, be 1000 μm. The lower limit has been defined as 250 and 225 μm but there are cartons in use at 200 μm and even lower. The units of measurement are microns (0.001 mm), or thousandths of an inch (0.001 in.). Weight per unit area is measured in either grammes per square metre (g/m^2) or pounds per 1000 square feet.

The carton manufacturer sells cartons by number of cartons, 1 million or whatever, and hence is interested in buying by the *area*, rather than the weight required to make a given number of cartons, taking account of set-up and in-process waste.

In practice, this is facilitated by modern paperboard manufacturing, which is computer-controlled on the paperboard machine within tight weight per unit area, i.e. yield, tolerances and in finishing by accurate sheet counting, in the case of sheeted orders, and length in the case of reels of a given width.

As has also been discussed in Chapter 1, the compression strength of paperboard is highly dependent on stiffness that correlates with thickness to a much higher degree than weight per unit area.

Packaging technologists, packaging buyers and brand managers in end-using companies often ask what type of paperboard they should use for a particular type of product.

The answer, however, depends on a number of factors and the starting point is to examine all the packaging needs. The use of a check list is advised to ensure that all relevant factors are considered. This review will provide guidance on the required appearance, for example surface, etc., and performance, for example strength and product protection characteristics, required to achieve the desired appearance, printability, conversion and usage. These needs in turn depend on:

- *Product* – type, weight, volume, shape or consistency, i.e. powder, granule, etc., and whether it is pre-packed in a pouch, jar, etc., or whether it is packed in direct contact with, or in close proximity to, the paperboard. Any special functional or legal requirements relating to the protection of the product in packing, storage, transit, merchandising and consumer use must be identified.
- *Presentation* – surface and structural carton design, standard of printing and overall visual impact. It maybe that the reverse side of the paperboard is seen or printed. Presentation is closely related to the positioning of the product in its particular market. Each product market will have characteristics. All products, for example breakfast cereals, chocolate confectionery, ethical prescription-only medicines, proprietary over-the-counter medicines, tobacco, etc., are presented in characteristic ways.

  There are also international differences in the ways products are presented. The ways products are presented also depend on the point of sale or use, i.e. whether in self-service display, vending, mail order or catering, etc. and whether the product is bought by one person as a gift for another. Additionally, within specific product markets, there will be luxury, or top-of-the range products, average, middle-of-the-range, medium-priced products and budget, value-for-money products, at the lower-priced end of the range. Packaging, including the choice of paperboard, will reflect this segmentation and product positioning.
- *Packing, distribution and use* – details of the number of cartons to be packed in a given time and whether production is variable through the year are needed at the outset to indicate the extent of mechanically assisted cartonning required.

Distribution and storage factors include consideration of the transit packaging and whether any special environments are involved, such as deep freeze or chilled distribution. Consumer use could include how the pack is used and whether this imposes specific needs such as the reheatable requirements of a convenience food product or the way the carton is handled in use, for example compression needs of a cigarette carton.

In practice, many of the requirements imposed by these needs interact. The carton structural design contributes to the carton compression strength, and the surface strength relates to printability and glueablity, etc.

Folding cartons are usually printed on the outside surface with text, illustrations and decorative designs. Varnishing is used to enhance appearance and to protect print. Graphical design reinforces brand values, particularly in self-service merchandising. Cartons are sometimes printed on the reverse side, for example cartons for chocolate confectionery. Printing provides information on the product and how to use it safely. Hot-foil stamping and embossing are also used to create visual impact.

Folding cartons are produced in a wide range of structural shapes having a choice of closure design, including reclosure features where necessary, together with 'add-on' features, such as handles, windows and internal platforms.

The structural design of most folding cartons is based on a rectangular or square cross section. The type of product to be packed, the method of filling and the way the pack will be distributed, displayed (merchandised) and used will influence the dimensions and design in general. Rectangular shapes are easy to handle mechanically, especially when packed in large volumes at high speeds, easily merchandised, and conveniently handled and stored by the consumer. Other shapes are, however, possible and are used to meet specific needs, for example round, elliptical, triangular, pyramidal, domed, wallet shaped, etc.

All this is possible in manufacture because of the fundamental paperboard properties whereby it is an inherently strong material which is printable, creasable and glueable.

The overall result is that folding cartons are used to package a wide range of products from foodstuffs – such as cereals, frozen, chilled foods and ice cream, confectionery, bakery products, tea, coffee and other dry foods – to non-food products, such as pharmaceuticals, medical and healthcare products, perfumes, cosmetics, toiletries, photographic products, clothing, cigarettes, toys, games, laundry, paper goods, household, electrical, engineering, sport and leisure, gardening and DIY products, etc. Around 55% of all cartons are used in the packaging of food products (Pro Carton, 1999).

10.2 Paperboard used to make folding cartons

The main types of paperboard, i.e. solid bleached board (SBB or SBS), solid unbleached board (SUB or SUS), folding box board (FBB or GC1 or GC2) and white lined chipboard (WLC, GT or Newsboard), have been described in Chapter 1.

The outer surface is usually coated with a mineral-pigmented coating based on china clay and/or calcium carbonate to enhance the appearance (colour, smoothness, surface structure and gloss level) and printability. The reverse side may also have a mineral-pigmented coating for appearance and printability.

The performance of paperboard and cartons can be extended by the use of additional materials and by using processes such as lamination, plastic-extrusion coating, impregnation and functional-surface coating. Such treatments are used to ensure that cartons meet the needs of product protection throughout the distribution and storage chain up to, and including, the ultimate consumer.

Performance laminations of paperboard are possible with greaseproof and glassine paper, polyvinylidene dichloride (PVdC or Saran®)-coated paper and aluminium foil. These surfaces provide grease/fat resistance. Wax used as adhesive for a greaseproof or glassine lamination enhances the barrier of these laminates to moisture and moisture vapour. For product release, greaseproof paper or glassine coated with a silicone-release coating is used. Aluminium foil provides a number of functional benefits, such as barrier to moisture and moisture vapour, grease/fat barrier, odour barrier, product release and heat resistance. PVdC provides heat sealability and a barrier to moisture and moisture vapour, grease/fat, flavours and odours; it is not, however, used widely in carton constructions. It is used as a coating on oriented polypropylene (OPP) film which is used as a barrier overwrap for chocolate confectionery, tea and cigarette cartons.

Coated paper with good printability can be laminated with paperboard using microcrystalline wax blends as the adhesive to provide a paperboard with moisture vapour resistance.

Paperboard can be plastic extrusion coated to achieve a range of barrier, heat sealing and heat resistant properties with polyethylene (PE), polypropylene (PP), polyethylene terephthalate (PET or PETE), polymethylpentene (PMP) and ionomer (Surlyn™).

Paperboard may be coated with silicone, wax or a heat seal varnish. It can be impregnated with wax during paperboard production. Water-based coatings can provide heat sealing and grease resistance. Wax is a good barrier to volatile contamination from outside and for the retention of flavour and aroma within packaging.

10.3 Carton design

10.3.1 Surface design

This involves all the aspects of a carton which relate to its overall visual impact. The basis is the colour of the surface of the paperboard, its smoothness and surface finish. The colour is usually white, though other colours are possible by the use of coloured mineral pigmented coatings. High whiteness enhances print contrast. Surface finish can be either high gloss, satin or matte. There are variations in appearance between paperboards, and the existence of the ultra high-gloss cast-coated products, also available in different colours, extends the gloss range further. A matte finish may increase print contrast and make text easier to read whereas gloss and sparkle can attract attention. It is also possible to apply an overall embossed design to the paperboard surface, for example linen effect. All other variations in surface appearance are achieved by conversion, printing and varnishing.

There are many possible types of lamination which are used to create a visual effect. Plastic film, for example cellulose acetate, polypropylene, etc. may be applied to enhance gloss and a luxury appearance. Aluminium foil or metallised polyester plastic film is used to produce an overall metallic effect. Papers, such as a high specification coated paper or coloured glassine, for example chocolate coloured, may also be laminated to a paperboard base. In the latter example, there is also a performance element relating to product protection.

Whilst plastic extrusion coating is primarily used as a functional addition to paperboard, it can also have a visual effect. This is usually to impart gloss.

Printing offers a very extensive range of possibilities for creating visual impact. It is used for brand names, text, illustrations and diagrams. This range can include tactile text and decoration. Printing can provide solid colour or patterned decoration.

Varnishing is done over print to improve rub resistance, and it can also be used to create a visual effect. This effect can result in a gloss, satin or matte surface, and may either be all over the surface or limited to specific parts of the design. Pearlescent varnishes can also be applied to create a special effect.

Localised effects can be produced by hot-foil stamping or embossing or by a combination of both. The hot-foil effect is achieved with an aluminium (coloured) foil applied to a heat-resistant film and a heated die profiled to the required design. Embossing can also be used to create an overall decorative effect.

10.3.2 Structural design

Structural design is based on the creative and functional needs of the pack. A carton has to perform efficiently in the packaging operation and thereafter to protect the product throughout its life during distribution to the point of sale or dispensing and to its use by the ultimate consumer. This represents the functional requirement. The function may need to include convenient features, such as opening and reclosure features, carrying handles, windows, internal platforms to locate and display the product, etc.

Structural design must also take into account the dimensions, volume and, if a solid, the shape of the product. The design is usually in three dimensions though there are examples of two-dimensional paperboard packaging, for example blister cards and wallet-style packs for retort pouches.

In addition to the development of a functional design, paperboard gives the designer the scope for creating more imaginative designs whilst not compromising the functional needs of the pack. Such scope arises in, for example, confectionery packaging for chocolate assortments, Easter Eggs or chocolate bar cartons with after-use play value. Examples exist in other end use areas, for example cartons for luxury cosmetics and gift packs of all kinds.

The structural design is facilitated by the strength and toughness of paperboard and by the ease with which paperboard can be accurately and cleanly cut, creased, folded and glued.

Several comprehensive guides on the mainstream types of carton construction are available. The ECMA (European Carton Makers Association) Code and 'The Packaging Designer's Book of Patterns' (Lászlo Roth and George L. Wybenga), published by John Wiley & Sons, Inc., from which several examples are quoted below (see 'References' for full description). Computer-aided-design (CAD) packages are also available.

As already noted, the most common shape of folding carton is based on a rectangular or square cross section. It has four rectangular or square panels. There is a fifth, narrow panel which when fixed, using an adhesive, to the underside of the first panel creates a tube. This structure is said to be side seam glued and it is folded flat by the carton maker for shipment to the packer.

The packer usually erects this style mechanically. The product is loaded, either horizontally, or from the vertical direction, and the end flaps are closed either by tucking, locking slits or with the help of an adhesive. It is referred to as an 'end load' or tube-style carton. An example of this design is shown in Figure 10.1.

Another popular rectangular shape is based on a tray style. In this instance, the carton maker supplies a flat blank. The base of the tray is a flat area of paperboard to which four panels are attached by creases. The tray is erected mechanically by folding these four panels through 90°. This structure is secured either by the use of a hot-melt adhesive or with locking, hook-shaped tabs which fit into slots in the adjacent panels. There are many variations to this style. Lids can be incorporated as extra panels and both lids and side panels can have extensions which are folded

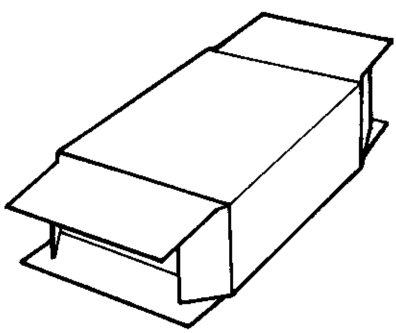

Figure 10.1 End load carton. (Reproduced, with permission, from Alexir Packaging Ltd.)

into position after the product has been loaded, as in Figure 10.2. In the case of the lids, they can be closed by tucking in a folded extension to the lid or by hot-melt gluing one or three closure flaps. This style is often referred to as a 'top load' carton. A point worth considering is that, depending on the product, it makes sense to load the product through the largest opening.

A simple tray style is the shallow tray with side walls 25–38-mm deep with glued or locked corners, which are used to collate groups of cartons for stretch or shrink wrapping, as in Figure 10.3.

The side walls do not necessarily have to be vertical – they may be tapered as shown in Figure 10.4.

Where these trays are plastic extrusion coated with PE, PP or PET they can be erected by heat-sealing. The method of corner-folding and heat-sealing makes this design leak-proof as shown in Figure 10.5.

Trays can also be made by pressing and deep drawing, as shown in Figure 10.6. This process places high demands on the paperboard. The normal depth of drawing

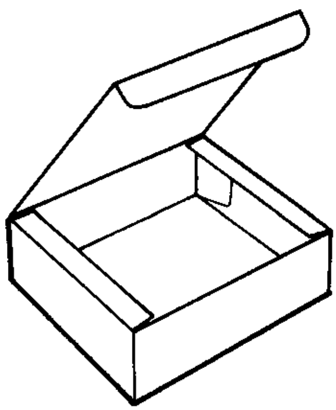

Figure 10.2 Top load carton. (Reproduced, with permission, from Alexir Packaging Ltd.)

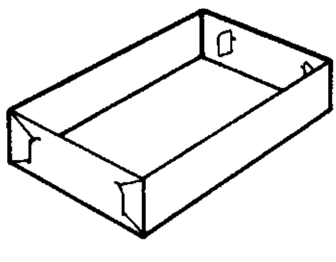

Figure 10.3 Shallow-depth tray with locked corners. (Reproduced, with permission, from Alexir Packaging Ltd.)

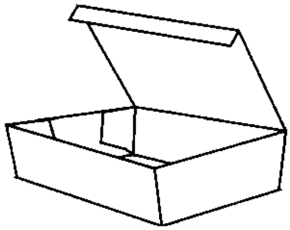

Figure 10.4 Tapered carton with lid. (Reproduced, with permission, from Alexir Packaging Ltd.)

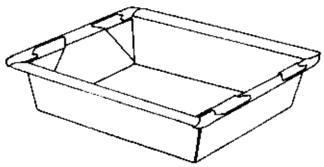

Figure 10.5 Tray with tapered sides and heat sealed corners. (Reproduced, with permission, from John Wiley & Sons, Inc.)

Figure 10.6 Deep-drawn, pressed trays. (Reproduced, with permission, from Iggesund Paperboard.)

is around 25 mm, and with additional moisture application and two-stage drawing, it is possible to extend this to 45–50 mm. Deep drawing can be used with paperboard extrusion coated with PET, which can be used to pack food products that are cooked and/or reheated in the pack. Reheating is possible using microwave or radiant heat. The trays can be lidded with plastic snap-on lids, heat-sealed plastic film or heat-sealed plastic-coated paperboard.

By changing the cutting and creasing of the paperboard carton blank and by corner-gluing, tray designs can be made by the carton maker, which are folded for packing and shipment to the carton user who then erects these cartons by hand. These can be four corner–glued or six corner–glued, the latter, which incorporates a lid, being traditionally used by cake shops (Fig. 10.7).

A modification of the tray design with hollow walls and a double-thickness lid, as shown in Figure 10.8, is a popular choice for chocolate assortments. This carton can be erected mechanically on the packing line. The hollow walls provide excellent rigidity, enabling the carton to be held by one corner when offering the contents around. The double-thickness lid results in the same high-quality printing

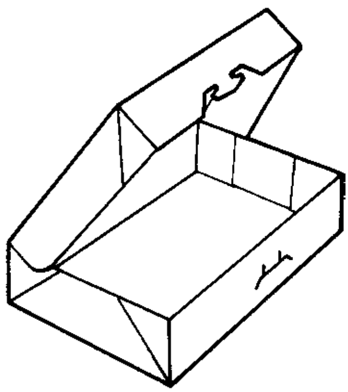

Figure 10.7 Six corner–glued cake box. (Reproduced, with permission, from Alexir Packaging Ltd.)

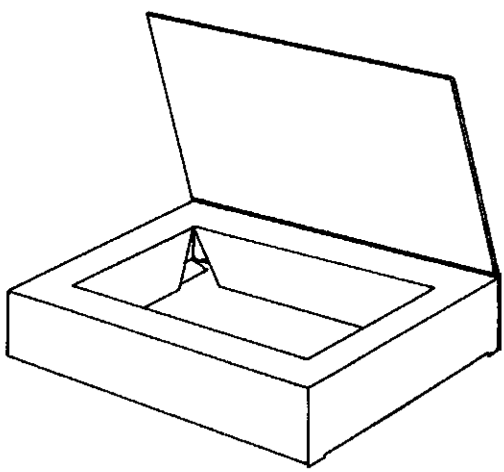

Figure 10.8 Carton with cavity walls and double thickness lid. (Reproduced, with permission, from John Wiley & Sons, Inc.)

which is expected with this type of application to be achieved on the inside surface of the lid.

A popular way of providing product protection is to overwrap a folding carton with a barrier-coated PP film with envelope folded and heat sealed end seals. Typical applications include cartons for chocolates, tea bags and cigarettes. Another material used in this way is high-gloss wax-coated paper used to overwrap unprinted cartons for frozen food.

A popular carton style is the hinged-lid cigarette carton as shown in Figure 10.9. This carton is erected at high speed from a rectangular blank. It incorporates a small additional piece of paperboard which provides strength and facilitates the design of the closure.

Other shapes are, however, possible and are used to meet specific needs, for example round, elliptical, triangular, pyramidal, hexagonal, domed, wallet shaped (for retort pouches), etc. (Figs 10.10 and 10.11).

Where a product requires protection from moisture, oxygen, contaminating odours and taints, etc., cartons may be lined by the carton maker with a flat tube of a flexible barrier material which is inserted during carton manufacture. The flexible material is usually heat sealable – examples include paper/aluminium foil/PE

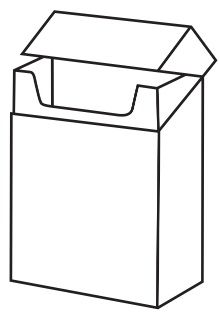

Figure 10.9 Hinged-lid cigarette carton. (Reproduced, with permission, from John Wiley & Sons, Inc.)

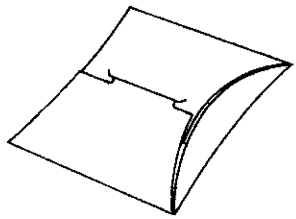

Figure 10.10 Wallet or pillow design. (Reproduced, with permission, from John Wiley & Sons, Inc.)

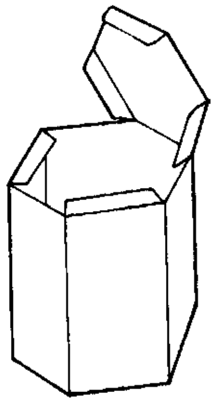

Figure 10.11 Hexagonal design. (Reproduced, with permission, from Alexir Packaging Ltd.)

and laminations involving plastic films. The lined cartons are supplied folded flat to the packing/filling machine. One end of the liner is heat sealed, the associated carton flaps closed and then, after filling, the other end is sealed and the carton flaps closed. This type of carton is used for ground coffee, dry foods and liquids. Packing machines can vacuum pack or gas flush a product such as ground coffee. A lined carton of this nature may be fitted with a plastic hinged lid incorporating a moisture vapour barrier and tamper evident diaphragm (Fig. 10.12).

Another type of lined carton, which can be formed by the packer on the packing machine, takes flat carton blanks and a roll of the material to be used as the liner, frequently bleached kraft paper. First, the liner is formed around a solid mandrel. The side seam and base are either heat-sealed or glued with adhesive, depending on the specification. The carton is then wrapped around the liner with the side seam and base sealed with adhesive. The lined carton is removed from the mandrel, the product is filled and both liner and carton are sealed/closed. This type of pack

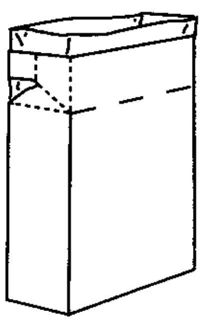

Figure 10.12 Lined carton. (Reproduced, with permission, from Alexir Packaging Ltd.)

is suitable for the vertical filling of powders, granules and products such as loose filled tea.

Folding cartons can have windows or plastic panels for product display, for example spirits, toys, etc (Fig. 10.13).

A *display outer* is a carton which performs two functions. At the packing stage, it is used as a transit pack or outer. When it arrives at the point of sale, the specially designed lid flap is opened and folded down inside the carton at the back of the product to become a display pack with a printed header display. This design of carton, as shown in Figure 10.14, is used to pack a number of smaller items which are sold separately, for example confectionery products, such as chocolate bars, also known as countlines.

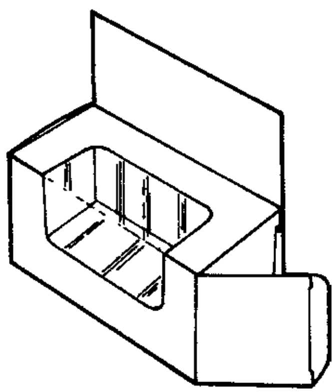

Figure 10.13 Windowed carton. (Reproduced, with permission, from Alexir Packaging Ltd.)

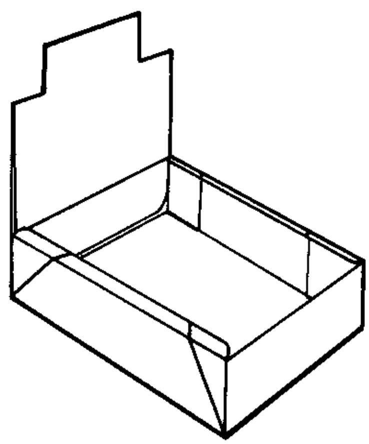

Figure 10.14 Display outer. (Reproduced, with permission, from Alexir Packaging Ltd.)

In the case of the end load or tube style carton, the carton flaps on the base are closed by either tucking, locking, gluing or heat-sealing. A heat sealed closure requires the presence of a thermoplastic layer, for example PE, PP or PET.

The crash lock base is made by the carton maker. The bottom flaps are creased and glued in a special way which enables the carton maker to fold the carton flat for shipment to the packer who erects the carton by hand in such a way that the bottom flaps snap, or crash, into position irreversibly. This type of base can support a considerable weight, for example bottle of alcoholic liqueur.

The lid flaps may be closed with a tuck-in-flap or flip top, or may be locked, glued or heat sealed. Closures may be made tamper evident. The top may have an easy opening device and where necessary, a reclosure feature. Closures which are repeatedly opened and closed during the life of the contents, for example perfume, require their creasing to have sufficient folding endurance. This requires careful consideration of the type of paperboard used.

Additionally, cartons can have integral, internal display fitments or platforms, sleeves can be used for trays of chilled ready meals and multipacks for bottles, drinks cans (Fig. 10.16) and yoghurt pots (Fig. 10.15).

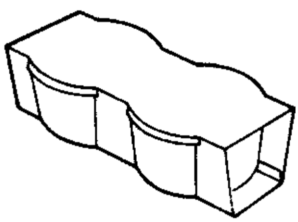

Figure 10.15 Sleeve for two plastic tubs. (Reproduced, with permission, from Alexir Packaging Ltd.)

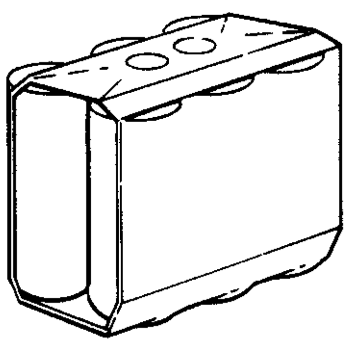

Figure 10.16 Multipack for six beverage cans. (Reproduced, with permission, from Alexir Packaging Ltd.)

Cartons can incorporate dispensing devices, carrying handles and easy opening tear strip features for convenience in handling and use. Cartons can be made into non-rectangular, innovative shapes, such as packaging for Easter Eggs.

This chapter is not comprehensive. It is intended to indicate that folding cartons can take many shapes and meet many packaging needs. A carton designer working to a project brief has many options and considerable freedom to express imaginative and creative ideas. The paperboard features that make this possible depend on the strength and toughness of paperboard and its creasing, folding and glueability properties.

Reference has been made to the use of CAD packages – an added advantage of CAD is that it can be linked to plotters which can quickly reproduce drawings and even make actual samples for evaluation.

Together with an appropriate coating, lamination or separate carton lining, paperboard can be used in conjunction with the design of the pack to produce cartons, sleeves, trays and blisterpacks which meet demanding performance requirements, such as liquid tightness, siftproofness, heat sealability, grease resistance, moisture and moisture vapour resistance, product release and reheating by microwave, convection and radiant heat. Folding cartons can meet the needs of a wide range of distribution, storage, packaging and use conditions, for example frozen, chilled, ambient, tropical and wet conditions.

Once a specific type of paperboard has been selected, it is necessary to choose the grammage (basis weight) and thickness to provide adequate carton strength at each stage of the packing chain from packing through to use by the consumer.

The outcome of the design phase for both surface design and structure is to provide one or more design proposals for evaluation by marketing, production, R&D, costing and functionality at each stage of the packaging chain.

10.4 Manufacture of folding cartons

10.4.1 Printing

The main processes for carton printing today are offset lithography, flexography and gravure. Letterpress and silk screen are used to a limited extent. The most recently introduced process, digital printing, can be used for short print runs and for customising packaging already pre-made in bulk.

All these processes are discussed in Sections 4.6.1–4.6.8.

The answer to the question as to which print process to use, is complicated. The considerations are:

- product, distribution and usage
- quality of reproduction
- run length
- lead time
- cost.

Printing involves solid print, text, illustrations and diagrammatic representations appropriate for the type of product concerned and its market positioning. As already noted, product positioning and specific brand values will have a major influence on the print design and the quality of reproduction required.

Functional needs of the packaging, depending on the product or method of distribution, may impose constraints. Products such as detergents can be aggressive to print, particularly in conditions of high humidity. Powdered products packed hot may impose the need for highly scuff and rub resistant print surfaces. Products such as chocolate and tobacco are sensitive to retained ink odours and this will influence the choice of inks and print process. In every case, the overall needs should be discussed with printing experts.

With respect to quality of reproduction, there is overlap in what can be achieved today with the different printing processes.

It is used to be said that flexo was poor for solids, half tones, as required for illustrations, and varnish gloss. This is not true today. Excellent results have also been demonstrated using UV cured varnish. A flexo press with cutting and creasing in-line was recently demonstrated for printing cigarette cartons, the printing of which is currently dominated by gravure.

Gravure was considered the best for solids, and offset litho the best for half tones. Offset gravure and conventional gravure with electrostatic assist may improve gravure half-tone reproduction, but the benefits are academic if the capacity to print large volumes is not available or if run lengths are too low to justify the high cost of gravure cylinders.

There was a time when, for example a rose would be printed by offset litho on a carton for chocolate assortments and the rest of the carton, with an overall solid print, would be printed by sheet-fed gravure. There were specific reasons for this. Gravure, provided the retained solvent level met the required standards, was the better choice since in those days the residual odours from oxidation–polymerisation drying oil-based litho inks were a potential hazard for chocolate packaging. Moreover there was a risk of set-off and poor rub resistance with litho on such large solid areas of print. Today there is a wide choice of offset litho ink and drying systems, particularly with UV (ultraviolet) and EB (electron beam) assisted drying.

It used to be the case that varnishing in-line by offset litho was poor in terms of colour and gloss. Today, this no longer applies as presses are fitted with coating units and can apply UV cured varnishes which are water clear, have high gloss and rub resistance.

It still the case that the cylinders are relatively dearer for gravure than plates are for litho and flexo, but they are longer lasting and hence are competitive when long runs are required.

Silk screen printing has always been known for its ability to print thick films of ink – it gives the best fluorescent effect, for example. It is possible to use UV systems in silk screen printing. This has the advantage of rapid ink drying. A recent review lists the range of effects which are possible – raised images, including braille text and warning symbols, highly opaque prints, high-lustre varnish finishes and textured finishes. Examples of the latter include a colourless varnish containing large particles to create a coarse feel and give an 'ice look' to a pack. The examples demonstrate the ability to mimic pastry and a luxury, metallic embossed leather look (Packaging, 2004). Silk screen is not going to challenge the high-volume package printing market but it has the ability to print special effects. Printing continues to innovate and surprise.

Overall pre-press, plate/cylinder and make-ready costs are relatively lower than 10+ years ago due to technical changes in scanning, digitalisation, processing, proofing and on-machine improvements in make-ready. If one wants to check out the printing industry for its application of new technology and higher productivity, one has only to visit one of the leading exhibitions, such as DRUPA (Druck und Papier) held in Düsseldorf.

Pre-press processing times including off-press proofing have greatly reduced lead times to meet end-user's needs for a quick response. Not only is there a need for rapid response but run lengths have reduced with the result that a higher proportion of medium size presses are used today in litho. There has also been an increased interest in narrow web gravure/flexo with cutting and creasing in-line. Speeds continue to increase for all types of printing press.

Despite all the high technology and investment to be seen in the press room today, the quality needs for paperboard to be flat, accurately and squarely cut, with dust and debris-free surfaces remain just as important as ever. In this respect, it is worth mentioning two areas where attention is still very important.

- The moisture-resistant wrapping, which protected the paperboard in transit and storage after manufacture, must not be removed until the mass of the board has assumed temperature equilibrium with the atmosphere of the press room. When cold board is unwrapped, moisture can condense on the edges in the same way as an inside window mists up when it is cold outside. Moisture which condenses on the surface of the paperboard is not visible but its effect may be, and can result in, a curled or wavy sheet.

  A problem experienced by the author occurred when paperboard having been delivered and immediately printed for an urgent (JIT) order during very cold weather had the liner *completely* ripped away by the litho inks. The temperature in the middle of the pallet of printed paperboard was still only 11 °C several hours after printing compared with a temperature in the pressroom of 20 °C! The litho inks which are already tacky became even tackier when they contacted the cold paperboard surface.

  This paperboard subsequently, nearly 48 h later, was printed satisfactorily. Warming-up times for various temperature differences and weights of paperboard are published by paperboard mills.

- Spots, also known as hickies and bulls eyes, result in poor print appearance in solid areas of colour when printed by offset litho. They are variously referred to as 'dust and debris' problems. There tends to be a general belief that these only arise from the paperboard and it is a fact that particles which are distinctive in appearance from this source do occasionally occur, and examples are as shown in Figure 10.17.

Particles may also originate from ink, the press and the pressroom environment. Examples in these categories are shown in Figure 10.18.

In theory, none of these particles should be present. A particularly memorable 'loose fibres from clothing' problem occurred when a man loading sheets into the in-feed of the press and wearing a thick red woollen sweater was surprised when the particles causing lines in the print were found to be red and woollen. Today, the press has a direct feed, so there is no need for such close contact and the operator will be wearing protective clothing. When a problem of this sort arises, it is always essential that the actual spots/particles be retrieved from the press and examined and identified microscopically so that the correct corrective action can be taken.

A major change in attitude within the press room has occurred in recent years which has resulted in the certification of carton manufacture by appropriate authorities to food and pharmaceutical packaging standards.

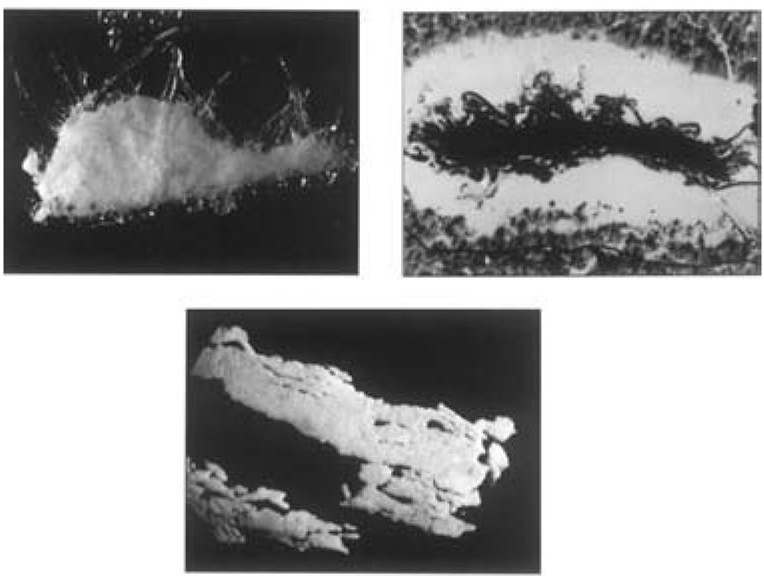

Figure 10.17 Coating particles, slit and chop edge particles. (Reproduced, with permission, from Iggesund Paperboard.)

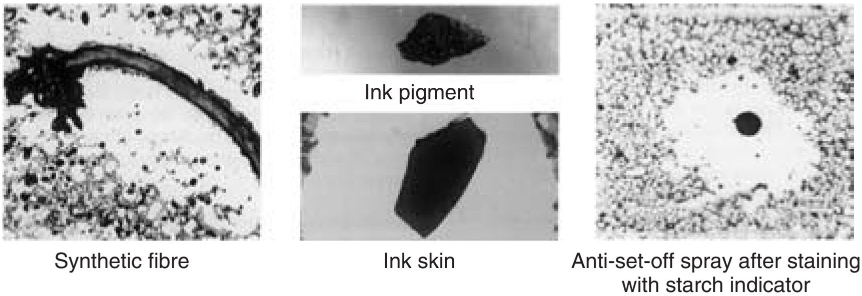

Figure 10.18 Anti-set-off spray, undispersed pigment, dried ink skin and synthetic fibre. (Reproduced, with permission, from Iggesund Paperboard.)

10.4.2 Cutting and creasing

The process of cutting and creasing converts the printed paperboard into flat individual profiles, or blanks, of the intended cartons with, in the case of printed cartons, all the cut edges, creasing grooves, panels, flaps, interlocking features, localised embossing, etc. in register with the print.

Cutting must ensure that the edges of the printed paperboard blank are clean and free from fibrous debris, such as loose fibres, fragments of fibres, clumps of fibres or thin whispy slivers of paperboard. This is important as otherwise loose material may be shed during gluing, if that is the next process, or on the packing line where it can interfere with efficient machine operation and contaminate the product.

A crease (score) is a groove in paperboard which facilitates bending or folding along a clearly defined line. In a carton blank, creases (scores) define the edges of the panels and flaps which are subsequently folded during gluing and carton erection, filling and closure. The action of folding or bending the board along the crease lines causes the carton to assume its three dimensional shape and contribute to the compression strength of the carton in storage, distribution and consumer use.

'Creases' are also referred to as 'scores' and this interpretation is used in this text. This has been noted because in some parts of the world, a 'score' has a different meaning, i.e. that a score is an actual cut, part way through the paperboard, which has been made in the surface of the paperboard. A cut score also facilitates bending and folding but the surface is weakened and the visual effect may be unsightly on printed board. An important use of the cut score is where it is used as part of an easy opening tear strip. Perforations are used to facilitate bending, for example on 45° glue flap creases for folded, glued trays and crash-lock bottom closures.

A crease (score) should operate as a hinge. It is possible to measure the force necessary to bend a creased panel through any given angle up to 180° and the spring-back force on a panel as it tries to resist being held after folding. Both aspects are relevant to the performance of a carton during and after the packaging operation.

Cutting and creasing are very different operations. They are clearly inter-related with respect to the carton profile and they are carried out simultaneously by a tool known as a die.

There are two types of cutting and creasing equipment, namely flat bed and rotary. The main difference between them is that while cutting takes place, with flatbed, the paperboard is stationary, and with rotary, it is moving. The rotary method is usually operated in-line following printing from the reel. Flatbed cutting and creasing can either be sheet-fed or take place, in-line, after printing on a reel-fed machine.

Despite the fact that the criteria for cutting and creasing are very specific, there are many different ways of achieving these criteria in practice. This has significant commercial implications relating to order size (number of cartons).

10.4.2.1 Flatbed die

The die is made by setting cutting knives and creasing rules, in a stable wooden forme, in pre-cut channels which have been accurately cut using a laser working to a carton design in a CAD system. Before lasers were introduced, other methods such as cutting with a jig saw or assembling with the help of accurately cut wooden blocks were used. Cutting is carried out with knives which have sharp edges, and these knives cut vertically through the paperboard. Creasing (scoring) is carried out with creasing rules which have rounded ends. They form a groove by indenting the paperboard surface by pushing it into a groove in a material known as the 'make-ready'. Knives are longer than creasing rules because they have to cut right through the paperboard.

The flatbed die is mounted in the upper platen of a cutting and creasing machine. Figure 10.19 shows a schematic layout. Sheets are gripped at the leading

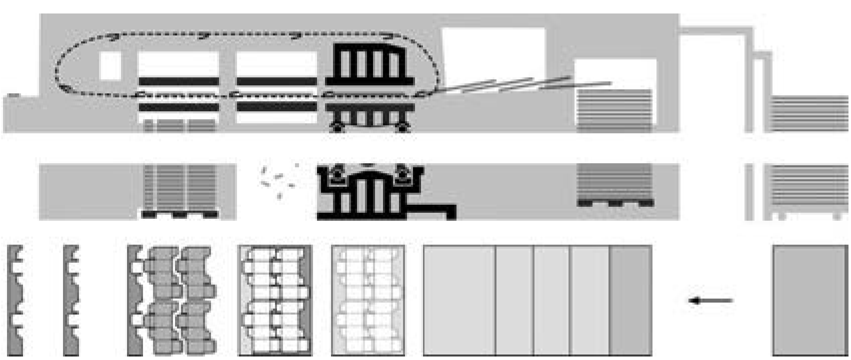

Figure 10.19 Automatic platen machine showing stages of sheet feed, cutting and creasing, stripping and carton blank separation. (Reproduced, with permission, from Bobst SA.)

edge and the gripper bars are connected to chains which move them through the machine. The motion is intermittent to allow the sheet to be processed at each stage.

The die also contains a compressible material, usually rubber of specified hardness, mounted on the die in close proximity to each side of every knife. The purpose of this material is to press the paperboard against the bed plate of the lower platen and hold it securely during cutting. It continues to push against the paperboard as the knife is retracted and ensures that pieces of paperboard do not adhere to the dieboard. The type of die described here is secured between parallel steel plates, one of which moves vertically and intermittently in a platen press. The sheet is inserted when the platen is open. In Figures 10.20 and 10.21,

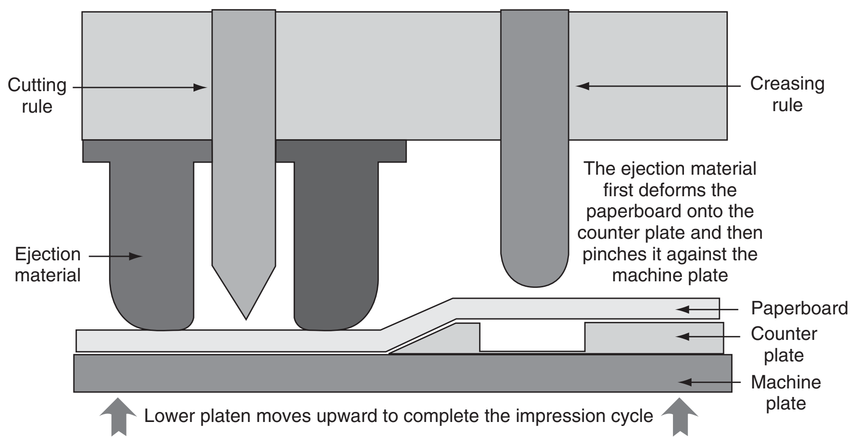

Figure 10.20 Stage 1 – Cutting and creasing – lower platen moves upwards. (Reproduced, with permission, from Dieinfo.)

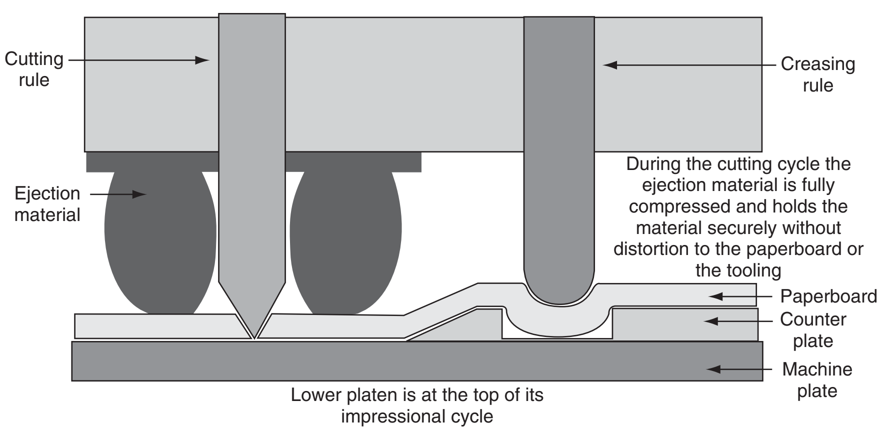

Figure 10.21 Stage 2 – Cutting and creasing – sheet is cut and creased. (Reproduced, with permission, from Dieinfo.)

sequence 1 and 2 respectively, the lower platen moves upwards to cut and crease the paperboard. In Figure 10.22, sequence 3, the lower platen moves downwards with the cut and creased sheet which is then pulled clear by grippers thereby allowing another sheet to move onto the lower platen. The cycle then repeats.

When the platen closes, the die cuts through the paperboard with the knives making ‘kiss’ contact with a backing steel plate. The backing plate is important in that it is possible to adjust the kiss contact of the knives by what is known as ‘patching up’ behind this plate. This is done with thin tissue, along the line of the cutting, as required, in localised areas of the die.

As the printed sheets, shown in Figure 10.23, may be passing through the platen at speeds up to around 7000 sheets per hour and as the individual cartons on each printed sheet are cut with every vertical cycle of the platen, it is important that the carton profiles remain attached sufficiently strongly together and to the gripper or front leading edge of the sheet, which is pulled through the machine, until the point when they are removed from the sheet. This is achieved by leaving the minimum number of very short uncut notches in the cutting profile. Keeping the number of notches as low as possible is important in edges which remain visible, and therefore possibly unsightly, when the carton is erected in its final shape.

The overall process is known as ‘platen die cutting’ and the method of cutting is ‘crush’ cutting, Figure 10.24, because the knife is forced through the paperboard. This type of platen requires high pressure in order to make all the cuts and creases

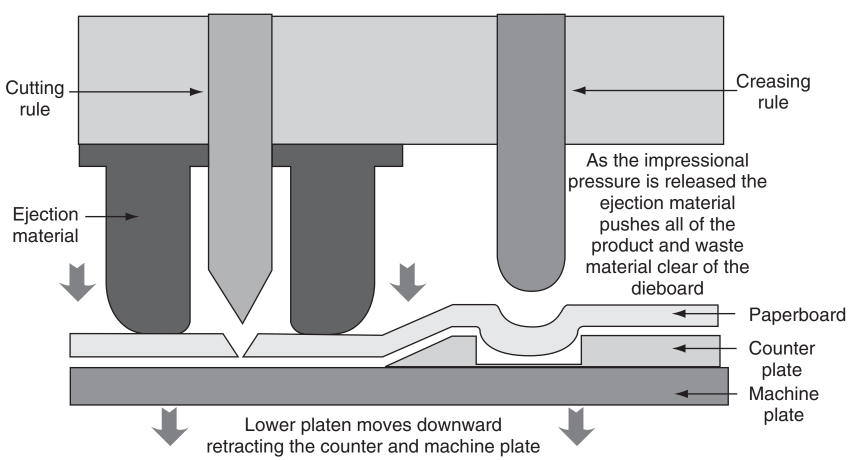

Figure 10.22 Stage 3 – Cutting and creasing – lower platen moves downwards. (Reproduced, with permission, from Dieinfo.)

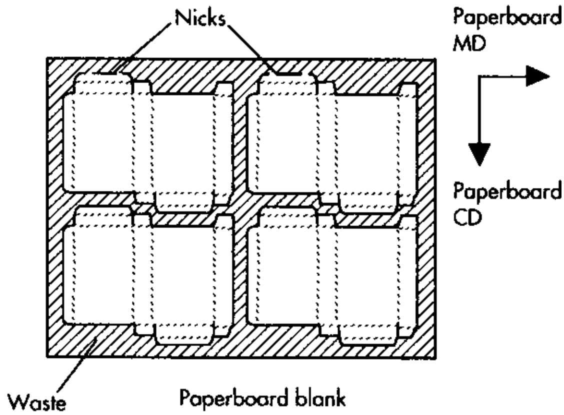

Figure 10.23 Cut and creased sheet, 4-up carton blanks, nicks and waste trim. (Reproduced, with permission, from Iggesund Paperboard.)

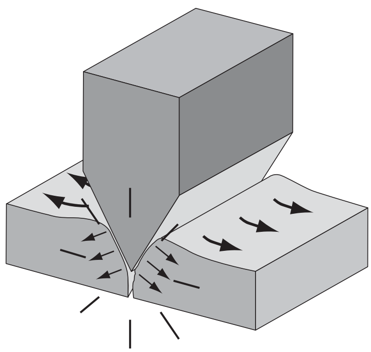

Figure 10.24 Crush cutting – in platen diecutting, paperboard is burst apart by using a steel wedge (knife) to convert downward force into lateral separation force. (Reproduced, with permission, from Dieinfo.)

simultaneously. It is important that the platen is evenly levelled. The sheet being cut is usually smaller than the area of the platen and it is important that the die is ‘balanced’, the latter being achieved by inserting knives in those areas of the platen area outside the area of the sheet being cut and creased. As noted, the pressure required is high and it is important to maintain an even pressure across the platen as a whole.

The top edge of the cutting knife, whilst sharp, will be slightly rounded, and horizontal stresses will occur in the paperboard as the knife is forced through the paperboard (Fig. 10.24). These stresses are greatest where there are creasing grooves situated in the vicinity of a knife, as is the case with the relatively narrow glue flap panel. Where the cut in such a situation is in the cross direction (CD) of the board, as it usually is for a glue flap, there is a greater tendency for 'shattering', or ragged tearing, along the line of the cut on the reverse side (back) liner, on the underside of the paperboard. This is because the simultaneous forming of the adjacent crease, also in the CD of the paperboard, stretches the board in the machine direction (MD). Dennis Hine (1999, p. 233) has shown that the increase in width which occurs under the creasing rule as the crease is formed is 57%, i.e. the difference between the length (semicircle) of the rounded end of the creasing rule compared with the width. This amount of stretch relaxes after the creasing rule is withdrawn, but because the elongation properties of the paperboard are lower in the MD, tension is applied to the adjacent narrow panel, which may result in the reverse side liner rupturing just *before* the crush cut is completed.

There are techniques for avoiding this effect. These include ensuring that the knives are sharp and the board is not allowed to dry out prior to cutting – as this reduces the 'stretch' or elasticity of the paperboard. It is also important that attention is paid to the setting and choice of the ejection rubber alongside the knife which holds the sheet in a fixed position during cutting and facilitates the removal of the knife from the paperboard.

10.4.2.2 Rotary die

The traditional rotary die comprises two sets of steel cylinders – one set for creasing and another for cutting, shown schematically in Figure 10.25. Metal is removed from a solid metal cylinder to create knives and creasing rules. The cutting die knives are set to have a 'kiss' contact with the backing roll. Grooves are cut into the creasing roll backing cylinder in line with the creasing rules. A modern method for making these dies is by electronic discharge machining (EDM) (Bernal, 2004).

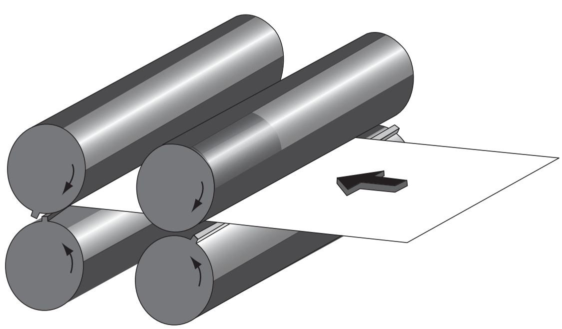

Figure 10.25 Rotary diecutting showing concept of separating the cutting and creasing operations whereby each unit can be adjusted independently. (Reproduced, with permission, from Dieinfo.)

The pressure for cutting is much less, compared with that needed on a platen press because the carton profile is cut incrementally as the die rotates at the same linear speed as the paperboard web. The method of cutting is, however, the same as with the platen diecutting already described, i.e. 'crush' cutting.

This type of rotary die is expensive though they are cost-effective for large orders of cartons in respect of the number of impressions they can make, for example 1.25 million. At this point, the die is resharpened and a further 1.25 million impressions are possible. The solid rotary die can be resharpened up to 4 times, i.e. over 6 million impressions overall.

Bernal has introduced a simpler, less costly version of this type of solid die which is journal-less. This means that less metal and less machining are required with respect to the bearing journals (Bernal, 2004).

There have been several important innovations to adapt the rotary die for shorter numbers of impressions. Wraparound plate rotary dies are thin steel sheets which have been chemically etched. These plates can give up to 800 000 impressions after which they have to be replaced. These plates are fixed to mandrels on the machine, either mechanically or magnetically.

There is another type of cutting which is used, known as 'pressure' or shear cutting, as shown in Figure 10.26. This can also be carried out using rotary dies. To make a cut, the knife, as used in 'crush' cutting, is replaced by two flat metal strips, known as 'lands'. One is located on the upper cylinder, the other on the lower. They are offset from each other, as shown in the diagram. The paperboard is squeezed between the plates causing a clean and dust-free cut. The cutting action is similar to the way scissors cut paper and paperboard. The method was developed by Marathon Corporation in the USA. The original dies were in the form of plates wrapped around cylinders. They were made using photographic and etching techniques and went under the name 'B11'. The original method was subject to problems of inaccuracy and life expectancy. After the patents ran out, Bernal redeveloped the concept using solid hardened cylinders and trademarked their system as the 'RP system' where RP stands for 'rotary pressure'. Today, this tooling

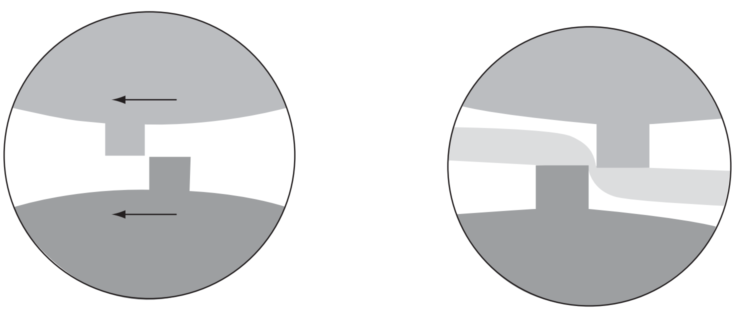

Figure 10.26 Pressure cutting lands – paperboard is 'cut' by raised 'lands' on the rotating cylinders (courtesy of Dieinfo).

is accurate, produces consistent quality over very long production runs, and very little fibre debris is produced (Bernal, 2004, pers. comm.).

The pressure, and hence the knife wear, on these dies is much less than with crush cutting and the dies have a much longer life before they need resharpening. Runs of 10 million impressions would be typical before resharpening and up to four resharpenings thereafter would be possible (Pfaff, 1999).

Pressure-cut wraparound dies based on thin sheets of steel are cheaper and are made by chemical etching. Such dies are cheaper than solid rotary dies and can give over 6 million impressions after which they are replaced.

Michael Pfaff (2000) also emphasises the fact that the important cost figure, which should be calculated for the various rotary die specifications, is the die cost per 1000 cartons (cpm). This reference explains the methodology for calculating die cpm. Both crush and pressure cutting rotary die sets can incorporate creasing within one set of cylinders with a saving in die costs and machine set-up time (Atlas Die, 2004a).

The most effective tear strip is achieved with cut scores. This is achieved by cut-scoring the surface from above the sheet and, in a slightly offset line, cut-scoring the reverse side using a shallow, chemically etched blade set onto the bed plate. The reverse cut score cuts against a flat anvil placed in the die. If this cut-scoring is carried out on either side of a narrow strip of paperboard, the strip can be easily and cleanly removed from the carton (Atlas Die, 2004b).

Perforations can be cut into the board with a serrated knife. They are used in place of creases on the short 45° folds which are used to form trays and crash-lock bottoms. After gluing these creases, the adjoining panels are folded back on themselves, i.e. towards the print, so that the tray or carton is folded flat.

The carton profiles, or blanks, are removed from the sheet by 'stripping'. This is carried out automatically on rotary and platen presses. The stripping unit needs to be carefully designed and set up to ensure that an upcurl (towards the print) is not induced as the blank is forced downwards away from the plane of the sheet. Where it is not carried out automatically on platen presses, stripping is, subsequently, carried out manually, using rubber-headed hammers. The automatic approach requires a system by which the waste, which surrounds the carton profile on the sheet, is efficiently separated and removed.

A key feature for ensuring a high cartonning machine efficiency is that the carton dimensions conform with the agreed specification drawing. Modern die and make-ready technology provides for this need. Many years ago, Pira introduced a measuring table with a travelling microscope and it was used by the author in the 1960s. Indocomp Systems introduced a computer-based system (ACT II) in the late 1980s, which automatically checks the profile of creases and the dimensions of panels. On a gable top milk carton, for instance, it would precisely locate the position of 74 creases (scores) and 32 edges (FCI, 1988, 1996). The system can provide a variety of management reports and has introduced ACT III with a Microsoft Windows-based system. This is faster and has several enhancements, such as 3-D crease (score) and edge profiling (Indocomp, 2004).

10.4.3 Creasing and folding

Creases are made using creasing rules. These rules are thin strips of metal with smooth rounded edges which indent the board surface and push it into an accurately cut groove on the underside of the paperboard. The groove is formed in a thin hard material called the 'make-ready' matrix or counter die. The critical, or important, dimensions which are relevant to the creasing operation are shown in Figure 10.27. The depth and width dimensions of the creasing grooves depend on the paperboard product being used together with the width of the creasing rules and the difference in height between the creasing rules and the knives used in the die.

Most paperboard manufacturers provide guidance on groove width and matrix thickness for given heights of cutting knife and the associated heights/thicknesses of creasing rule. The groove width is usually 1.5 times the thickness of the paperboard plus the width of the creasing rule, and is slightly narrower for creases parallel with the MD of the board.

A note of caution should be made concerning the convention for describing a crease in terms of MD and CD. Some publications define an MD crease as a crease *parallel* with the machine direction of the paperboard, whereas this publication and others, including Dennis Hine's *Cartons and Cartonning*, define an MD crease as one where the *MD stiffness* is involved when the crease is *folded*. In this case, an MD crease would be a crease at *a right angle* or *90°* to the machine direction of the board. Some writers refer to this as an 'across the grain' crease. Therefore to avoid confusion, it is always advisable to define the terminology used (Fig. 10.28).

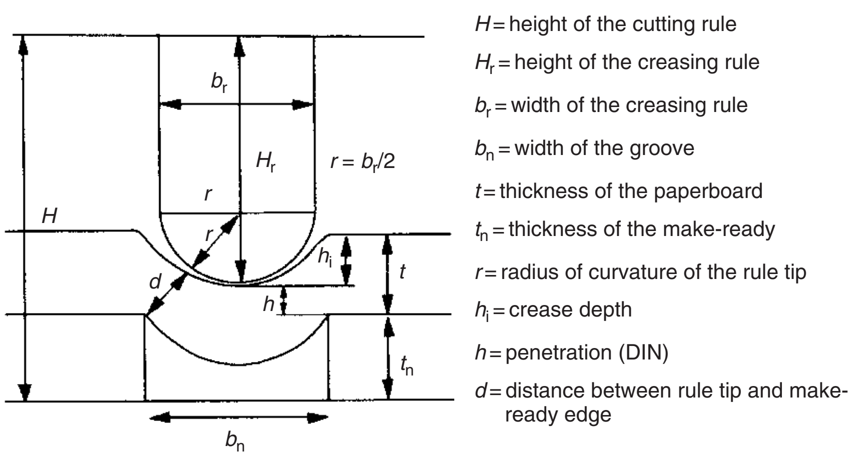

Figure 10.27 Critical dimensions for the creasing operation. (Reproduced, with permission, from Iggesund Paperboard.)

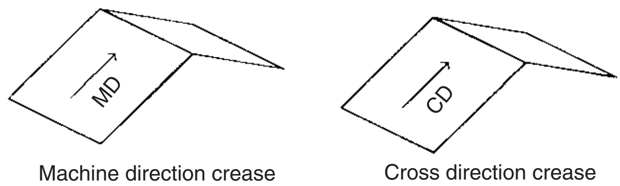

Figure 10.28 Crease definitions – the crease line is at right angles to the indicated board grain direction. (Reproduced, with permission, from Pira.)

There are several types of matrix material available in a range of thicknesses in common use. Platen counter dies can be made from hard phenolic plastic sheet, vulcanised fibre sheet (Presspahn) or steel, depending on the length of run required, i.e. number of impressions. An alternative approach is to use polyester channel (pre-made) of fixed width and depth. Creasing grooves in rotary metal cylinders have the longest life.

There are many possibilities which affect the commercial considerations for any particular carton estimate/enquiry requiring the same paperboard and printing specification. The choice of die, platen or rotary, the various make-ready options and, in the case of rotary, the various die options discussed have different commercial implications depending on order and run length. Add to this, the different machine make-ready times for the various options, stripping waste and the number of cartons possible with the various formats, which are set by the maximum platen area, and the position looks very complicated.

In practice, any given carton maker will have a limited range of machine sizes. This is relevant as the machine size will determine the number of cartons per impression with the die area or format. Format in this sense is the arrangement of the cartons on the area available. Sheet-fed machines have a maximum area which they can print and cut and crease. Reel or web fed machines have a fixed maximum width and the repeat length, or cut-off, limit for the dimensions in the MD, is controlled by the circumference of the cylinders. In any factory, machine sizes are matched for sheet area and production output as between printing and cutting and creasing (scoring). In the case of rotary, it is likely that both processes will take place on the same machine, in-line. Just to make it a little more complicated, depending on the rotary machine concerned and how it is equipped, one can have either a flat bed die or a rotary die. Hence the price for the same enquiry from carton makers with different types and sizes of machinery can be significantly different.

The format area is not only controlled by the maximum and minimum sheet size that will fit on the machine. The way the cartons can be laid out in the available area also has to take account of the carton grain direction. An interesting case study where this went wrong for a carton maker was as follows.

Two companies were supplying a carton design to an end-user. Company A printed and cut and creased with a format of 9 cartons on a sheet; the price and the quality were satisfactory. Company B only had a larger format machine available and produced 15 cartons per sheet in 3 rows of 5 cartons. Quality was satisfactory but the cost of production was too high. Company B recosted at 16 per sheet, which was theoretically possible with 4 rows of 4 cartons. But to keep the grain direction the same on the cartons they had to change the grain direction on the sheet of paperboard. Printers normally use a sheet with the grain direction parallel to the axis of the cylinders of the printing press – this is known as a long grain sheet. In this case, not only was the grain direction of the sheet changed but the front-to-back dimension was now right on the limit for the printing press. This might have been all right except for the fact that the carton had a very heavy, i.e. overall solid, ink coverage, which at the back edge of the sheet was right on the edge of the sheet – so near in fact that the vertical side of the pallet of printed board at the back was the same colour as the print. This resulted in a severe tail-edge hook, or hump, in the accumulated sheets on the pallet, along the back row of cartons. When these cartons were cut and creased, they had a severe down curl (away from the print) which rendered them useless for use on the packing machine. Hence the conclusion is that those concerned must take care to recognise the limitations of what can be achieved – they may not simply be dimensional.

The effect of the creasing process on both the surfaces and the internal structure of the paperboard is complex (Fig. 10.29). Across the crease there are:

- tensile strains, which are greatest in the surface and reverse-side liner plies
- compression in the direction perpendicular to the surface
- shearing strains within the paperboard, parallel with the paperboard surfaces.

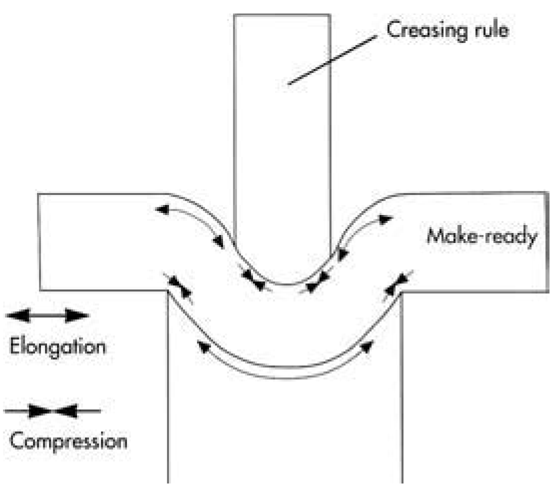

Figure 10.29 Strains (forces) induced on paperboard during creasing. (Reproduced, with permission, from Iggesund Paperboard.)

Reference has been made to the fact that depth of the creasing groove in the surface causes a certain amount of stretching in the surface. Moreover, the initial depth of the groove formed in the surface reduces after the creasing rule is withdrawn from the paperboard. These forces have been studied by a number of researchers (Hine, 1999, pp. 232–241).

The internal shearing forces which occur during the formation of a crease cause some internal delamination of the interply adhesion. This results in a bulge on the reverse side of the board, as shown schematically in Figure 10.30.

When the crease is folded, further internal delamination occurs as shown schematically in Figure 10.31. A good crease should not show any liner

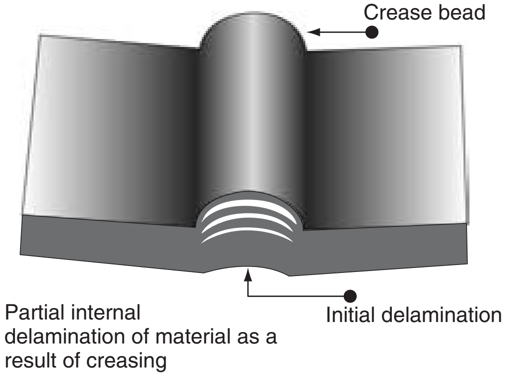

Figure 10.30 Creasing causes internal delamination. (Reproduced, with permission, from Dieinfo.)

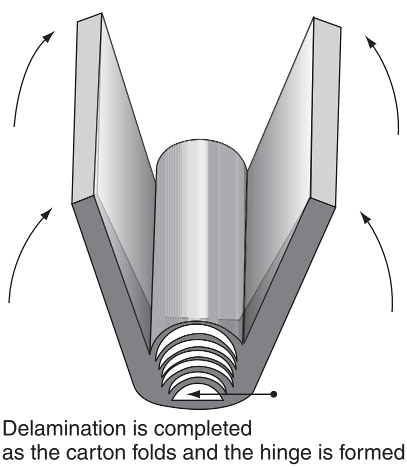

Figure 10.31 Further internal delamination occurs on folding. (Reproduced, with permission, from Dieinfo.)

cracking on the printed side and an even symmetrical rib or bulge, with no signs of crumpling, on the reverse side. These conditions should be maintained when the crease is folded through 180°. After such folding, it will be noticed that the bulge on the reverse side has expanded and the thickness of the paperboard in the middle of the crease is much thicker than the nominal thickness of the paperboard. The delamination which occurs inside the bulge is confirmed by photomicrographs of the folded crease (Hine, 1999, p. 226), as shown in Figure 10.32.

A number of ways of examining the creasing groove have been described, such as by microscope with calibrated graticule, use of lamp and lens assembly to project a shadow profile of the groove and electromechanical devices used in engineering surface examinations where they traverse the groove (Hine, 1999, p. 226). In the author's experience, the latter quickly demonstrates the differences in creases resulting from the misalignment of a rule with the make-ready groove and early warning of the make-ready deteriorating as a result of wear. The Indocomp ACT testing equipment also profiles the crease outline, using a 'high precision LVDT probe (Linear Variable Differential Transformer) probe' (FCI, 1996).

Good creasing is necessary for the following reasons:

- visual appearance of the carton
- efficient performance on the packing line
- maintaining the compression strength of the carton in storage, distribution and use.

Poor creasing is apparent when the folded crease shows liner splitting. This is particularly obvious if there is solid print colour covering the crease because the internal layers of the paperboard are exposed. A possible cause of a crease bursting

Figure 10.32 Photomicrograph showing delamination. (Reproduced, with permission, from Pira.)

along its length can be that the paperboard has dried out as a result of excessive heat being applied during radiation-assisted print drying. A burst over a very short distance in a folded crease can occur if some foreign material jams in the make-ready groove. Other visual defects could be apparent in the bulging of panels and the shattering of the back ply adjacent to a narrow panel such as the glue seam.

The creasability of paperboard can be assessed in the laboratory using a small platen or an instrument such as the Pira Cartonboard Creaser using BS 4818:1993. This is a press which simulates creasing whilst the sample of paperboard is clamped with adjacent creases formed at the same time as the test crease. The instrument can make creases at a range of crease depths and widths. The results are evaluated visually. For a paperboard to be considered to have good creasability, it is important that it should give good creasing over a range of crease settings.

The performance of creases on a packing line is very important. Creases behave like hinges which enable adjacent panels to move through specific angles, usually 90°, and remain there. The bending force is an important parameter. It is especially important for creases which have not been broken previously. Folding is carried out as the carton is moving in relation to fixed rails and ploughs, and therefore undue pressure from crease spring back can at least cause rub and, at worst, delays and jams. Flaps may be glued, and during the setting time of the adhesive, the flap may attempt to spring back and hence must be restrained for sufficient time. In these examples, if the force required to make the fold or the subsequent spring-back is too high, the efficiency of the operation will be poor.

The question therefore arises as to how creasing at the point of carton manufacture can be measured and controlled. This is even more important as it has been shown that a rise in the resistance to folding can be measured well before any visual change in the appearance of the crease can be detected (Hine, 1999, p. 250). This is because of the wear in the groove width which takes place, depending on the make-ready material, over time.

Consideration of how and what to measure starts with identifying the parameters which are involved in the bending of a crease. These parameters are the angle through which the flap is turned, the force required, the distance between the application of the force and the crease, and the time to complete the folding. There is a further consideration. If the crease resistance is greater than the paperboard stiffness, the panel will bow as the panel rotates around the crease. On the other hand, a certain minimum spring-back force is necessary for the correct operation of certain design features such as the retention of a tuck-in-flap locking slit.

The implication of this is that the ratio of crease stiffness to paperboard stiffness is an important parameter and that it should be maintained within upper and lower limits. The limits suggested are 1.5–3.0 for MD creases and 3.0–7.0 for CD creases, and these limits have been accepted for many years (Hine, 1999, pp. 111–139).

(The MD crease convention used here is that MD creases are those where the creases are at right angles to the MD of the paperboard.)

The parameters listed have to be considered when designing a method for testing crease resistance at the point of manufacture. Several methods have been used successfully, such as the Pira Crease Tester and the Marbach Crease Bend Tester. The latter has the advantage of recording and displaying the bending force (torque) dynamically from 0 to 90° and from 0 to 180°. There is a choice of folding time, either 1.0 or 0.1 s, the latter simulating high-speed folding in gluing and cartonning machines.

Faulty creasing results in a poor carton appearance and low packaging-machine efficiency, both of which are easily observed. A further consequence is that cartons affected by faulty creasing will not achieve their optimum compression strength as panels and flaps will not be correctly positioned with respect to each other, leading to bowing and twisting. Damaged creases will not provide the required strength.

10.4.4 Embossing

Embossing is a process which imparts a relief or raised design in the paperboard surface. It can be applied all over the surface, for example a sand or linen pattern. Embossing can also be applied after printing in register with the print, in which case it would be applied as a separate process or during cutting and creasing. Embossing is a design option which enhances visual impact; it is tactile and can impart a luxury feeling. The design could be text or any graphical representation, for example coat of arms (crest), a flower, automobile, fruit, food, bottle, etc. The relief can be raised (positive emboss) or impressed (negative emboss). It is carried out with a shaped metal surface above the paperboard and an inverted pattern underneath using heat as well as pressure (Fig. 10.33).

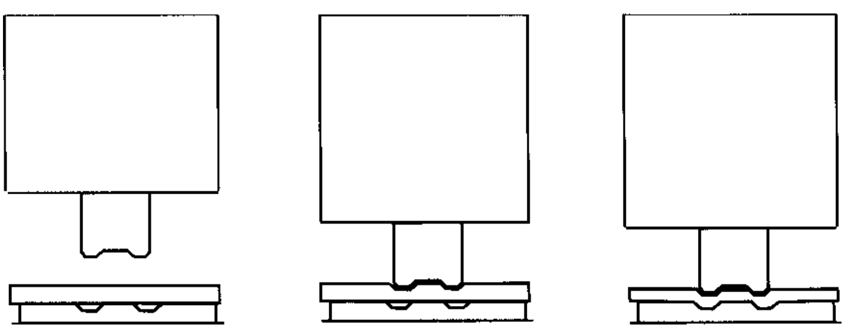

Figure 10.33 Embossing operation. (Reproduced, with permission, from Iggesund Paperboard.)

Whilst all types of paperboard can be embossed, the suitability of any given paperboard for a specific emboss should always be investigated (proofed). The finer the detail and the deeper the emboss, the greater are the demands placed on the paperboard in terms of the strength, toughness, rigidity and elasticity required to achieve the required result. As with creasing, embossing creates forces in the surfaces and the internal structure of the paperboard. The relevant paperboard properties for embossing are tensile strength, percentage of stretch (elongation), toughness, moisture content, stiffness, short-span compression strength and density.

10.4.5 Hot-foil stamping

Hot-foil stamping is a form of surface printing or decoration. It is applied to paperboard using a heated die, containing the design, from a special film. The colour may be either a pigment or a plain (silver), or coloured, aluminium foil (Fig. 10.34). It is applied either in register with the print or to an embossed design feature. It can be applied using a special machine or incorporated with the embossing tool at cutting and creasing.

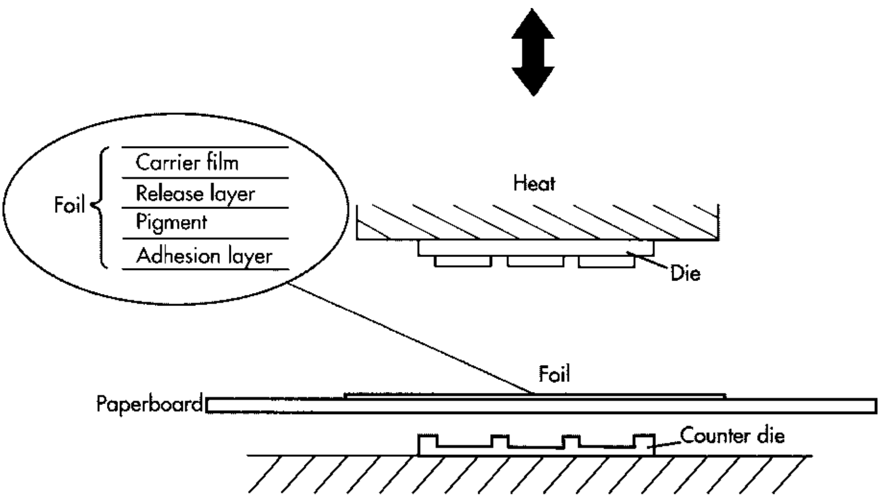

Figure 10.34 Hot-foil stamping and embossing. (Reproduced, with permission, from Iggesund Paperboard.)

10.4.6 Gluing

Gluing is the technique used to erect and close cartons using adhesives which are also referred to as ‘glues’. Several different types of adhesive are used with folding cartons depending on the surfaces being joined and the pressure–time parameters of the gluing system. The principles are discussed in Section 1.5.3.15. In its broadest sense, gluing includes heat sealing plastic coated paperboard, where the molten plastic in the sealing area acts as the adhesive.

In carton manufacturing, the gluing operation is used to seal carton side seams, in corner gluing and in sealing the base flaps of a crash-lock bottom.

The most common type of folding carton is the straight line, side seam–glued, tubular style with open ends. Flat carton blanks are placed in the feeder of a high-speed folder gluer, print face down. This operation can be made more efficient by the use of a pre-feeder which has high capacity storage, is easy to load and presents the cartons in a smooth high-speed rate into the machine. Two distinct operations are carried out. First, the glue-flap crease 1 and crease 3, i.e. the crease opposite the glue flap crease in the finished carton, are pre-folded or 'broken' by folding them over as far as possible, as near to 180° as possible and back to the horizontal. Then the adhesive is applied to the glue flap (Fig. 10.35).

The choice of adhesive depends on the nature of the surfaces being sealed and the parameters of open time, setting time and compression time inherent in the system. The choice must also take into account any special environments and product needs, for example frozen food storage, moist humid conditions, soap/detergent resistance, etc.

For most types of paperboard, the adhesive of choice is a polyvinyl acetate (PVA) emulsion applied by wheel to the glue flap. Creases 2 and 4 are then folded over, and a bond created between the glue flap and the edge of the overlapping panel. The carton is then compressed to allow the adhesive to set. On exiting the compression section, the cartons are counted and packed, usually, in non-returnable corrugated cases, where the drying process takes place. This operation can be automated and run at up to 200 000 cartons per hour.

Modified machines can form and apply tubes of flexible packaging materials to carton blanks, prior to side-seam sealing for bag-in-box cartons.

The gluing of the crash lock bottom style is similar to the side seam–glued tube style with the additional gluing of two diagonal flaps attached to the base of either panels 1 and 3, or panels 2 and 4. As with ordinary tube-style glued cartons, they are then folded flat. As mentioned above, this style can be erected manually by the packer/filler so that the base panels lock into place, after which the carton is filled and closed.

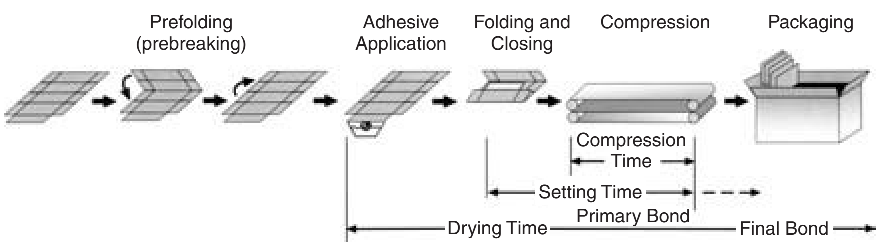

Figure 10.35 Straight-line folding and gluing operation. (Reproduced, with permission, from M-Real.)

Double thickness side walls which are derived by the folding of additional panels can be glued on the straight-line gluer. This style is folded flat and erected by the packer/filler to produce a rigid-tray construction. It is also possible to plough, fold and glue additional panels in such a way that integral platforms to support, display and locate products inside a normal end loading tube style carton can be incorporated – such a carton may have been fitted with a window.

The 4- and 6-point glued trays are glued by applying the adhesive from overhead glue pots to diagonally folded back flaps. The 6-point glued style, Figure 10.7, has an integral lid. Where diagonal flaps are folded back on themselves, and folded flat, it is usual to make the creases with perforating rule at the cutting and creasing stage.

Special adhesives are used where the joining surfaces are not suitable for PVA emulsion sealing. Hot-melt adhesive can be applied on the gluer as a coating which solidifies. This coating is reactivated by heat by the packer/filler in a way which allows the hot melt coating to flow and create sift proof and pinhole-free seals in the packed carton.

Polyethylene coated cartons can be sealed with hot air on a straight-line gluer. Straight-line gluers can be fitted with detectors which check for the presence of a glue line and the measurement of glue line film weight. They can be fitted with code readers to ensure that multiprint orders on the same size cartons do not get intermixed during conversion.

Other important quality issues concern the avoidance of any skewing of the glue flap, vertical or horizontal displacement of the glue flap, glue splashes and glue squeeze-out which can prevent automatic opening on the packing line. The glue flap panel must be free from ink and varnish in the glued area and this also implies tight control of print 'bleed' from adjoining panels.

The effect of the pre-folding, the pressure applied to the outside creases in the compression section and storage aspects are all relevant to packing-line efficiency as they relate to the carton opening force.

Glued cartons are counted and batched automatically prior to packing in corrugated fibreboard cases, and palletised. Automatic case packers can be fitted at the end of the gluing machine. Pallets may be stretch or shrink wrapped in PE film for reasons of hygiene and moisture protection.

10.4.7 Specialist conversion operations

10.4.7.1 Windowing

Cartons can be windowed to enable the contents to be displayed. The windows are made from plastic films, such as cellulose acetate, PVC, PET/PETE and PP. The window is in either one panel or two, in which case it bends around one of the corners when the carton is erected. The paperboard aperture is cut at the cutting and creasing stage. The window patch is applied on a window-patching machine which applies adhesive to the reverse side of the carton blank in line with the perimeter of the window. The film is cut automatically from a reel and applied over the adhesive. The carton is then sent to a straight-line gluer for folding and gluing.

The windowing machine can also be used with attachments to apply flexible packaging tubular material for bag-in-box cartons. Specially designed windowing machines, which can also make creases in plastic film, are available to make paperboard cartons with windows on three or four panels.

10.4.7.2 Waxing

In addition to making cartons from paperboard impregnated with wax during paperboard manufacture, it is also possible to apply wax to one or both sides of a cut and creased flat carton blank. Wax can be applied in patterns and can be kept off glue flaps.

Waxing in this way is either ‘dry’ waxing, where the wax solidifies on the surface giving a matte appearance, or ‘wet’ waxing, where the carton passes under heaters which remelt the wax before the blank is carried on belts through refrigerated water. The shock cooling produces a high-gloss finish on the surface of the wax. With appropriate wax blends, cartons which are high gloss waxed can be heat sealed. Waxed cartons are used for frozen foods, ready meals and ice cream.

Cartons with tapered sides in tub and conical shapes and with a round or square cross section can be waxed after forming. The first liquid-packaging cartons were made in this way.

10.5 Packaging operation

10.5.1 Speed and efficiency

Cartons are erected, filled and packed by product manufacturers, also known as end-users or packer/fillers. There are, additionally, contract packers who provide a packaging service, which includes cartonning, to manufacturers, particularly in order to meet promotional and test marketing needs.

Carton packing may be either manual, partly manual and mechanically assisted, or fully automatic. Speeds vary considerably from, for example, 10–1000 cartons per minute (cpm), though not many would be running at speeds in excess of 500 cpm. Mechanical cartonning with manual product-assisted loading is possible up to 40–60 cpm. Fully automatic cartonners start at speeds of around 60 cpm and most cartonning machinery manufacturers offer equipment which can run at higher speeds, such as 120–240 cpm. Higher speeds are possible in the range of 250–400 cpm, thereafter the machinery is designed with specific products in mind, and in this respect, cigarette cartonning is unique. Packets of 20 cigarettes (sticks) in the special style of carton with a flip-top – also known as a hinged lid, and incorporating a three-sided inner frame – are running at 400–700 cpm. A new generation of cigarette-cartoning machine running at 1000 cpm was launched in 2002 (*A-B Journal*, 2002).

Whatever be the speed and overall output needs of a particular operation, there will be a choice of cartonning machinery to meet the needs of the business. Some manufacturers may prefer three machines rated at 60 cpm to one machine rated at 180 cpm. Several factors will influence the choice, such as:

- factory layout or features of the production process
- need to pack several sizes of product concurrently
- need to pack different products concurrently.

The sequence of operations on a packing line is:

- feeding and erecting the cartons from a box or magazine
- filling with the product
- closing the carton
- checkweighing and metal detection depending on the product
- end-of-line operations preparing the product for distribution.

A survey (unpublished) of different types of packing line in several locations by a multinational FMCG manufacturer revealed that problems associated with the in-feed section of packing machines were the most prevalent cause of stoppages.

10.5.2 Side seam–glued cartons

Side seam glued cartons are placed in a magazine from which they are removed one at a time by vacuumised suckers (pads). There are two basic methods by which cartons are extracted from the magazine and erected. In the first, the suckers pull on one panel and transfer the cartons into the moving pockets of a flighted conveyor. The length of each pocket, which is controlled by the flights, reduces automatically to the width of the carton and, in so doing, erects the carton by pressing on the two opposite, folded creases. This method is referred to as ‘diagonal’ loading. The other method is to use suckers on adjacent panels and pull the carton in opposing directions such that the carton assumes a rectangular cross section by the time it is dropped into the pocket of the flighted conveyor. This is known as ‘rotational loading’. Another mechanical opening method inserts knives from both sides which are twisted as the carton is eased into the flighted conveyor in a diagonal loading mode.

The opening of side seam glued cartons has been studied in depth, and the carton opening force measured using methods which replicate both diagonal and rotational loading. For a full treatment, see Hine (1999, pp. 111–139). This reference relates carton gluing, crease prebreaking, and the variation in carton opening force with storage time.

An important conclusion of this work is that with *diagonal* loading, carton opening force increases rapidly after gluing and packing by the carton maker during the first 6 days of storage, levelling out after two or three months. However, with *rotational* loading, there was no significant rise in carton opening–force torque with storage, suggesting that this is a superior method of carton erection. Another conclusion is that for both methods of carton erection, the main resistance to opening comes from the pre-folded creases, indicating the importance of this aspect of folder gluer operation.

An additional aspect of folder/gluer operation is the effect of compression on the folded creases. This can be assessed by measuring the height of a given number of cartons at the end of the gluing operation. The higher the compression pressure, the lower the height and the greater likelihood that the carton will be difficult to open on the packing line. If, however, the compression is too low, the side-seam adhesion may be impaired and, in addition, it would be difficult to load the cartons into the magazine of the cartonning machine. In practice, for a given carton, this height should be maintained within a range established by correlation with the acceptable range of heights at the cartonning stage, i.e. after storage. This height feature is also referred to as the 'bounce'.

One of the main causes of carton-feeding problems at the packing stage is the distortion of folded cartons which may occur in storage. In particular, the shape distortion, which is described as a 'banana' or 'armchair' shape, is virtually impossible to open. Another form of distortion produces an 'S' shape. Hence the recommendation is that cartons are stored on edge and isolated from stacking pressure in non-returnable corrugated fibreboard outer cases. The resulting rows of cartons should not be too tight. Hanlon suggests that the combined thickness of the row – calculated as three times the paperboard thickness, i.e. the thickness at the glue flap, multiplied by the number of cartons and adding 15% of the result – should be used as the internal length dimension of the case (Hanlon *et al.*, 1998).

Consideration of carton opening force has led in some case to changes in the way the gluing of cartons is organised. Cartons may be printed and cut and creased in large batches, taking account of the cost-benefit of longer production runs. The gluing, however, has been organised in much smaller batches to minimise the risk of a high carton opening force and/or distortion in storage. In some cases, the gluing has virtually been organised on demand in a location and facility remote from the carton manufacturer and adjacent to the cartonning operation. Alternatively, some cartonning machines have included a simply designed side-seam gluer actually attached to the infeed.

Side seam–glued cartons may be filled horizontally or vertically (see Figure 10.36), depending on the product. A free-flowing product which is apportioned gravimetrically would have an integral weigh filler with many filling heads. This type of filler can progressively fill the cartons vertically as the filling heads travel around a semicircular (carousel) track. This type of filling can run at high speed, for example hundreds of cartons per minute.

Some cartonning machines are fitted with a pre-feeder. The object is to extend the time given to erecting the carton under controlled conditions. This can be done by designing a circular pre-feeder and fitting it alongside the cartonning machine infeed whereby *erected* cartons are transferred to the flights (pockets) of the cartonning machine.

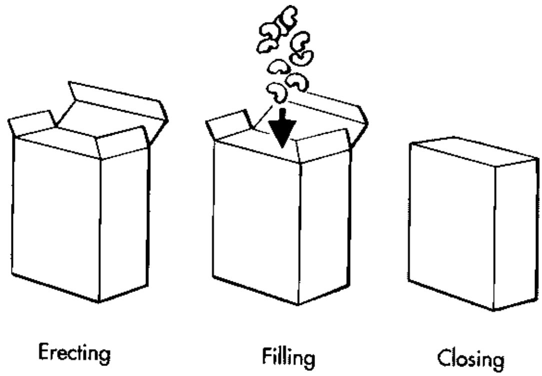

Figure 10.36 Vertical filling and sealing operation. (Reproduced, with permission, from Iggesund Paperboard.)

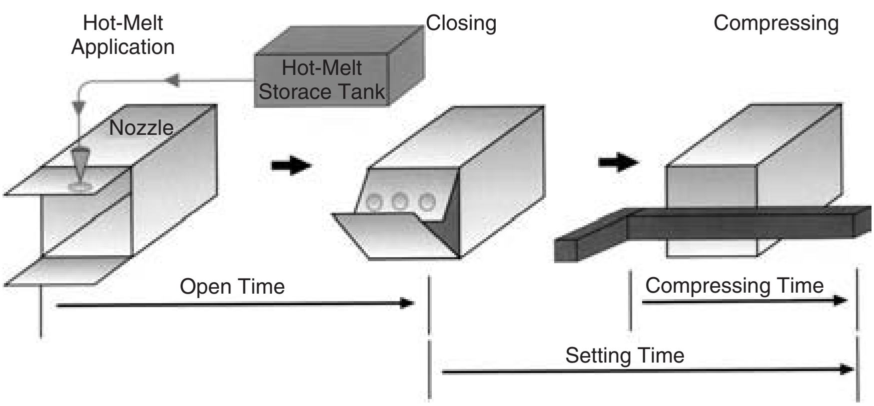

Figure 10.37 Carton closing using hot-melt adhesive (courtesy of M-Real).

Carton machinery, where the product is free-flowing and filled vertically, can incorporate carton tare weighing and product top-up features to achieve very high accuracy in fill weight. This is beneficial when filling expensive products.

The closing of side seam–glued cartons is by hot-melt sealing, as shown in Figure 10.37, tuck-in-flaps or locking tabs. Sealed closures would usually have an easy-opening feature, the design of which would be dependent on whether a reclosure feature is also required.

10.5.3 Erection of flat carton blanks

Flat carton blanks are erected by the packer/filler using one of the following methods:

- Using a reciprocating tool which is pressed against the base panel thereby forcing the side panels through 90° into the vertical (usually, there are exceptions) position. The side panels are then secured in this position, forming a tray shape either by means of interlocking tabs or by hot-melt adhesive (Fig. 10.38).
- Applying an adhesive to a side seam and folding the carton blank around a mandrel. This is usually preceded by wrapping paper, paper coated with a barrier coating, such as PE or PVdC, an oriented polypropylene film (OPP) with PVdC coating or a film laminate around the mandrel, sealing the side seam and base.
- Forming the hinged lid blank together with a reinforcing inner frame – a design mainly confined to the packing of cigarettes.
- Applying adhesive to the side seam as the first operation on the packing line using a simplified side seam gluing unit.

The efficiency of operation, where the cartons are presented in the form of flat blanks, mainly depends on the flatness of the paperboard blanks being maintained. This is because a blank which has a curl or twist can easily misfeed and cause a stoppage. For example, if the carton blank is pulled out of the magazine, print face downwards, onto a short conveyor, the lugs which are supposed to push the (back) edge of the board, instead, pass under the upturned edge. Curl may also prevent a tuck-in-flap from being pushed in accurately.

The tray-type carton is top loaded, either by hand or mechanically by an automatic ‘pick and place’ action. The integral lid is closed and sealed on one or three sides with hot-melt adhesive. Where the product is filled hot, water-based adhesives based on PVA, starch or dextrine are required. The efficiency of water-based adhesives depends on the absorbency of the surfaces being sealed and the compression time to allow the adhesive to set, i.e. to become tacky enough so that unrestrained joints do not open.

Plastic-coated trays are usually erected and lidded by heat sealing but plastic coated end-loaded cartons are usually sealed, though not always, using hot melt adhesive.

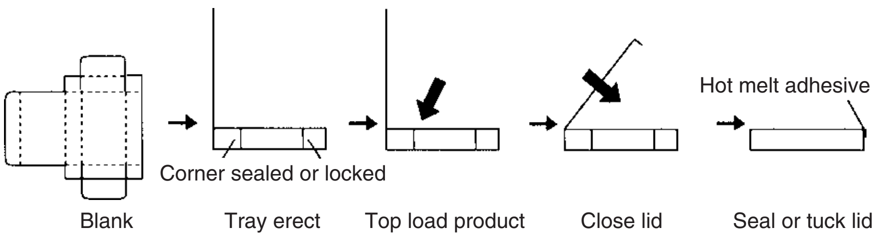

Figure 10.38 Erection of tray-style carton for top loading and closing. (Reproduced, with permission, from Iggesund Paperboard.)

An important precaution in the use of hot-melt adhesives is that they must not be exposed to air for long periods at the working temperature when the machine is not in production. This will cause heat degradation and subsequent loss of adhesion. A situation was investigated where the packer claimed that the surface of the paperboard was defective because the hot-melt adhesive would not close the cartons permanently. It was found that the heat supplied to the adhesive reservoir had not been switched off when the machine had been left unattended overnight and at the weekend. This, it was claimed, had been standard practice to ensure a quick start-up when production was resumed. There was evidence of severe carbonisation in the adhesive system. The hot-melt adhesive had been degraded. The solution was to use time switches set to remelt the adhesive a short while before packing was required to recommence. Today, pressurised on-demand nozzle applicators are preferred to open-to-air glue pots.

10.5.4 Carton storage

Reference has been made to the fact that paperboard will absorb moisture when exposed to high humidity and lose moisture in low humidity. Moisture content changes are usually accompanied by changes in flatness (shape). Hence reasonable precautions should be taken at all stages where the paperboard may be exposed to changes in RH. The carton manufacturer should provide moisture protection for storage and transit. The packer/filler (end-user) must ensure that cartons are not unwrapped until they have attained temperature equilibrium with the area in which the packaging is carried out.

Problems have been observed where unwrapped pallets of cartons awaiting packing have been left near exits to the outside environment. Also cold cartons have been found to affect the efficiency of hot-melt adhesion due to the fact that the adhesive open time is reduced by being applied to a cold surface and the tackiness is lost before the surfaces being sealed are brought together.

Packer/fillers should also replace moisture-resistant wrappings to pallets and boxes of cartons left unused at the end of a production run and over a weekend. This is especially important in dry (low RH) packing areas handling dry food products, such as tea and baked products, for example biscuits and cereals. In this dry environment, unprotected flat paperboard carton blanks are likely to develop downcurl, i.e. curl away from the print and this will cause problems on cartonning machines.

10.5.5 Runnability and packaging line efficiency

Good runnability is essential. The requirements of good runnability are many and varied. Good runnability is difficult to define, but everyone knows when it is missing. In a general way, it describes a packaging operation running with minimum disruption, at a specified level of efficiency, which can be measured and monitored.

Packing line efficiency is dependent on:

- the machine(s), or method of packaging in the case of a manually operated line
- reliability and maintenance of the machinery
- the product
- the operators, level of training, etc.
- quality of the cartons.

The packer/filler's aim is to avoid, or minimise, the production of damaged packs, wasted product, wasted packaging and to achieve the rated output of the packing line. The efficiency of a packing line is given by,

$$\text{Line efficiency }\% = \frac{\text{Actual output}}{\text{Expected output}} \times 100$$

In establishing 'expected output', it is important to base this on the real time available for packing. This means that setting-up time and routine maintenance must be eliminated from overall production time.

A packaging line may comprise several, linked, packaging machines, for example form/fill/seal pouch or sachet machine, cartonning machine and case packer. If the efficiency of each machine is 90% then the efficiency of the line as a whole would be the *product* of these individual machine efficiencies, in this example 72.9%. This must be taken account of when planning a packaging system.

A mistaken poor efficiency complaint arose when a packer reported high carton wastage. The line was fed from a carton erector fitted with a counter which counted every vertical cycle. The carton erector could erect cartons faster than the rest of the packing line could pack and close the cartons – it itself a good feature. When the line was full of partially loaded cartons, an automatic switch stopped the carton feed into the carton erector. However, the carton erector continued to cycle automatically even though no cartons were being erected. The counter ticked away and at the end of the shift the counter figure was taken as the number of cartons erected, clearly this was erroneous. The production of filled cartons was much lower than the figure from the carton erector and the difference was interpreted as *high carton* wastage! Eventually, the correct usage was established by reconciliation with the quantities of cartons in, and issued by, the warehouse, but not before someone had initiated an investigation by the supplier of the cartons and the paperboard!

Some examples of features which affect runnability are more nebulous than others, and one which comes into this category is 'timing'. This relates to the settings on a cartonning machine within which an established carton specification can be run with a satisfactory packing-line efficiency. Settings control mechanical movement whereby the machine interacts with the carton and the paperboard. Some settings can be advanced or retarded in response to, for example, the paperboard stiffness or the resistance to folding or spring back of carton creases.

The importance of timing was highlighted by the following example which occurred when an alternative carton specification was trialled on a well-established packaging line. The alternative paperboard specification was significantly different in that it was based on FBB from a machine fitted with Foudrinier wires whilst the established carton was based on recycled board, WLC, made on a modified vat machine, and the thickness of the two boards was the same which meant that the FBB was 23% lower in grammage.

The cartons were medium to large in size. They were erected for horizontal end-loading of the product which was already packed in a PE coextruded film bag. The cartons were therefore moving in the same direction as the MD of the paperboard. There was a large difference between the MD stiffness of the WLC and that of the FBB, with the MD stiffness of the WLC being about 25% higher. This mainly resulted from the difference in forming on the paperboard machine. The MD/CD stiffness ratio for the WLC was 2.8 and for the FBB 2.1. When the settings which suited the carton made from WLC were used for the FBB cartons, the machine quickly jammed. This could have been the end of the trial and the result recorded as a failure. However, with the co-operation of engineering personnel new *settings and timings* were found for chains, flights and conveyors, which enabled the FBB cartons to run satisfactorily.

Today all settings and adjustments can be logged and retained electronically so that cartonning machines can be quickly reset after size changes. Machines are also fitted with technical support visual displays for troubleshooting to minimise the effect of any stoppages which may occur.

Coefficient of friction, measured in the dynamic mode as opposed to the static mode, is frequently found to be involved in runnability investigations. A note of caution should be made when deciding which surfaces to use in the test method. As the guide rails and ploughs on the machine are likely to be made of steel or aluminium, it is likely that the particular metal surface involved is used in checking the coefficient of friction against the carton surface. This, however, has been found to yield confusing results. It should be recognised that the metal surfaces on the machine can become coated with material which transfers from the cartons, and account of this should be taken.

Surface friction resulting from inks and varnish can be modified with the help of the respective suppliers. The inclusion of silicones, or wax, to improve rub resistance can lower coefficient of friction or angle of slide. It can also reduce gloss levels and hence care is necessary when any changes are contemplated.

Whilst high surface friction is sometimes the cause of poor runnability, it is unlikely that the carton surface will be too slippy as this would give other problems, such as making it difficult to handle a bundle of cartons.

Another property of paperboard where problems have arisen in the past is air permeability (porosity). In a particular case study, the carton blanks were supposed to be picked out of a pile, one at a time, by rubber vacuumised suckers which contacted the *reverse unprinted side* of the paperboard. A problem arose resulting in misfeeds or partial pick-up which led to misalignment and jamming in the infeed section of the cartonning machine.

The carton was made from mineral pigment-coated paperboard. This is virtually impermeable to the *rapid* passage of air. In this case, the vacuumised suckers were set quite close to the cut edge of the carton. As a result, air was being sucked in through this edge into the middle plies of the paperboard, and from there to the point where the suction was applied. The problem was solved by adjusting the position of the suckers away from the edge of the carton blank.

Where *uncoated* and *unlined*, thin paperboard is used, less frequently today compared to years ago, it has been known that the suckers can pull air through two sheets causing a double feed and a machine jam.

The study of cartons and cartonning machine interactions is important and co-operation between the manufacturers of cartons, paperboard, packers and machinery companies should be encouraged. It must always be appreciated that there is an explanation to every problem and the real explanation must be found if the problem is to be understood and solved. This is often difficult when problems interfere with production.

Sometimes a repetitive sequence is detected in the occurrence of a specific fault. For example, the problem may be associated with one particular carton die station, it may be associated with a damaged flight on a packaging-machine conveyor or it may be due to a damaged carton-forming mandrel. Sometimes the cause of a problem is related to some aspect of either the packing machine or the carton, or to some obscure interaction between the two; but it cannot be observed because the speed is too fast or the suspected position is difficult to access. In these cases, high-speed video should be used to observe the features in slow motion.

In his summary of carton–machine interactions, Hine (1999, p. 182) lists the important paperboard and carton properties in relation to the efficiency of the various machine functions and carton movements.

The properties and features listed are porosity, smoothness (roughness), friction, adhesion, dimensions (accuracy thereof), cut quality, paperboard stiffness, fold stiffness, carton opening force and flatness (Hine, 1999, p. 182: Table 8).

The machine and operation features which were related to these properties of the paperboard and features of the carton are the efficiency of:

- loading the carton feed magazine
- extracting the cartons from the magazine
- erecting the carton
- conveying the carton through the machine
- filling of the product
- closing of the flaps
- collating the cartons as they leave the machine.

10.6 Distribution and storage

Cartons are usually collated or grouped together and packed in secondary packaging for distribution and storage. Typical distribution packs, Figure 10.39, are as follows:

- Unsupported blocks of cartons are stretch or shrink-wrapped – the cartons may be packed in shallow-depth paperboard trays prior to stretch or shrink-wrapping.
- The blocks of cartons may be protected with a wraparound corrugated fibre-board sleeve and then stretch or shrink-wrapped. There are other designs which make use of corrugated fibreboard in this way. One of the objectives is to ensure that some cartons are visible so that the pack has good visual appeal when displayed in cash-and-carry type warehouses from which many small traders obtain their bulk supplies.
- Regular slotted containers (RSC) are made from corrugated fibreboard. The cases may have tear tapes to facilitate opening and displaying the contents at the point of sale. The case can be a wraparound blank erected in situ at the end of the packaging line.

All these examples may be accompanied by the use of automatic equipment to collate the cartons and erect/pack the trays or corrugated fibreboard packaging. When the transit packing is completed, the packs are palletised, sometimes automatically.

The specification of all packaging components must take account of any special environments involved in the distribution, storage and merchandising at the point of sale.

Typical examples of special environments are those for frozen food (–40 to –20 °C), and chilled food (0 to +3 °C). An aid to monitoring that these products are not exposed to higher temperatures exists in the form of temperature monitors. At its

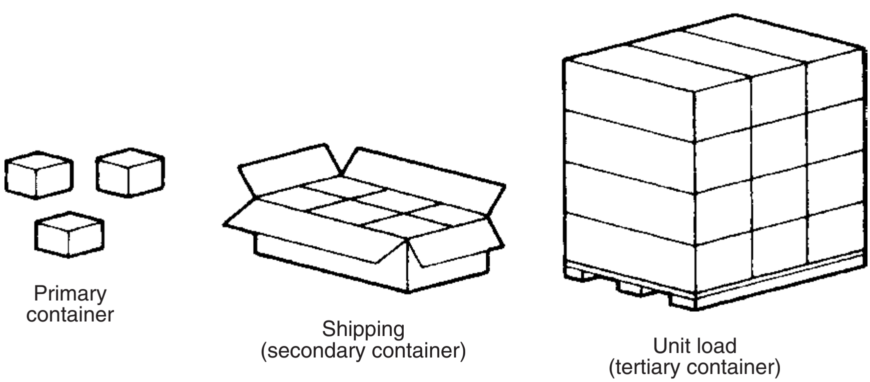

Figure 10.39 Packaging for distribution and storage. (Reproduced, with permission, from The Institute of Packaging.)

simplest, this comprises a colour patch which can change colour if the temperature rises above specified limits.

In practice, there are several ways of ensuring a satisfactory carton performance in distribution. One of the considerations is the level of moisture resistance required. Moisture condenses on the surface of cartons when they are removed from the cold environment. Moisture will also affect cartons of chilled foods as they are stored in an environment with high RH.

Paperboard absorbs moisture on the surface and through cut edges. The effect is visual and results in distortion of the surface and loss in strength. Surface treatments, such as printing and UV varnishing, slow down moisture adsorption. Hard sizing also slows down moisture adsorption. Plastic coatings can be applied to one or both sides of the paperboard. Low density polyethylene is the most commonly used plastic. High density polyethylene (HDPE) has a better moisture vapour barrier. If additional performance needs are required, then there are additional choices. PET or PETE provides additional product resistance, and can also be used where the product is reheated in microwave and conventional radiation heated ovens. PP is satisfactory for reheating in convection steam heated ovens. PET (PETE), PP and HDPE have good grease/fat resistance. All these plastics are heat sealable, and this property is frequently made use of by forming trays with the plastic on the inside. These trays can be lidded with peelable film and plastic coated paperboard.

Care must be taken with exported goods which may be containerised and which pass through extremely warm conditions. In these instances, hot-melt adhesives used to erect and/or close cartons must be replaced on the packaging machines because hot-melt adhesives can soften and the adhesion fails at high temperatures.

The hazards associated with distribution comprise:

- shock, for example due to dropping
- compression – both static, slow rate of loading, and dynamic, fast rate of loading
- vibration in transport causing destabilisation of the pallet and product damage (FOPT, 1999).

These factors can be studied in the laboratory. Safety factors are applied to static compression loading results because, in practice, the box compression of the carton depends on:

- the structural design
- direction of loading
- whether contents support the carton, as with a bottle or jar, or not, for example breakfast cereals in pouches
- type of transit pack, for example corrugated fibreboard case
- storage, palletisation, stacking and climatic conditions
- paperboard properties, such as grammage, thickness, moisture content, stiffness and short-span compression strength.

Complaints of carton damage need to be investigated carefully to find the real cause of the problem, because some examples of transit damage would not have been avoided even if the paperboard used to make the carton had been twice as thick and therefore much stronger. Everyone wants to reduce packaging and clearly a balance must be achieved where the carton is strong enough without being open to criticism of overpackaging. This is best achieved with practical tests and by considering the whole packaging system, as it may be better to improve a situation by changing the specification of the transit pack or pallet arrangement rather than the specification of the carton.

A vast amount of work has been reported on the subject of relationships between paperboard properties and observed box compression strength (Hine, 1999, pp. 111–139). An example of this research is that carried out by Fellers *et al.* (STFI, 1983). This research showed that the compression of a panel, minimum size 60 mm × 90 mm, is described by the relationship

$$F_p = c\sqrt{F_c\sqrt{S_{MD} \times S_{CD}}}$$

where F_p is the panel compression strength; F_c is the compression strength (short span) in the direction of loading; S_{MD} is the MD stiffness; S_{CD} is the CD stiffness; and c is a constant. $\sqrt{S_{MD} \times S_{CD}}$ is known as the geometric mean stiffness. It is recognised as an important strength-related feature of paperboard.

Under certain conditions and for a range of panel sizes, it was found that the constant c has a value 2π or 6.28. On the basis of that, for a complete box of four panels, the compression would be $F_B = 4 \times F_p$. Then:

$$F_B = 4 \times F_p = 8\pi\sqrt{F_c\sqrt{S_{MD} \times S_{CD}}}$$

This shows that the box compression strength is dependent on paperboard stiffness and the short-span compression strength. Figure 10.40 shows the relationship between measured panel compression strength (N) and the predicted value based on stiffness and short-span compression using this equation, and the agreement is very good.

The importance of this work, in the author's opinion, is not that it is predictive, within limits, with respect to box compression, but that it shows that stiffness and short-span compression are important paperboard performance-related properties.

The short-span compression is measured by compressing a sample which is only 0.7 mm long. If a longer sample length is chosen, as would be the case with a tensile test, then under compression it would merely bend and buckle. When 0.7 mm is compressed, the failure point occurs when the fibres slide in relation to

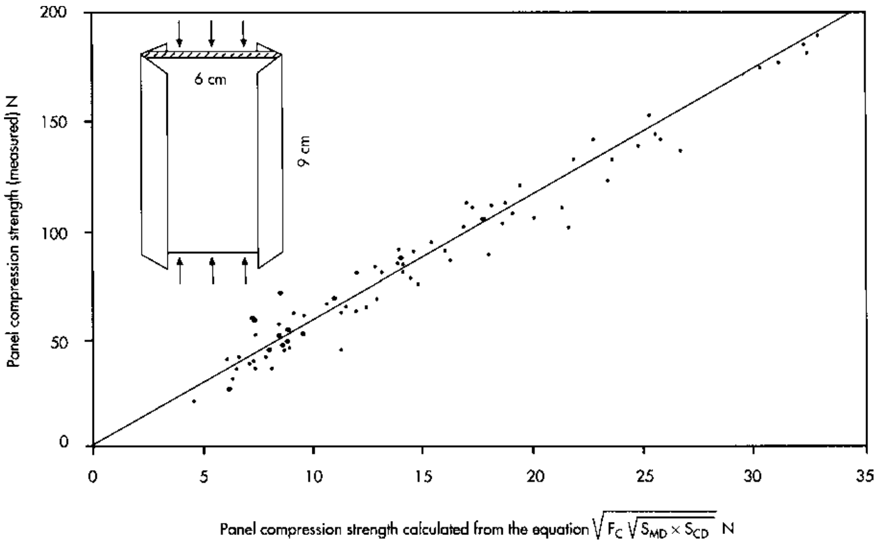

Figure 10.40 Panel compression strength, measured vs calculated (Fellers, de Ruvo, Htun, Carlsson, Engman and Lundberg). (Reproduced, with permission, from Iggesund Paperboard.)

each other. This is an interesting phenomenon, bearing in mind the fibrous structure and interfibre bonding. The range in length of the fibres present in any given sample is also relevant, bearing in mind that the thickness of hardwood fibres is around 1.0 mm and softwood 3.0–3.5 mm.

The compression strength is two to three times lower than the tensile strength and prior compression in this way does not affect the tensile measurement. This discussion explains how creasing and folding can occur, given the internal stresses withstood by fibres in tension and compression in close proximity. The various factors which are involved in studying compression strength are shown in Figure 10.41.

10.7 Point of sale, dispensing, etc.

The consumer eventually takes possession of the cartonned product. As noted in Paragraph 10.1, this can take place in a number of ways depending on the product and the intended market. In some situations, for example self-service retailing, the appearance of the pack is extremely important – a damaged or faded carton is unlikely to be purchased and an attractive carton may result in an impulsive purchase. In some situations, such as in the dispensing of a prescription medicine, the carton may play no part in the transaction, but nevertheless the brand owner would still want the carton to have an hygienic, quality image. Hence the printed

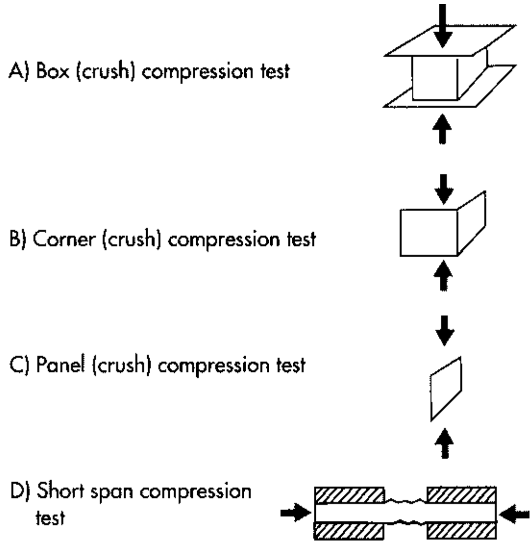

Figure 10.41 Compression testing. (Reproduced, with permission, from Iggesund Paperboard.)

appearance should be maintained, and the carton should be strong enough with an adequate box compression strength, good rub resistance, etc.

In the supermarket, the transit pack should be a conveniently handleable unit, easy to open and recycle. The cartons should be easy to merchandise, i.e. easy to stack and display, at the point of sale. The integrity of the pack is important to demonstrate that the product has not been tampered with.

An important consideration for the consumer today is that the product is genuine, i.e. not a counterfeit product. Several techniques are available to detect this:

- Printing an identification on the carton using a clear, transparent varnish containing an ingredient which is only visible under UV illumination.
- Incorporating a clear mark in the paperboard that is similar to a watermark. A recently published system can provide a mark which may be either visible to the naked eye or only visible under UV illumination (Tobacco Reporter, 2002a).
- 'Fingerprinting' the approved paperboard using near infrared spectroscopy (NIR) (*Tobacco Reporter*, 2002b). Every paperboard has an individual spectrum depending on the ingredients used in its manufacture and which will remain the same unless any of the ingredients are changed.
- Use of RFID labels on pallet loads and transit packs (*Paper Technology*, 2003a). RFID labels are discussed in Section 4.5.3. This is a rapidly developing area mainly depending on reduction in the cost of the electronic components.

10.8 Consumer use

Quality aspects of packaging which are particularly noticeable to the consumers generally relate to such features as the ease of handling, any form of damage including security against pilferage, ease of opening and ease of reclosure (where relevant). If the reclosure uses a tuck-in-flap, then the durability of the lid-hinge crease is critical. The print should not be rubbed when handled – wet rub is a critical requirement for cartons used for frozen food, chilled food and ice cream. The printed instructions should be easy to read and unambiguous.

Convenience in the use of packaging is a feature that consumers respond to and manufacturers seek to provide. One of the more technically innovative developments which provides convenience in several ways has been the development of the PET (or PETE) extrusion coated paperboard tray for microwaveable and radiant oven reheating of frozen and chilled convenience ready meals at temperatures up to 200 °C. To achieve this, several technologies have been brought together in a 'system'.

The extrusion coating process has already been described. For the best results, the coating is applied to the reverse side of SBB which can be formed into a tray by one of two methods. In using the first method, a tray format can be cut and creased and formed on a tray erector, by either heat sealing or interlocking corners. A leakproof tray-erected heat-sealed, web cornered style is also possible (Fig. 10.5). Alternatively, the tray can be formed by deep drawing using metal tooling (Figs 10.6 and 10.42). Depths up to 25 mm can be formed in one operation and if the paperboard is moistened, a second draw to a depth of 45–50 mm can be achieved with heat and pressure, as noted in 10.3.2.

These tray designs can incorporate flanges to which plastic film or plastic coated paperboard can be applied with peelable seals. Initially, microwave-heated foods provided convenience and rapid reheating (Fig. 10.43). The system could not

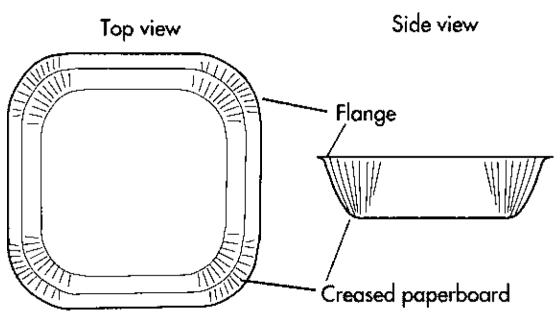

Figure 10.42 PET-lined paperboard deep-drawn tray with flange for applying lid. (Reproduced, with permission, from Iggesund Paperboard.)

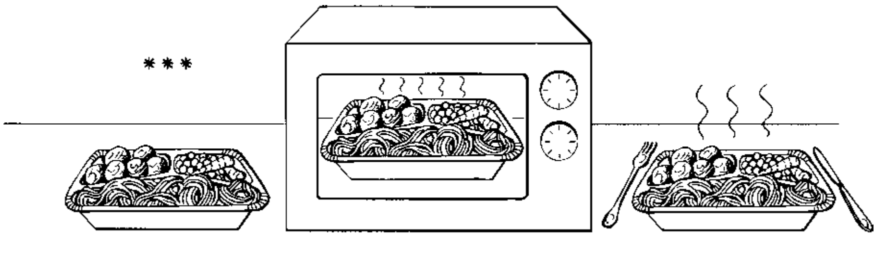

Figure 10.43 PET-lined paperboard trays stored in deep freeze and reheated in microwave oven. (Reproduced, with permission, from Iggesund Paperboard.)

brown or provide a degree of crispness, i.e., until a way was found to overcome the deficiency. This was achieved by including a susceptor inside the pack. Susceptors work by absorbing microwave energy which is made available to the food in the vicinity, causing localised browning and crispness. The susceptor is made from aluminium metallised PET film. They are also made using iconel (nickel/chromium), which can induce even higher temperatures (ASTM, 2003).

Another example of innovative paperboard packaging is provided by the following 'intelligent packaging' application (*Paper Technology*, 2003b). In this example, an SBB, chosen for its high security against cracking when the creases are folded, was printed with a conductive ink containing an embedded microchip, antenna and electronic circuitry. The application is a pharmaceutical blister pack. The microchip detects the removal of a pill, records the time of the event and can be programmed to bleep when the next pill is due to be taken. In addition, there is a row of buttons which enable the patient to enter feedback on the side effects of the pill. The information, which is encrypted, is stored in the chip, which includes the Internet address to which the information can be sent. When the pack is empty, it can be scanned and the information downloaded to a PC. Alternatively, the data can be retrieved on a doctor's computer and viewed on screen.

Procedures are operated by paperboard manufacturers, carton makers and end-users to ensure that the consumer's needs in terms of product safety are met, particularly where the paperboard is in direct contact with, or in close proximity to, food, or other flavour or aroma-sensitive product.

Two of the best-known authorities in this field are:

- United States, Food and Drugs Administration (FDA)
- Germany, Bundesgesundheitsamt (BgVV) (German Federal Institute for Consumer Protection and Veterinary Medicine Regulations).

There are particular regulations which apply to certain products, for example in Europe EN71 Safety of Toys, Part 3 sets limits for the migration of certain elements which are applied to packaging. There are requirements for plastics in the EC Plastics Food Packaging Directive 128 EEC and subsequent amendments.

The Confederation of European Paper Industries (CEPI) Food Contact Group is co-operating with the Council of Europe with respect to food contact safety. It is expected that the work will result in a European Union Directive.

The protection of products from loss of taste, flavour or aroma is critical for some products. Chocolate confectionery, tea and tobacco are all particularly sensitive in this respect, and paperboard and paperboard cartons are regularly evaluated to ensure that they meet customer specifications in respect of odour and taint. There are several potential sources of contamination. These comprise:

- synthetic binders used in mineral-pigmented coatings
- pulp – chemical, mechanical and recycled: whilst the fibres comprise cellulose fibre which is tasteless and odourless, some fibres contain additional materials; there is the possibility of the oxidation of residual organic fatty acids to aldehydes and internal microbiological activity
- ink and varnish residues, such as residual solvents, products arising from oxidation–polymerisation of drying oils and unreacted components of radiation curing
- contamination as a result of pallets, and conditions in transit and storage.

The human sensations of taste and smell are most sensitive. These faculties are used to test paperboard and printed cartons organoleptically. Panels of observers whose taste and smell faculties are normal test the samples for odour and taint. There are procedures for choosing panel members, and there are comprehensive standards issued by the main Standards organisations, for example ISO, ASTM, CEN, BS, DIN, etc. Topics covered include sensory testing and analysis. Many new and updated standards have been issued between 1995 and 2005, and an up-to-date search is recommended. The main methods involve Triangular and Pairs testing for difference in both taint and odour evaluation as well as methods which allocate scores quantitatively, for example DIN 10955 for which a new standard was issued on 1 June 2004 (also known as the 'Robinson' test).

In addition, gas chromatography is carried out. Samples of the headspace of jars containing fixed amounts of paperboard conditioned for a fixed period at a fixed temperature are passed through a gas–liquid chromatograph (GLC). This separates the various components, indicates their relative volumes on a chart recorder (Figs 10.44 and 10.45), and measures their concentration in the material. It is possible to split the contents of the column and have an observer check the smell against the indications on the chart recorder. It is also possible to pass the eluted material from the gas chromatograph to a mass spectrometer (MS) and thereby identify the actual volatile materials arising from the original sample.

Meeting consumer packaging needs is the responsibility of packer/fillers, carton manufacturers and the manufacturers of the raw materials used in carton manufacture.

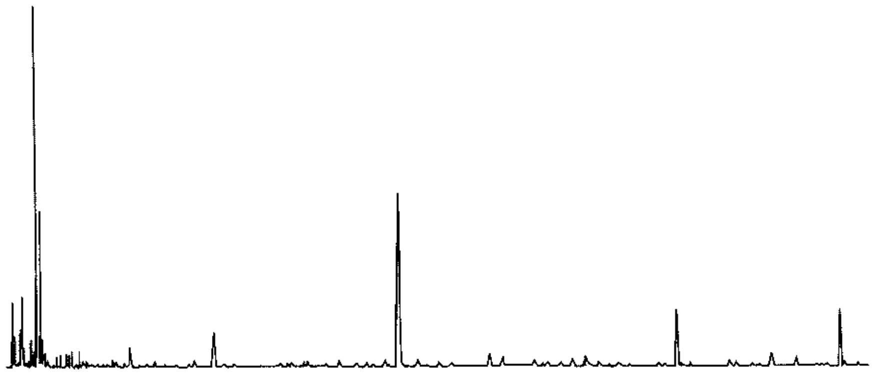

Figure 10.44 Chromatogram of unprinted paperboard. (Reproduced, with permission, from Iggesund Paperboard.)

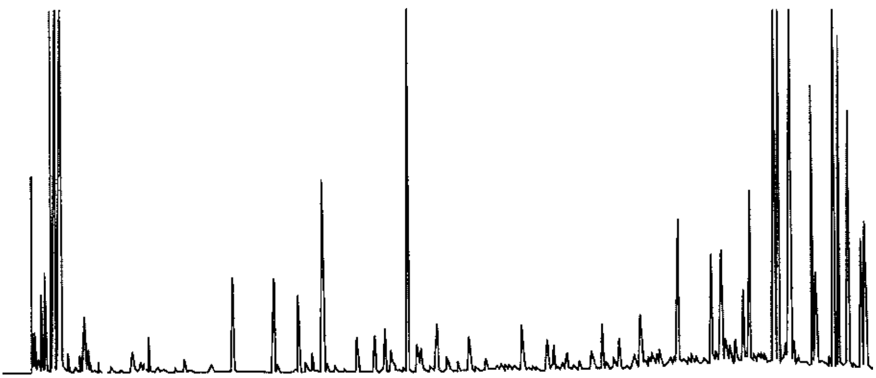

Figure 10.45 Chromatogram of paperboard printed with low odour offset litho ink. (Reproduced, with permission, from Iggesund Paperboard.)

10.9 Conclusion

The folding carton has been around from the 1880s and whilst traditional in concept is the subject of constant innovation with respect to:

- increased productivity at all stages of manufacture and use
- manufacture and specification of paperboard, inks, varnishes, plastic coatings, adhesives, etc.
- surface and structural design

- printing and all conversion processes
- packaging machinery and methods, including product handling
- meeting new market needs and opportunities
- taking account of societal needs in respect of the environment, product and consumer safety.

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Paper and Paperboard Packaging Technology
Edited by Mark J. Kirwan

11 Corrugated fibreboard packaging

Joël Poustis

11.1 Introduction

11.1.1 Overview

Corrugated fibreboard packaging is, in terms of tonnage, by far the commonest type of paper and paperboard-based packaging. It fulfils two main functions:

- it is a medium which displays printed information
- it is a protective or structural entity, particularly in the distribution of goods.

The relative split between these functions by product type is shown in Figure 11.1.

The basic function of corrugated fibreboard packaging is the same as for any packaging – namely to protect products during distribution until the product is removed from the package. It may also protect the environment from the product – for example in the distribution of dangerous goods and liquids in glass or plastic containers.

The growing use of palletization in warehousing and distribution requires corrugated boxes with good stackability. Corrugated board is an appropriate material for achieving high stackability, forming a lightweight rigid structure composed of liners separated by corrugated fluting papers. Moreover, the corrugated-board package is designed to *contain* products during distribution. Product containability and cost-effective adaptation to logistics systems in packing and distribution are important issues in corrugated-board transport-packaging design.

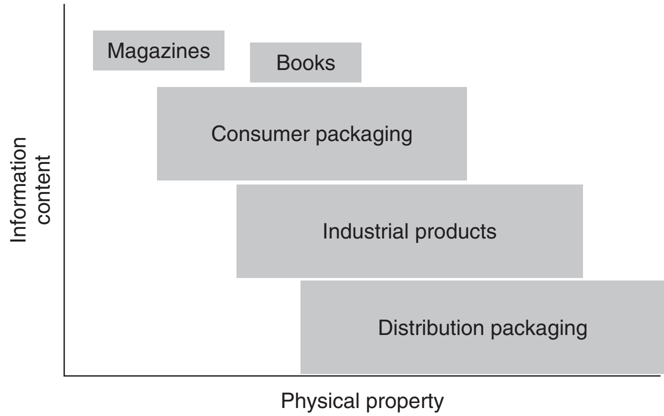

Figure 11.1 Relative positioning of functions of information provision and protection. *Source*: Pira International – Nigel Jopson – June 2001.

Corrugated fibreboard boxes are erected and packed manually or automatically. The packaging can be either erected, filled and closed, or formed around the product and closed. To ensure packing-line efficiency, corrugated fibreboard boxes, also referred to as 'cases' and 'cartons', have to present flatness, structural stability and suitability for closure.

Today, packaging is used not only as a protection for the products contained but as advertising and brand promotional support. It is a communication medium, carrying information and artwork, and printing quality has been developed to meet these promotional needs. The attractiveness of the print can be decisive in catching the customer's eye.

11.1.2 Types of corrugated fibreboard packaging

The most commonly used corrugated fibreboard package is the case (box or carton) with a rectangular cross section together with top and bottom flaps. This is known as a regular slotted container (RSC) as shown in Figure 11.2. Slots have to be cut between adjacent flaps to facilitate neat folding when the case is closed. When corrugated packaging is discussed, creases are often referred to as 'scores'. The manufacturer's joint can be glued, taped or stitched with wire staples. Gluing provides strong seals and can be carried out at high speeds. Stitching is not normally used in food packaging or allowed into food manufacturing factories.

An alternative to the RSC is a wraparound design where the manufacturer supplies a flat blank to the packer. This is folded around the product and the overlap sealed, Figure 11.3.

Shrink or stretch wrapping, usually with polyethylene (PE) film, is a popular form of transit packaging. It is cost effective and provides product visibility in storage and distribution. Product visibility is an important requirement for packs bought by small shopkeepers in 'Cash and Carry' wholesaling, where the quantities purchased do not justify direct supply from the manufacturers. Many products

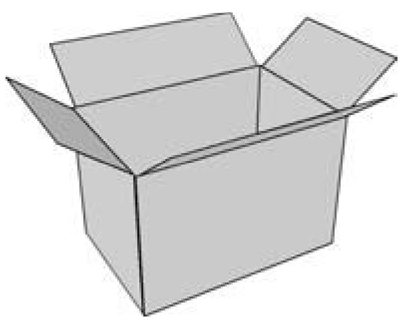

Figure 11.2 Regular slotted container.

still require a shallow tray to contain a number of unit, or primary, packs. The use of a shallow tray, Figure 11.4, also facilitates palletization.

A U-shaped fitting to provide increased stacking strength may be used in combination with a tray and stretch or shrink wrapping, Figure 11.5.

Considerable ingenuity is possible in pack design to produce one-piece packaging to meet specific market needs. An example, shown in Figure 11.6, is the carry-home pack for six bottles of wine. This would be supplied as a flat one-piece pack which is erected by hand on demand.

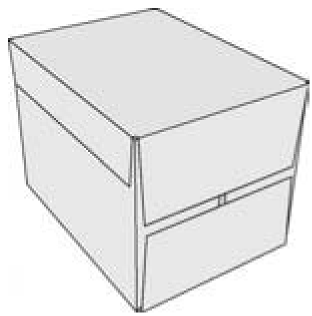

Figure 11.3 Wraparound case.

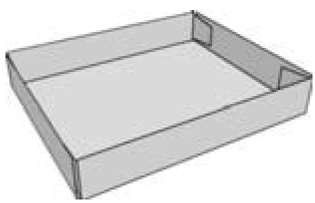

Figure 11.4 Corrugated fibreboard tray.

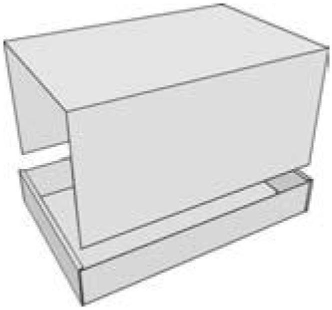

Figure 11.5 Tray with U-shaped fitting.

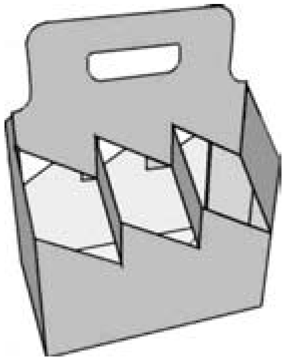

Figure 11.6 Carry-home pack for six wine bottles.

Corrugated fibreboard is also used for shock amelioration in various forms, for example as full-depth interlocking dividers or cells to protect labelled bottles in a corrugated case, Figure 11.7. Corrugated fibreboard is also used in the form of pads and fittings to locate and protect vulnerable product components.

A specific in-store use of corrugated fibreboard is the point of purchase (POP) display stand, Figure 11.8. These stands may be combined with plastic components.

Bag-in-box, two-or-three litre, wine packs are widely used. They combine:

- product-barrier protection against the effects of oxygen and light through the use of heat-sealable, metallized plastic laminates
- selection of plastic material provides leak-proof sealing
- a bag which collapses as the wine is withdrawn so that air does not enter and cause deterioration
- stacking and handling strength through the use of corrugated fibreboard
- tamper evidence and convenience in use with spouts (taps) and caps
- high quality printed graphics.

Bag-in-box suppliers support their customers through the supply of all the necessary pack components and filling equipment.

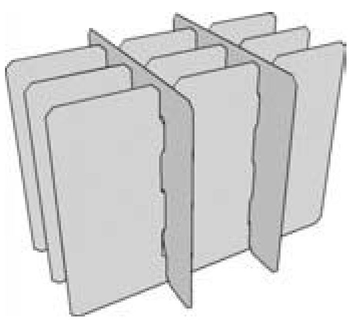

Figure 11.7 Full depth divider for bottles in case.

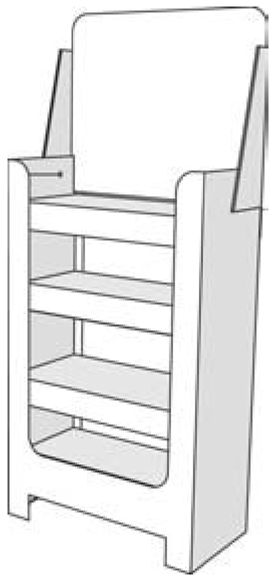

Figure 11.8 Point of Purchase display stand.

Large, heavy and bulky products, particularly in the automotive, chemical, engineering and electrical industries, are packed in heavy-duty corrugated fibreboard packaging. The weight of the product on a pallet can be as high as one tonne and pallets may be stacked two or three high. This often involves packaging which combines other materials such as plastic foam, plastic components, plywood and timber, for example corner posts. Heavy-duty corrugated is based on double and triple wall corrugated fibreboard, high grammage liners, for example 400 or 440 g/m^2, and wet-strength adhesives. Wire stitching and heavy-duty tape can also be used for the manufacturer's joints.

Generally, the most common printing used with corrugated fibreboard packaging is flexo – either as post-print, i.e. after the corrugated board has been made or as pre-print where it is printed, reel to reel, prior to use on the corrugator. However, other print processes are used appropriately, for example offset litho for the high quality required with some, usually branded, higher value, retail packaging; or silk screen for short runs of POP-display packaging. High-quality printed self-adhesive labels may also be used.

11.2 Corrugated board – definitions

11.2.1 Structure

Corrugated board has a sandwich material structure. It comprises a central paper (called the corrugating medium, or, simply, the 'medium') which has been formed, using heat, moisture and pressure, in a corrugated, i.e. fluted, shape on a corrugator and one or two flat papers (called liners) have been glued to the tips of the corrugations. The sandwich can be formed in several ways. If one liner is used, the product is known as ‘single faced’ (Fig. 11.9a). If two liners are used, one on either side of the fluting, the product is known as ‘single wall’, or double faced (Fig. 11.9b). The combination of two media, or flutings, and three facings is called double wall (Fig. 11.9c) and the combination of three media and four facings is called triple wall (Fig. 11.9d).

Corrugated board is normally made in one of the nine flute sizes, i.e. D, K, A, C, B, E, F, G and O. The flute size is defined by the pitch, the number of flutes per unit length and the take-up factor. The pitch is the distance between two fluting tips.

The take-up factor defines the length of the medium (fluting) material used in a corrugated fibreboard structure compared with the length of the facings (Table 11.1).

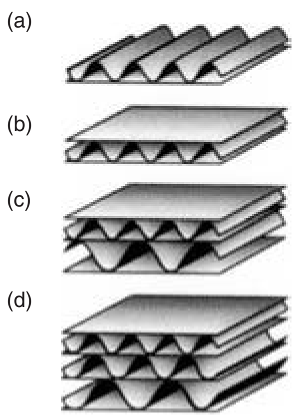

Figure 11.9 Corrugated boards: (a) single face; (b) single wall; (c) double wall; and (d) triple wall.

Table 11.1 Corrugating flutes’ profiles

Flute	Average number of flutes per metre	Pitch (mm)	Take-up factor
D	75	14.96	1.48
K	95	11.70	1.50
A	110	8.66	1.53
C	129	7.95	1.42
B	154	6.50	1.31
E	295	3.50	1.24
F	310	2.40	1.22
G	350	1.80	1.21
O	360	1.25	1.14

Source: ‘Technical Corrugating Roll Data’, BHS Corrugated brochure by Edmund Bradatsch and Lothar Jobst – July 2000.

The properties and specifications of a corrugated board are defined as follows.

11.2.1.1 Weight per unit area (grammage) and thickness (calliper)

The grammage is the weight of one square metre of corrugated board (unit is g/m^2 and measured under standard conditions: 23 °C – 50% RH). It can be evaluated from the component paper grammages using a simple linear formula. For a single wall corrugated fibreboard, the relation is

$$\text{Grammage} = L_1 + (a \times F) + L_2$$

where L_1 and L_2 are the liners, F is the medium, with all the measurements being made in g/m^2 and 'a' is the take-up factor.

In the European countries, for a single-wall corrugated quality, the average grammage is 500 g/m^2 and for a double wall, it is around 750 g/m^2.

The thickness (calliper) is measured under 20 kPa pressure. Average values are reported in the Table 11.2. In North America, weight per unit area is reported in pounds per 1000 square feet.

11.2.1.2 Strength properties

Bursting strength

The measurement of burst strength is described in ISO 2759. The unit is kPa. The burst strength of a corrugated board can be predicted using a simple formula. For a single wall corrugated board, the following equation is applied:

$$\text{Burst strength} = L_1 + L_2 + 100$$

where L_1 and L_2 are the burst strengths of the liners in kPa.

Burst strength is a commonly used measurement for classifying the quality of the corrugated board. Depending on the grammage and the nature of the liners, i.e. whether they are made from virgin, recycled or blends of virgin and recycled fibres, a large range of qualities from 800 to 8000 kPa are available.

Table 11.2 Average calliper (thickness) for different corrugated board grades

Flute	Calliper thickness (mm)
D	8.0
K	6.5
A	4.8
C	4.2
B	2.8
E	1.7
F	1.2
G	1.0
O	0.7

Rigidity or bending stiffness

Rigidity or bending stiffness relates the force required to deflect a flat specimen of corrugated board through a given angle. Figure 11.10 shows a schematic of the normal 3-point bending stiffness loading geometry.

On a standard dynamometer, the load (N) is applied in the centre of the sample and deflection (m) data are collected using a data acquisition system.

The specimens are cut with a width of $b = 5$ cm while the length used varies for the machine direction (MD) or cross direction (CD). MD is the direction of movement of the board through the corrugator.)

The expression of the 3-point bending stiffness is calculated using the slope of the load–deflection curve at the origin and the dimensions of the structure by the following formula:

$$\text{Bending stiffness (MD or CD)} = \frac{\text{Load}}{\text{Defection}} \frac{L^3}{48b}$$

where L is the distance between the anvils.

The standard unit is newton metre (N m) and the corrugated board sample is tested according to ISO 5628. Bending stiffness is fully expressed by a global matrix which is described in Pommier & Poustis (1990).

The experimentation carried out with different grammages and qualities of liners shows that:

- C flute has a higher bending stiffness than B flute
- corrugated fibreboard based on kraft liner has a higher bending stiffness than test liner at the same grammage
- bending stiffness increases with increasing liner grammage.

Edge crush test

The edge crush test (ECT) is used to evaluate the compression strength of the corrugated board. The standard unit is kilonewton per metre (kN/m). The corrugated board sample is tested according to ISO 3037 for ECT on a sample of board mounted vertically, with flutes running vertically, between horizontal platens.

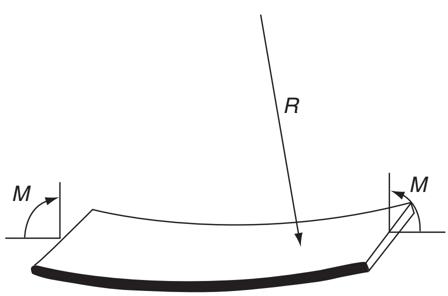

Figure 11.10 Loading principle and deflection for 3-point method.

Puncture

The puncture test, Figure 11.11, illustrates the energy required to penetrate the corrugated board. According to ISO 3036 standard, the measurement is expressed in millijoule per metre (mJ/m).

Flat crush and hardness

One of the main criteria for the stability of corrugated board is its ability to retain its structure and its geometry. The traditional flat crush test (FCT) makes it possible to evaluate and classify the performance of the fluting in accordance with its type and basis weight. The board sample is tested according to ISO 3035 for flat crush as illustrated in Figure 11.12.

Flat crush values depend on the shape of the flute and the quality of the fluting. There is about a 40% difference between semi-chemical fluting and recycled fluting for a similar grammage (Table 11.3).

Flat crush testing gives the intrinsic performance of the flutes predicted by the Concora Medium Test – CMT and by basis weight. The flat crush test thus records how appropriate the fluting medium is for processing on the corrugator.

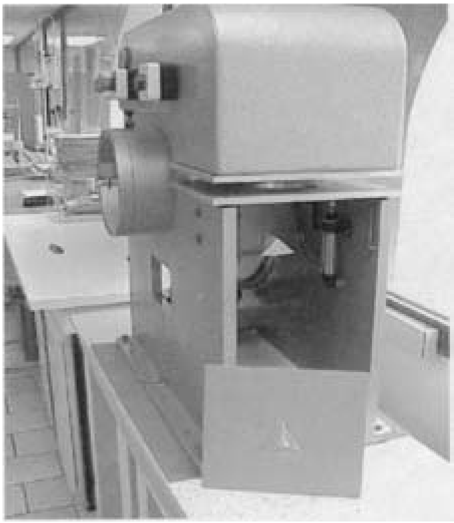

Figure 11.11 Puncture testing.

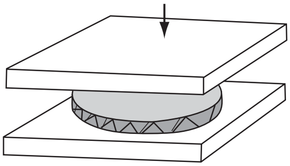

Figure 11.12 Flat crush corrugated board testing.

Table 11.3 Flat crush performances for C flute at 23 °C and 50% RH

Board combination			
Liners	Fluting	Grammage (g/m^2)	Flat crush (kPa)
2 × 175 Kraft	140 Wellenstoff	580	260
2 × 175 Kraft	150 Semi-chemical	595	360

The concora medium test (CMT) is described in ISO 7263. It is a test of the compression of the paper after fluting in a fluting apparatus (A flute), shown in Figure 11.13. The measurements made are CMT_0, i.e. the compression strength immediately after fluting, and CMT_{30}, which is the compression strength after 30 min conditioning at 23 °C and 50% RH.

As a first approximation, there is a good relationship between the FCT of the board and the CMT strength of the flutes (Fig. 11.14). Because the thickness

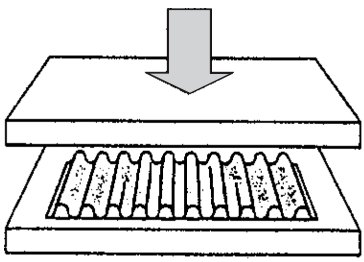

Figure 11.13 Concora Medium Test apparatus.

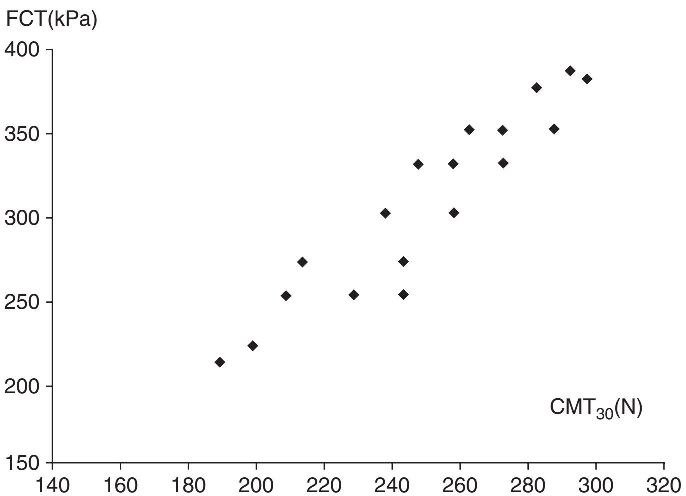

Figure 11.14 FCT and CMT relationship. *Source*: Database SWR-Europe – 1990/1997.

(calliper) of the board is the main criterion for preserving the stiffness of the board, it is an important measurement of the degradation of corrugated board (see Nordman *et al.*, 1978; Azens, 1985).

Different crush levels of corrugated board were obtained by crushing the board sample between two rotating cylinders. This pre-crushing was done in the range of 0–60% by various settings of the pressure rolls. Thickness (calliper) was measured before and after crushing under standard pressure (20 kPa) and at higher pressures: 80 kPa for C and A flutes and 150 kPa for B flute. Thickness (calliper) decreases dramatically after 20% pre-crushing (see Figure 11.15).

To guarantee the non-degradation of the corrugated board, in order to control calliper during manufacture in the plant, and to retain the ultimate strength and cushioning properties of the board, a gauge so-called 'Differential Micrometer', has been developed from the same thickness (calliper) loss measurement concept. The differential micrometer indicates the difference in corrugated board calliper (thickness) when measured at two different pressures (20 kPa and 80 or 150 kPa). A recommendation to the manufacturing plants is that the difference must not exceed 10% of the flute height.

In order to evaluate properly the performance of soft board, *the hardness of the corrugated board* is the other important criterion. Hardness is the resistance of the board in the early stages of the FCT (ISO 3035) as illustrated on the load–compression curves in Figure 11.16. Contrary to FCT values, hardness is more sensitive to calliper nips (roll pressure) and consequently, the extent of crushing. Hardness relates to the real strength of the flutes whereas FCT is a late yield point.

In summary, hardness and softness are quantified values of what is generally described as the 'softness' property of the corrugated board.

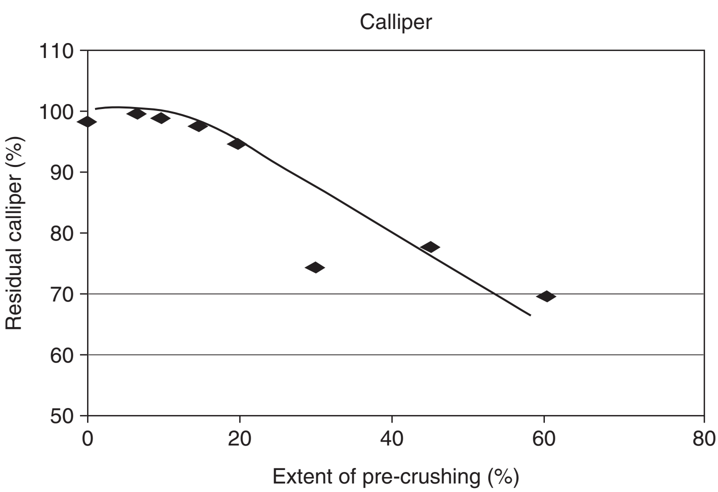

Figure 11.15 Impact of pre-crushing on the final calliper.

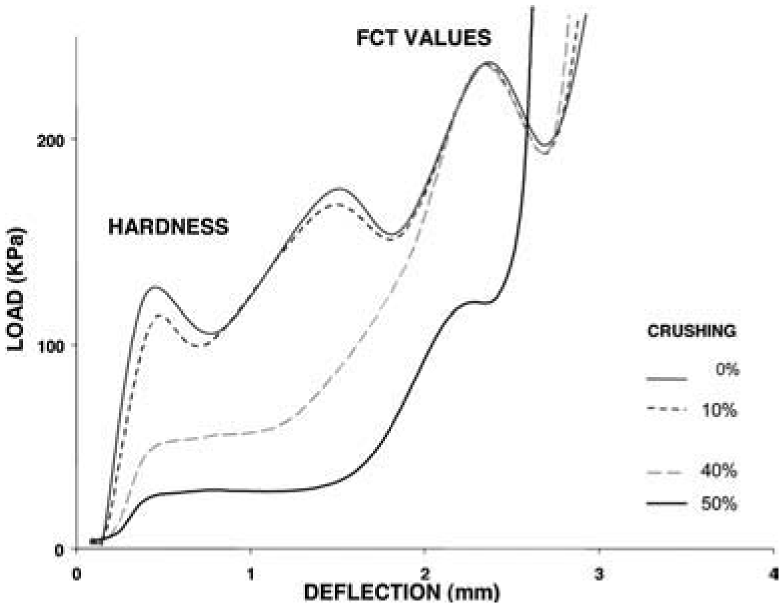

Figure 11.16 Flat crush detailed curves.

Flute bonding and score cracking

The pin-adhesion test (PAT) is used to evaluate the bonding between the fluting and the liners. It measures the force, in newtons per metre, required to separate the fluting from the liner by TAPPI method T 821 pm81. Pins are inserted between the flutes and the force required to break down the adhesion is measured as indicated in Figure 11.17.

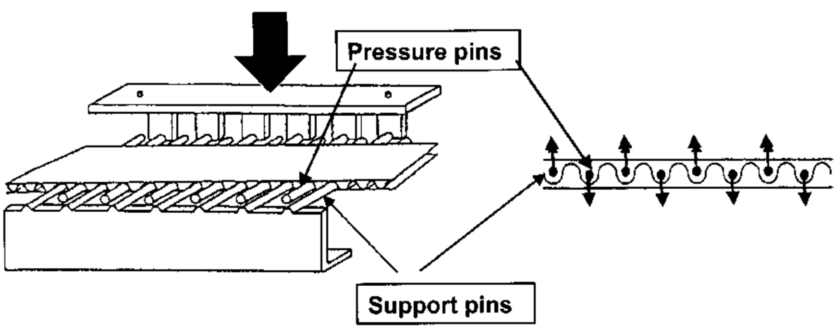

Figure 11.17 Pin-adhesion test.

As shown in Figure 11.18 the glue bonding of the tips of the fluting to the liner is very important for the performance of the corrugated structure throughout its life in packing, storage and distribution.

Single-face bonding is quite different to the bonding on the double backer due to a difference in the morphology of the adhesive deposit between single face and double backer. In single-face bonding, the adhesive is distributed on each side of the flute tip. In the double backer, the adhesive deposit is placed on top of the tip. This difference in position comes from the difference in the technology used for the application of the tip of the fluting to the liner. Figure 11.18 shows the double backer bonding position. The average starch adhesive in a B or C flute is varying between 6 and 9 g/m^2 for the two places.

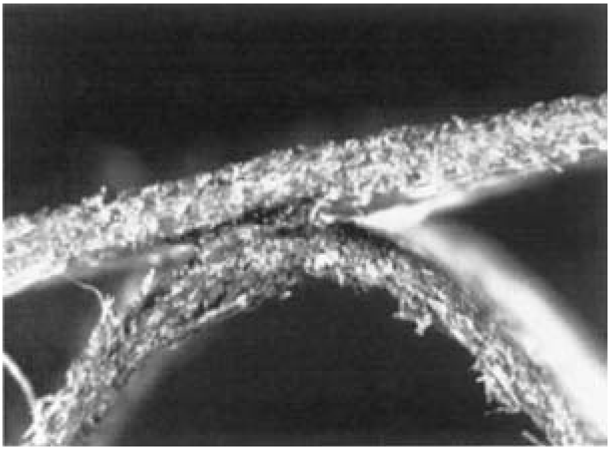

Figure 11.18 Photograph of bonding seen by microscope (double backer).

Score cracking effects frequently occur in the corrugated plants while converting the corrugated board sheets. Strain–stresses can occur in folding and erecting the case in some conditions. During the converting of the corrugated board, moisture is one of the key parameters to influence the score cracking behaviour (see paper properties below).

This effect can occur when the moisture content of the board is high and it can also occur when it is low.

Several series of measurements have indicated that the optimum moisture content is approximately 8%. Figure 11.19 illustrates this point.

In Figure 11.20, the difference between the three papers – referenced Test Liner No. 3, Test Liner No. 2 and Kraft Liner – is the burst index level. For the first paper, the burst index is below 2.5 kPa $(g/m^2)^{-1}$ while this property is below 3 kPa $(g/m^2)^{-1}$ for the second paper and above 4.0 kPa $(g/m^2)^{-1}$ for the third.

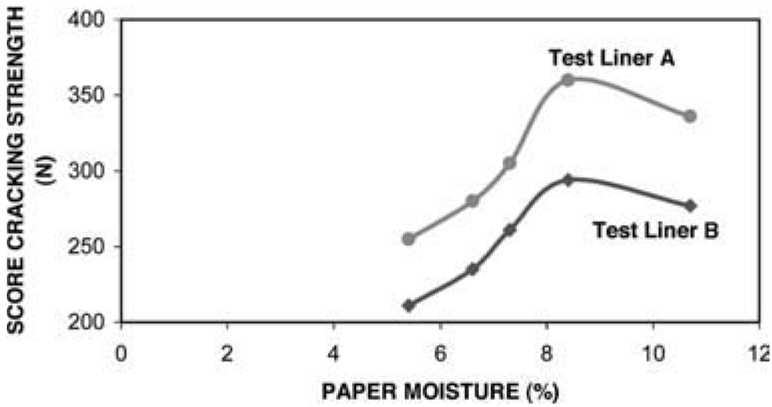

Figure 11.19 Score cracking variation with paper moisture.

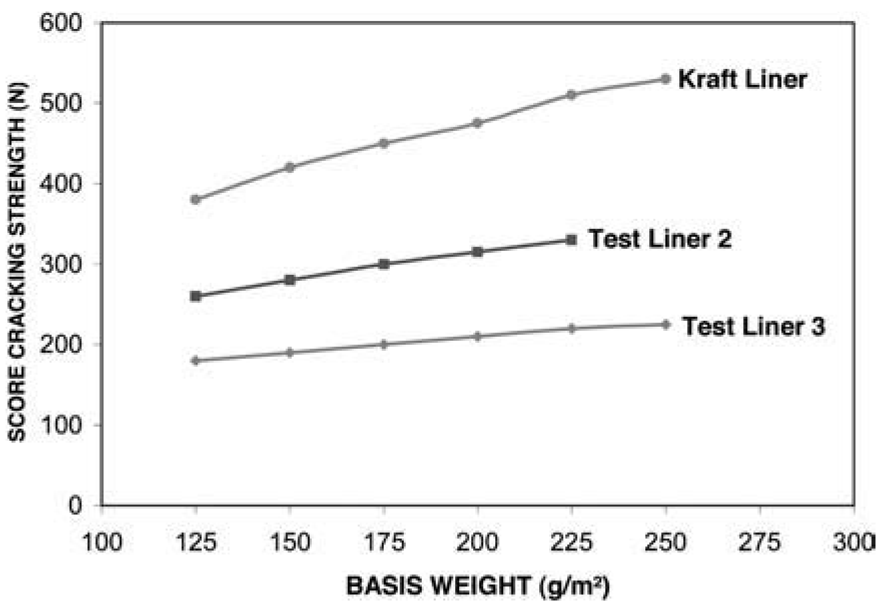

Figure 11.20 Score cracking variation for different lining papers.

Moisture resistance

The sensitivity of the paper to moisture variations is very important. The procedure for moisture measurement is by a gravimetric moisture analysis. This procedure is used to determine the moisture content of a sample of the corrugated board. It is achieved by the removal of water from a weighed sample in an oven.

The corrugated board sampling is defined in the Standards and the calculation of moisture content is described below:

$$\text{Weight of moisture} = \text{wet sample} - \text{dry sample}$$

$$\%\ \text{Moisture} = \frac{\text{weight of moisture} \times 100}{\text{weight of wet sample}}$$

The moisture at the end of a corrugator for B or C flute board must be in the range of 7–7.5%.

Paper properties

The papers used in corrugated board are made from wood fibres which are used to produce paper. Recycled fibre from recovered paper and board is a major source of fibre for the corrugating industry. Papers are defined by their structural properties, their mechanical properties and their moisture sensitivities. The basic properties of paper as a component of the corrugated board are described in Table 11.4.

Table 11.4 Basic benchmarking table of paper characteristics

Properties	Characterization	Critical element for
Nature of fibres	Virgin or recycled	Price
Grammage	Basis weight (g/m^2)	Weight reduction
Thickness	Microns	Structure
Sheet density	Porosity, IBT	Cohesion
Strengths	Burst, stiffness and compression	Performance, equivalence
Surface	Smoothness, brightness, gloss . . .	Printing
Orientation	Machine or cross direction (MD, CD)	Stability
Moisture sensitivity	Cobb, repellency	Curl, warp, lifetime

Note: **IBT = internal bond test**. This is the energetic load, or force, required to separate the layers of a paper in the *Z* direction (thickness), i.e. perpendicular to the paper surface, several test methods are available (ISO, TAPPI and Scott Ply Bond).

For corrugated board, the liners comprise unbleached and bleached fibres (virgin or recycled) and for fluting medium, recycled or semi-chemical fibres are used.

The basic packaging-paper classification was defined by the European Association ‘Groupement Ondulé’ in the year 1990. This classification corresponds to two classes of liner (test liner and kraft) and two selections for the fluting (semi-chemical and recycled).

Test liner is a paper predominately comprising recycled fibre. Table 11.5 presents the European classification. Table 11.6 presents the kraft liner range for

Table 11.5 Test liners range – 3 levels, with Test liner 1 being the best

	Test liner 1			Test liner 2			Test liner 3		
Grammage (g/m^2)	125	150	200	125	150	200	125	150	200
Burst index	3.0	3.0	2.9	2.5	2.5	2.4	2.0	2.0	1.8
SCT_{CD} value (kN/m)	2.15	2.60	3.40	1.90	2.35	3.00	1.65	2.05	2.70

Note: SCT_{CD} is the test value for the CD of the liner.

Table 11.6 Kraft liner range – 2 types (bleached and unbleached) and 2 levels of grammage

	Burst index		ISO brightness
Grammage (g/m^2)	<250	>250	—
Unbleached	>3.5	>2.9	No brightness specified
White top	>3.5	>2.9	>70%

both unbleached and white top (bleached). Fluting is classified by the CMT_{30} index class (Table 11.7).

Table 11.7 Fluting range

Fluting medium	CMT_{30} index
Semi-chemical	>1.8
Recycled	>1.6

In order to provide the basis for satisfactory corrugated box board performance, it is very important to know the relative orientation of the papers because the strength properties depend on the orientation: MD and CD.

The variation of characteristics for one Kraft Liner, 140 g/m^2, is presented in the graphs in Figure 11.21a, b.

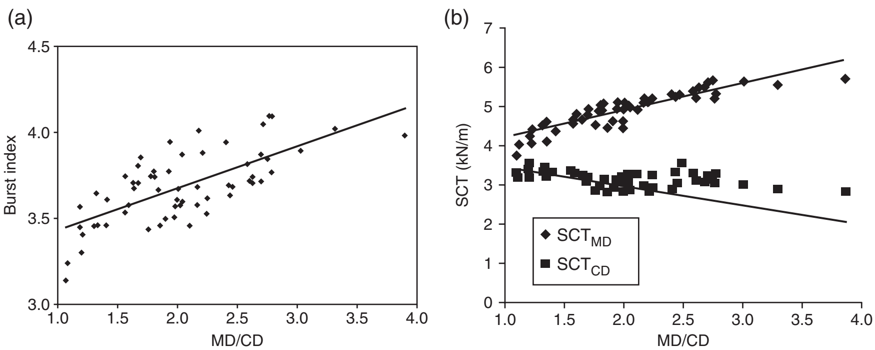

Figure 11.21 Strength and orientation of papers (a & b).

Paper and corrugated board humidity

The natural paper and board sorption is illustrated in Figure 11.22 (Poustis & Vidal, 1994).

In the sampling procedure, to evaluate the paper moisture, seven or eight outer layers of the paper reel are always removed before the specimen is selected, Figure 11.23.

The take-up of moisture occurs more through the unprotected reel end rather than through the body of the reel, Figure 11.24.

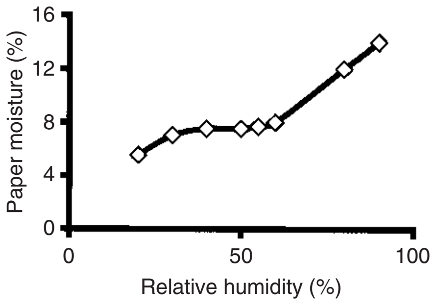

Figure 11.22 Paper and moisture equilibrium.

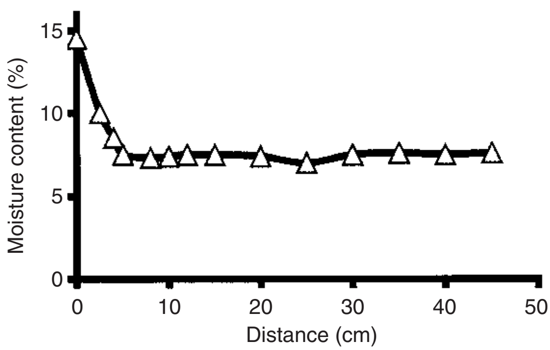

Figure 11.23 Typical moisture distribution from the outside to the inside of a reel.

11.2.2 Corrugated fibreboard manufacture

Corrugated fibreboard boxes are manufactured in a corrugated board plant or in a sheet feeder plant. The corrugated board plant consists of the corrugator which produces flat sheets of corrugated fibreboard and of the converting equipment where the corrugated sheet is converted into corrugated board boxes by printing, cutting, scoring (creasing) and gluing (or possibly, taping or stitching). These latter processes are known as the converting operations.

Corrugated fibreboard in sheet form is also sent to smaller factories known as sheet feeder plants, where they are converted into packaging for short run length orders, quick deliveries and for very specific local markets.

The production of the corrugated board is carried out in several stages in-line.

- Production of the *single face* corrugated board – Figure 11.25: The fluting medium is conditioned with heat and steam to make it pliable enough to accept and retain the shape of the fluting. The fluting shape is pressed into the medium

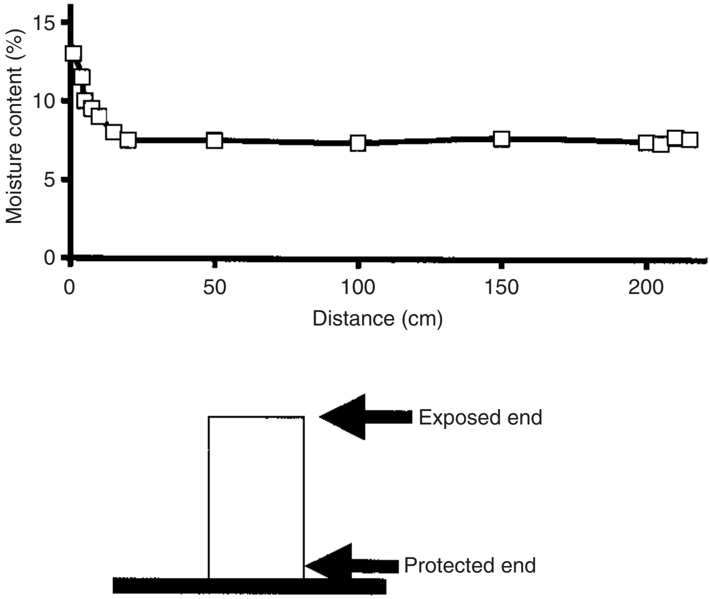

Figure 11.24 Typical moisture distribution from end to end of reel.

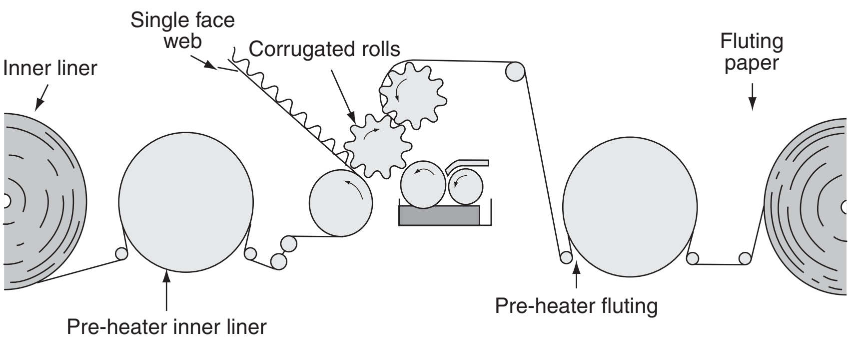

Figure 11.25 Production of single face corrugated board.

either using two profiled rolls or, in the 'fingerless' process, by forming the fluting medium on one profiled roll using vacuum. After the corrugation of the fluting medium, starch adhesive is applied to the tips of the corrugations and the medium is combined with the liner which has also been conditioned to bring it to the same temperature and moisture content as that of the fluting medium.

- A second liner is applied at the double backer to produce *single wall*, or double face, corrugated board – Figure 11.26.

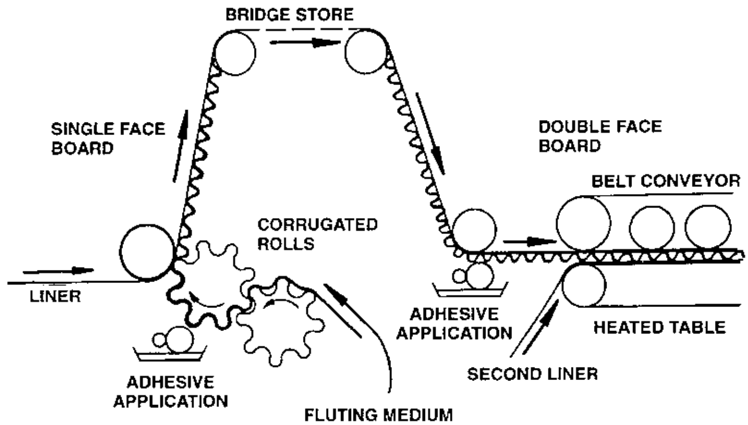

Figure 11.26 Production of single wall (double face) corrugated board. (Reproduced, with permission, from The Institute of Packaging.)

- After passing through a drying section, the board is matured and cooled before being slit to the required width and cut to the required length. Scores (creases) may also be applied to the board in the MD of the corrugator.

The key parameters of the process are:

- fluting roll profile (A, B, C, etc.)
- roll temperature and pressure
- viscosity of the adhesive
- relative speed of the pre-heated inner liner and the fluting medium
- pre-heat conditions for the liner and fluting medium.

The speed of the single facer is more than that of the double backer, and the excess board accumulates in a bridge system between the two lining stations balancing the difference in speed.

In order to make a *double wall* corrugated board, the machine would incorporate additional sections as shown in Figure 11.27. In this process, two single face corrugated webs are formed in Zone A. The flutes of Single Face 1 are glued to the liner of Single Face 2 in Zone B. A liner for the flutes of Single Face 2 is applied to the flutes of Single Face 2 and the combined board is dried between heating plates in Zone C.

Starch adhesive preparation is an important element for the orderly running of the process. Essentially, a corrugating starch adhesive is a four-component system. It consists of a carrier or cooked starch component, a raw starch component, caustic soda and borax, all prepared in water. All ingredients are mixed together in a 'kitchen'.

The carrier (cooked starch) component carries the raw starch component to the tips of the fluting so that when heat energy is supplied, the raw starch swells

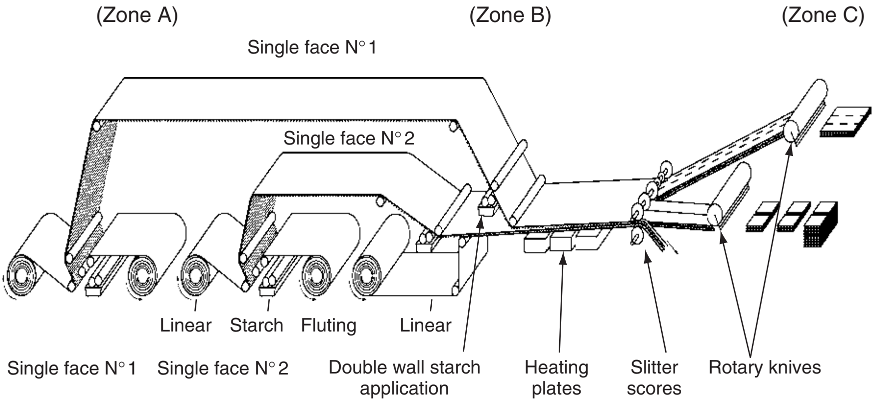

Figure 11.27 Production of double wall corrugated board.

'in situ', in the situation where sufficient water is present in the glue line to adhere to the tip of the medium to the liner. The caustic soda helps prepare the carrier for its 'duties' and determines the initial gel point or swelling point of the raw starch component.

Borax (hydrated sodium borate) is added in the form of penta-hydrate or deca-hydrate, i.e. hydrated to the extent of 5 or 10 molecules of water of crystallization, respectively. The primary function of the caustic/borax treatment is to bring about extensive chemical changes in the starch structure, which modify its physical properties.

The action of the borax causes the starch to become a more highly branched polymer chain with higher viscosity and tack. It contributes the necessary rheological properties for efficient adhesive roll pickup and transfer to the tips of the formed fluting.

At this point, one may as well ask, 'What are the essential characteristics of a good, commercial corrugating starch adhesive?' There are four basic adhesive characteristics that a starch system must deliver:

- reproducibility from batch to batch
- viscosity stability during storage and circulation to the combining machine
- proper rheological or filming properties to permit the desired pickup and transfer of adhesive from applicator roll to the flute tip of the corrugating medium
- deep, penetrating adhesive bonding consistent with the needs of production and downstream operations.

If any of the above elements are missing, then the adhesive cannot be classified as a good commercial corrugating adhesive.

The flat sheets of corrugated board coming off the corrugator are transferred to the converting operations where the main machines are printer/slotters, die cutters and folder gluers, depending on the corrugated product being produced.

Blanks for RSCs from the corrugating machine are further converted on flexo folder gluers. Special design profiles are cut and scored on a die-cutter/scorer.

Machines are also available which incorporate many typical features of corrugated box printing and conversion in one in-line machine, Figure 11.28.

The following features are indicated in Figure 11.28:

A is the feeder which can handle a wide range of board thickness, from thin microflute to double-wall corrugated board
B is a 4-colour flexographic printing unit
C is a rotary diecutter. A diecutter is necessary for the production of sophisticated box designs, i.e. boxes with features other than simple scores and slots
D is a slotting unit with waste removal
E is a folder-gluer unit where the side seam is completed
F indicates two-process touch-control screens which are used to set up and operate the machine
G stacks the boxes in bundles and ejects them from the machine in a controlled way.

Features of such a machine are the automation of the adjustments, i.e. the set-up, required when changing from one box design to another, attention to the removal of board dust generated during cutting and noise reduction.

11.3 Corrugated fibreboard – functions

11.3.1 Box stackability

The main function of a corrugated paperboard box is to contain and protect packed goods during distribution. The growing use of palletization in warehousing and transportation requires that corrugated boxes have good stackability.

11.3.1.1 Pallet arrangements

Specific commercial software is available to design the best position of the corrugated boxes on the pallet with respect to utilization of the volume and overall stability. The structure, as shown in Figure 11.29, is calculated using a software, such as the CAPE system or other expert systems.

11.3.1.2 Intrinsic compression

Corrugated board is the most appropriate material to achieve high stackability, forming a lightweight rigid structure composed of liners separated by corrugated fluting papers.

Stackability is best measured using the box compression test (BCT) expressed in Da N or kg. BCT is the top-to-bottom compression strength. Several standards have been published, for example FEFCO, ISO, AFNOR, etc. In the FEFCO method, the measurement is made on an empty box. The application of a method for measuring BCT, mean and standard deviation is defined in FEFCO Testing Method No. 50. In ISO 12048, BCT measurement is made on filled boxes.

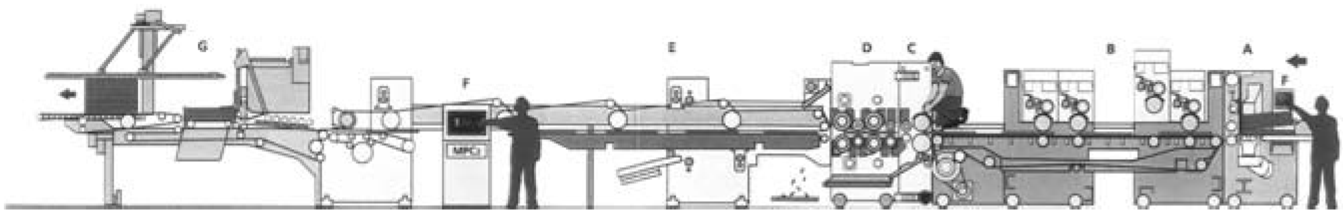

Figure 11.28 Martin combined in-line rotary diecutter, slotter, flexo folder gluer. (Reproduced, with permission, from Bobst SA.)

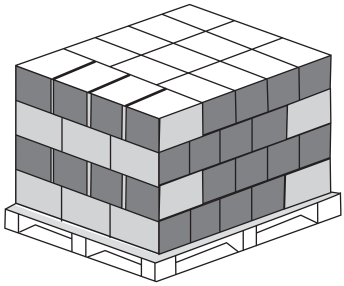

Figure 11.29 Structure of the pallet.

Empirical approach to compression strength: McKee formula

The most widely known formula which links the box compression strength with the mechanical properties of its components is the one devised by McKee (McKee *et al.*, 1963):

$$\text{Box compression strength} = K \times \text{ECT}^a \times \text{FS}^b \times D^c$$

where D is the dimension of the box (perimeter); FS is the flexural stiffness of the board; ECT is the edge crush test of the board; and K, a, b and c are empirical constants.

Box dimensions have an important role in determining stackability, and designers take this into account, using a chart based on the perimeter and height of the box together with the basis weight or grammage of the corrugated board. Figure 11.30 illustrates the relationships involved.

For given box dimensions, the BCT (measured in DaN) of the corrugated board package depends both on the ECT and the flexural stiffness of the combined board.

The original McKee equation (statistically derived from a relatively small number of experiments run in the early 1960s) overestimates the effect of the ECT and underestimates the effect of the flexural stiffness.

To improve on this, more extensive laboratory tests have been run. It has been seen that the BCT is mainly a function of the box dimensions, the combined board thickness (calliper), the grammage and the flexural stiffness of the combined board.

Figure 11.31 shows the variation of BCT for rectangular cases 40 cm × 30 cm × 30 cm, with the board grammage for two different stiffnesses.

The first one given is for C flute (4.2 mm calliper), the second for B flute (2.8 mm calliper).

In addition to the factors already discussed, it is very important to take into account the flute size and hardness of the corrugated board as well. The thickness of the combined board is an important element in determining the vertical

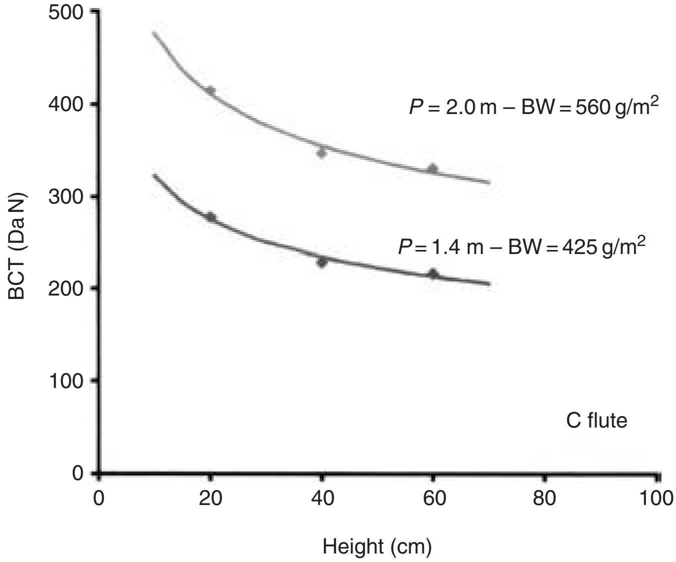

Figure 11.30 Effect of box dimensions and grammage (basis weight) on stacking strength BCT. (Height of box in cm.)
P = perimeter of the box, BW = basis weight or grammage of the corrugated board.

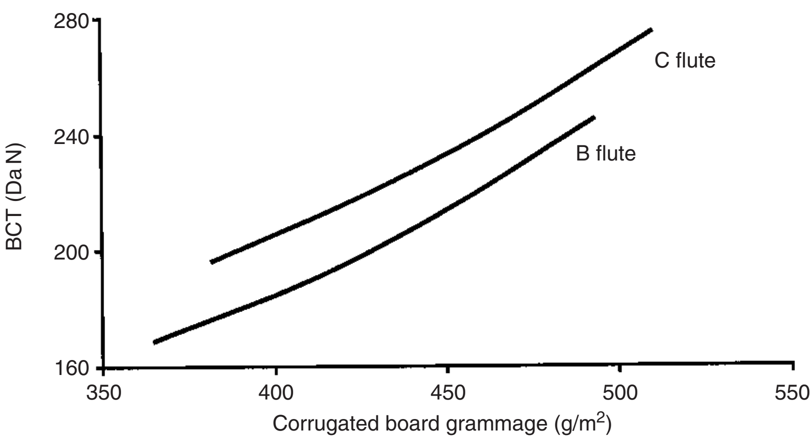

Figure 11.31 Effect of flute size, i.e. C and B flute with different stiffnesses, on BCT.

compression performance. Multi-wall combinations like B+C=BC or B+E=BE combine to increase the board thickness and thus the weight and stiffness of the structure.

The flexural stiffness term (FS) in the McKee formula is obtained from classical thin plate theory (Pommier & Poustis, 1989). (Thin plate theory is the classic approach for evaluating raw material performance in mechanics in order to predict the bending stiffness of composite materials, i.e. sandwiches.) This stiffness is created by the moment of inertia of the material.

The thickness of the board and the quality of the fluting (or its hardness, defined later) both play important roles in determining the moment of inertia. In order to get the ultimate box compressive strength, fluting with perfect waveform is also needed.

A second factor used in calculating flexural stiffness is the modulus of elasticity (Young's Modulus, or MOE) of the liners. This is currently measured using an ultrasonic test, the tensile stiffness index. Figure 11.32 compares two liners of equal thickness (calliper). Liner 1 has a high MOE compared to Liner 2. The flexural stiffness of the combined board is strongly differentiated by the difference in MOE, especially as liner basis weight increases.

In practice, flexural stiffness is difficult to measure and is not used as a regular test.

The ECT test is better known, and is commonly used to estimate the potential strength of the board. As shown in Figure 11.33, this element is not dependent on the thickness of the board; but depends mostly on the grammage of the board.

A combination of paper strength parameters can be made and used to predict ECT with more precision, as indicated in the following formula for a single wall corrugated board.

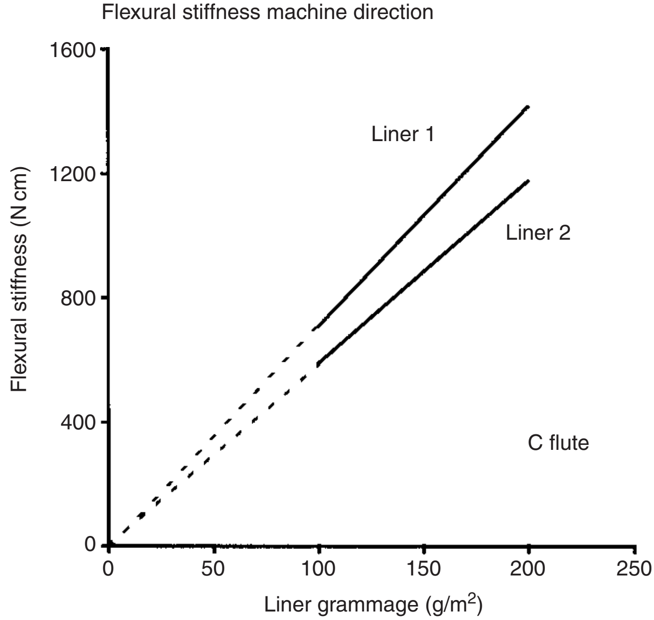

Figure 11.32 Effect of liner MOE on combined board flexural stiffness.

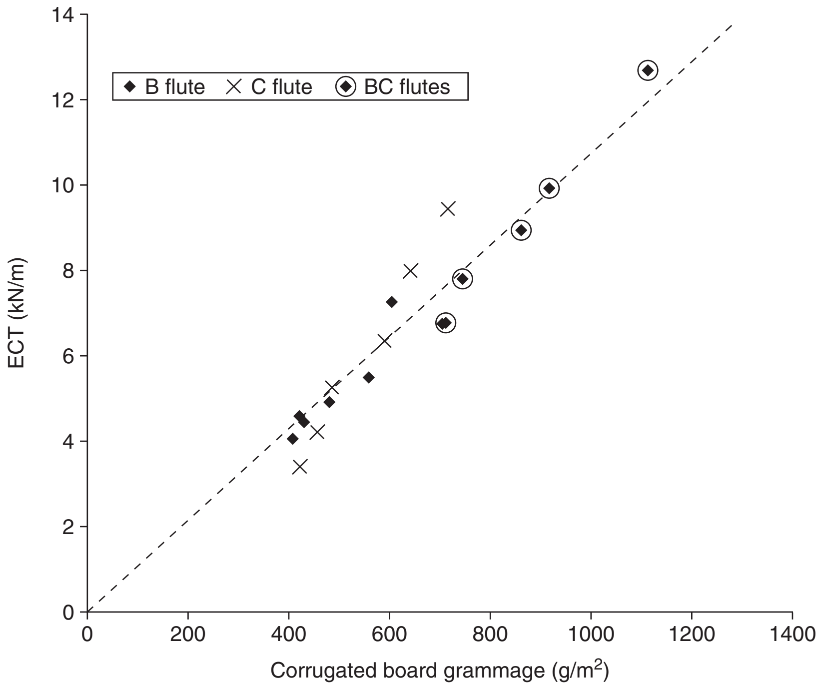

Figure 11.33 Effect of grammage and flute size on ECT.

$$\text{ECT} = 0.585\,(\text{SCT}_{\text{CD1}} + \text{SCT}_{\text{CD2}}) + 1.203\ \text{CCT}_{\text{CD}} \qquad r^2 = 0.944$$

SCT_{CD} is the short compression crush test strength in the CD of the liners (1 and 2) and CCT_{CD} is the compression crush test strength in the CD of the fluting. (*Note*: CCT is *not* Concora Compression Test – a similar shaped sample is used as for Concora Medium Test, CMT, but the load is applied totally differently. The load is applied at the edge of the paper. The test is not used very often, but it is similar to the ECT test.)

Semi-empirical prediction of compression strength

In order to expand beyond the classical box theories, new methods of measuring stackability are always being considered.

The following diagram is based on a photograph, Figure 11.34, which shows the stress distribution in a boxboard panel under compression. The influences of the bi-directional distribution (MD and CD) of the material can be seen. This buckling phenomena, not accounted for in classical theory, is characteristic of corrugated board material behaviour under load, and has been the basis of R&D investigations (Gunderson, 1981; Pijselman & Poustis, 1982; Thielert, 1984; Springer *et al.*, 1985; Pommier & Poustis, 1986a; Thielert, 1986; Pommier *et al.*, 1988).

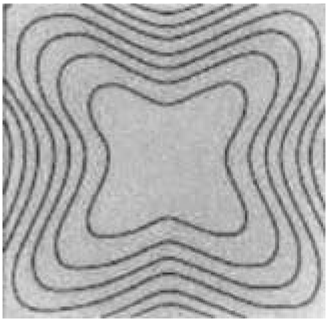

Figure 11.34 Based on a photograph of stress distribution in a board panel under vertical compression.

Mathematical models of prediction

The application of finite element analysis has been developed to predict the behaviour of corrugated board panels and structures.

A developed linear elastic analysis code, referred to as SYSTUS, is able to evaluate the bending stiffness of corrugated board.

The corrugated medium defined in the calculation code incorporated trapezoidal mesh structure and the models assumed perfect bonding between fluting and the liners. By applying the technical theories of corrugated performance and with good control of calliper (thickness) and board hardness in the box plant, it is possible to predict, accurately, how a corrugated box will perform under a stacking load. Figure 11.35 is a prediction of corrugated board shape produced using ANSYS software.

Finite element software to predict package performance under load can be applied for test cases, predicting the effect of complex design features such as access (hand) holes.

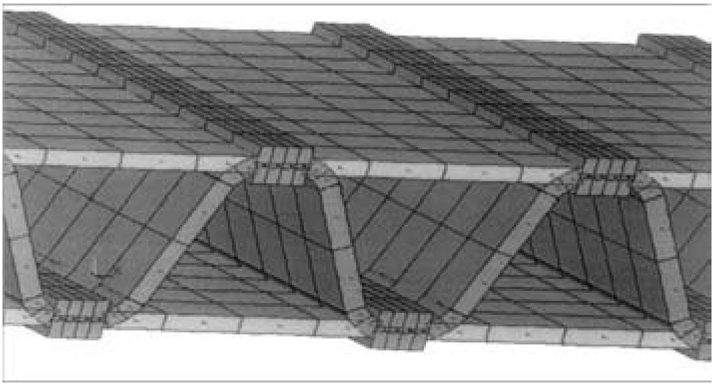

Figure 11.35 Corrugated board shape predicted by ANSYS (software).

11.3.1.3 Lifetime and safety factors

To define box compression (BCT) in the environment means that one takes the life cycle of the box into account together with the duration of the stacking mode and safety coefficients (factors).

As creep material behaviour is concerned, i.e. slow deformation over time under load, the box performance has been simulated using the following experimental protocol, named fatigue, resistance of the corrugated boxes.

Whereas the life of a box begins while the corrugated board is being produced, the whole set of constraints which are mostly determining its enduring appearance become manifest when the box is used in the course of distribution. The box is subjected to many different kinds of stresses: vibrations, shocks, falls, ageing, and sometimes cycles of moisture and temperature variations.

In the laboratory, it is possible to quantify these stresses in order to describe the evolution, or variation, in the course of time of the performance of a box when it is subjected to compression and when it passes through moist environments.

The box resistance to vertical compression (BCT) is the parameter that gives the best account of the effects of transport and storage conditions, and of the stackability of the boxes. The user is thus interested in obtaining the best possible resistance of the box to vertical compression, not only at the time of purchasing a box, but also throughout the life cycle of the box. This can be translated in terms of a search for the maximum lifetime of the box, which can be expressed as the time at the end of which the box will collapse under a calculated compression load (BCT_0).

This describes the standard course of creep tests which we have followed for obtaining a representation of the box behaviour. For simulating the dynamic and climatic stresses, we have subjected the box to a system of vibrations and we have placed it in atmospheres with variable temperatures and humidities. In the laboratory, it is possible to accelerate the time required for the box to collapse under a given load – by selecting the load BCT_0. According to the stress conditions or the environment conditions, the time for the box to collapse depends on the value of the load being applied versus the value of the compression strength of the box (BCT_0/BCT). For instance, if the box is stored at 23 °C and 50% RH, the load required to cause the box to collapse between 5 and 15 min is approximately 90% of the box compression strength.

In the following example, RSCs, C flute, size 400 mm × 300 mm × 300 mm, made with Kraft liners from 150 to 225 g/m^2 and various fluting mediums (recovered papers and semi-chemical, from 110 to 180 g/m^2), have been tested in two different environments.

The BCT values of the various cases have been measured under static conditions. They fall within a range of 350 ± 50 kg at 23 °C and 50% RH, and within 130 ± 15 kg after having saturated them with moisture during 72 h at 20 °C and 90% RH.

The lifetime versus the percentage of load being applied is plotted in the graph shown in Figure 11.36. Each dot represents the average value of 10 measurements

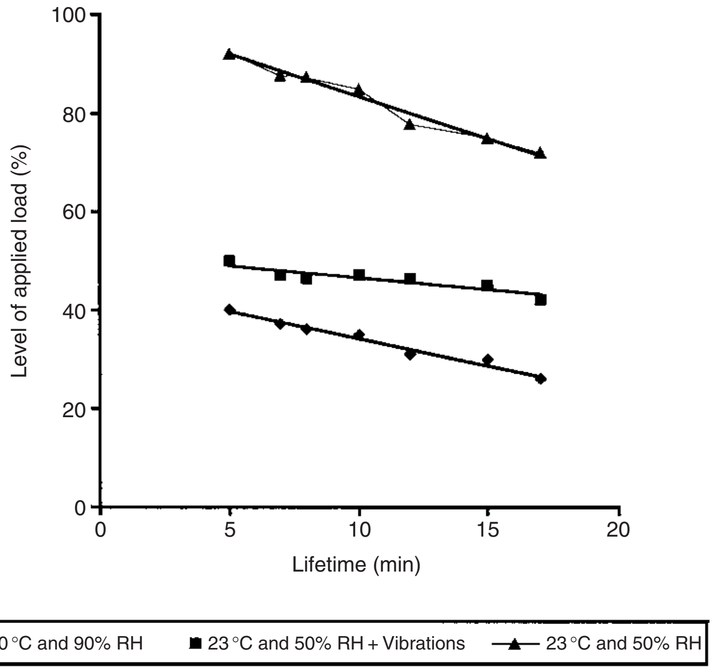

Figure 11.36 Corrugated board lifetime versus compressive load applied.

made on each composition. This average time is significant, since we have verified, as Thielert (1984, 1986) also did that this time followed a normal law of statistical distribution.

It has been observed that:

- As expected, the passage through a moist environment significantly reduced the compression strength compared with that which was obtained on the same box specification stored in a dry environment. A box composition which has withstood 310 kg average in a dry surrounding had the same lifetime as the one which could withstand only 120 kg in a damp surrounding.
- Vibrations disturb the system's stability: for a same lifetime, another box composition which has withstood 300 kg had its potential decreased by 40%, meaning that it will only withstand a 170-kg load.

It is interesting to apprise the behaviour of each one of the box components. A classification of papers is possible using the creep rate parameter.

From the creep rate of the paper, i.e. a test developed by Smurfit which is similar to the short span compression of the paper components, it is possible to measure, as a function of time, the dissipation energies involved during the deformation under the stress being applied. It is logical to consider that the resistance to this stress varies in an inverse relation versus the value of the energy being released.

Thus, the more resistant the material will be, the smaller will be its deformation; the amount of released energy will therefore be smaller.

Under fixed operating conditions as to stresses and time, working within the elastic range of the material, it is possible to compare the papers together and to define a fatigue resistance (FR) index.

This FR index is given by the relation:

$$\mathrm{FR} = \frac{W_{\mathrm{ref}}}{W}\ (\%)$$

in which W_{ref} is a reference energy value selected arbitrarily as the lower limit for the observed values, and W is the energy released through creeping. In order to illustrate this proposition, we have opted to present the following results obtained from a comprehensive sampling of many industrial papers available on the market, and these results are expressed as the mean geometric values for the MD and CD.

If we bring together the set of creep rate measurements and the traditional classification of papers according to their bursting index, it is found that the two parameters vary inversely with each other; equally, from its very definition, the fatigue resistance index is proportional to the bursting index, Table 11.8. Thus Figure 11.37

Table 11.8 Results illustrating creep rate, energy release and fatigue resistance (geometric mean values)

Nature of paper	Burst index	Creep rate ($\mathrm{Pa^{-1}\,s^{-1}}$)	Energy release (kPa)	Fatigue resistance (%)
Test liner 180 $\mathrm{g/m^2}$	2.5	5.7	130	46
Kraft liner 150 $\mathrm{g/m^2}$	3.5	1.6	86	70
Kraft liner 150 $\mathrm{g/m^2}$	4.5	1.2	76	80

Notes: Experimental conditions: $\sigma_{0\,\mathrm{MD}} = 18\,\mathrm{MPa}$, $\sigma_{0\,\mathrm{CD}} = 8\,\mathrm{MPa} \rightarrow \sigma_0 12\,\mathrm{MPa}$; creep time = 15 min. Reference energy: $W_{\mathrm{ref}} = 60\,\mathrm{kPa}$.

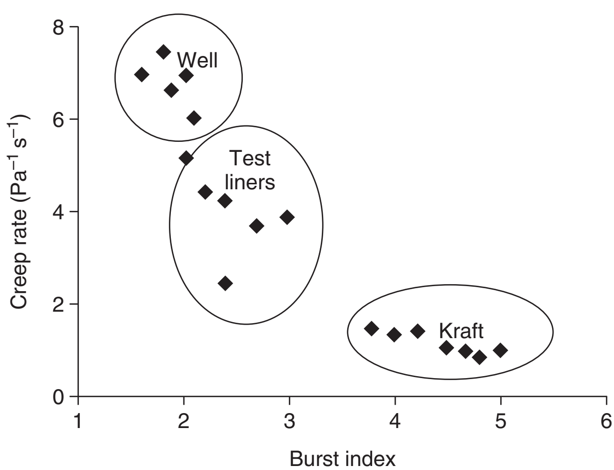

Figure 11.37 Creep rate classes of packaging papers (Well = Wellendorf, fluting paper).

represents the respective positioning of the major families of industrial papers by classes of creep rates. It is thus possible to define paper classes which are homogeneous as to burst strength and fatigue resistance, where strong bursting indices go together with a strong fatigue resistance of the paper and therefore of the corrugated board case.

Theory of creep behaviour

When carrying out the creep test, a constant stress (σ_0) is applied to a material, and the change in its deformation ($\in$) in the course of time is analysed.

The creep function derived there from is of the type:

$$f(t) = \frac{1}{\sigma_0} \in (t)$$

The material is characterized by its creep rate, which takes the form:

$$v = \left[\frac{\delta f(t)}{\delta t}\right] \quad \text{in Pa}^{-1}\,\text{s}^{-1} \text{ as } t \rightarrow 0$$

If the phenomenon is examined from a mechanical theory approach, it will be shown that for the stress σ_0, the energy released by the material, as it becomes deformed through creep, can be written at every instant as a function of the creep rate:

$$W(t) = \frac{\sigma_0^2}{2E} + \sigma_0^2 \int_0^T v(t)\,\mathrm{d}t \quad \text{in Pa}$$

where E is the Young's modulus of the paper.

For standard experimentation, the designers commonly choose the safety factor coefficients shown in Table 11.9.

There is a large amount of box performance safety data within the corrugated board industry. The safety factor coefficients indicated in Table 11.9 are taken into account at the design stage to ensure that the boxes used will have sufficient strength to protect the contents during the expected storage life.

Table 11.9 Safety factor coefficients related to external conditions

Environment	Specificity	Safety factor
Stacking mode	Column	1.00–1.33
	Interlocked	1.67–2.00
Moisture (RH)	65%	1.07–1.25
	75%	1.25–1.67
	90%	1.82–2.50
Storage at 90% RH	1 hour	1.11–1.40
	10 days	1.33–2.00
	360 days	2.00–2.55

The basis of the calculation, which is the prediction of the required BCT, is based on the BCT of a box which is tested after a short storage life and which has not been stacked. This is known as BCT_0. The predicted required BCT is calculated from this value multiplied by a cumulative safety coefficient, C_T.

For design centre calculations, BCT_0 is measured in the laboratory at 23 °C and 50% RH. It is multiplied by the cumulative safety coefficient, C_T. This is calculated by multiplying the various safety factor coefficients which correspond to the factors which have an influence on box, or case, performance:

$$C_T = C_1 \cdot C_2 \cdot C_3 \cdot C_4 \cdot C_5$$

where C_1 is the coefficient which represents the packaging operation; C_2 is for pallet stacking (interlocking or in columns); C_3 for fatigue during the storage time; C_4 for the climatic conditions during transport and storage and C_5 is for the vibration during transportation.

C_T is generally evaluated at between 2 and 7, and often between 3 and 4. As an example, a box stored in an interlocked arrangement in a pallet for 10 days at 90% RH will require a BCT four times higher in compressive strength than a normal individual box non-stacked and stored for a short time. (*Note*: $C_2 \times C_3$ is $2 \times 2 = 4$, from Table 11.9.)

Hence a result of a BCT_0 of 200 kg in the laboratory will not be strong enough to support more than 200/4 = 50 kg in real conditions.

Moreover, a factor of 25% must also be taken into account if tests are made with hand-made boxes to take account of the mechanical stress which can be experienced during erection filling and closing at speed on a packing line.

11.3.2 Containability and protection

The basic function of corrugated board packaging is the same as for any packaging, namely to protect products during distribution until the product is removed from the package. It may also protect the environment from the product – e.g. in the distribution of dangerous goods.

The corrugated board package is mainly designed to contain products during distribution. Containability together with adaptation of the box strength to logistics systems (packing lines) are becoming important issues in corrugated board transit packaging design.

11.3.2.1 Cushion performance

Corrugated board is a structural material which has few energy adsorption characteristics compared, for example with expanded polystyrene or other cushioning materials (Table 11.10).

The performance required from cushioning is to eliminate or minimize damage to packaged product arising from impact and vibration.

Table 11.10 Cushion properties for corrugated boards and other materials

Material	Energy absorption (kJ/m^3)
PE bubbles	70–95
PS sheets – density 15 kg/m^3	140–270
Corrugated fibreboard	60–300

Source: Swedish Packaging Research Institute (1978).

The effect of a damaging shock or impact can be reduced by three principles:

- Spreading the forces on impact, so that the force per unit area or the force on any part in contact with the cushion is reduced.
- Localizing the force, so that the forces at impact are directed to the stronger parts of the package or the product.
- Absorbing the energy of the packaged product.

This third principle is called cushioning, i.e. absorbing energy – the material is compressed during impact and so absorbs much of the impact energy and, subsequently, the force. It reduces the stress on the outer face of the product as well as the shock, which causes the damage to the contents.

Corrugated board quality is essential to provide product protection by cushioning, i.e. cushioning in this context means the amelioration of damage likely to be caused by shocks such as dropping.

The calculation of the required thickness of the cushion may be carried out by an empirical formula as:

$$H = C \times \frac{T}{G}$$

where H is the drop height; T is the board thickness; C, the cushioning factor (for corrugated board), C is between 1.8 and 3.6; and G is expressing the level of fragility of the packed product.

Charts can illustrate this formulae variation, Figure 11.38.

The cushioning possible with corrugated board packaging is the subject of ongoing research.

11.3.2.2 Drop protection

The structure and quality of a corrugated board are essential to ensure the protection of the product when the case is dropped.

Drop testing is carried out according to ISO 2248 standards. The height of the drop is increased incrementally during the test and the percentage of boxes damaged at each height is evaluated.

The evaluation of corrugated board packaging is performed with 8 and 15 kg of packed sand and there are different modes of drop. The case can either be dropped horizontally or on an edge.

For the same weight of contents, the drop-height failure depends on the grammage of the board as shown in the Figure 11.39.

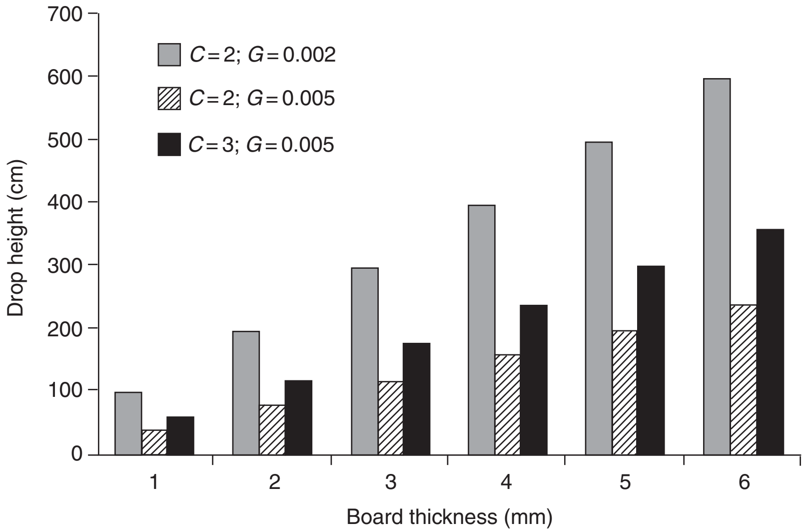

Figure 11.38 Relationship between the thickness of the board and the drop height.

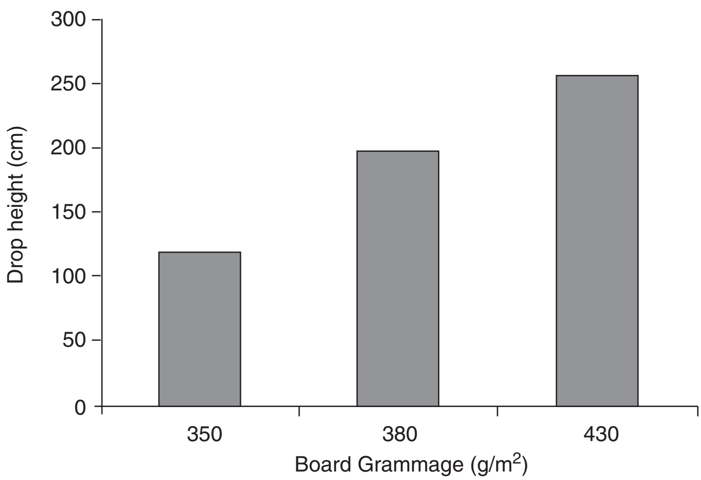

Figure 11.39 Drop height failure of B flute RSC boxes with 8 kg of packed sand.

The potential energy of the box in drop testing is the product of the weight of contents and the drop height.

The following histogram for B flute boxes, Figure 11.40, which represents this potential based on the height at which 50% of the boxes fail the drop test shows that the potential energy depends on the weight of the corrugated board which protects the contents.

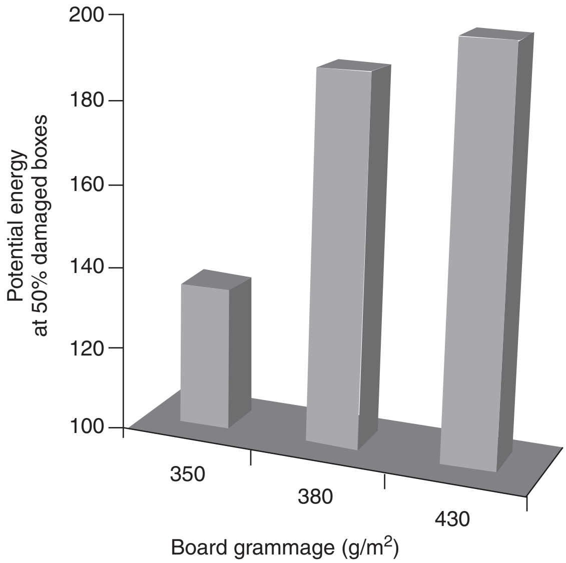

Figure 11.40 Potential energy versus corrugated board grammage (B flute – RSC boxes 40 cm × 30 cm × 30 cm, 8 kg packed).

The main material parameters which influence the protection of the case in drop testing have been analysed in detail.

From drop test experiments conducted with B flute RSC boxes of 40 cm × 30 cm × 30 cm and two content weights (8 and 15 kg), correlations have been made. The potential energy is directly related to the burst strength of the corrugated board as presented in the Figure 11.41.

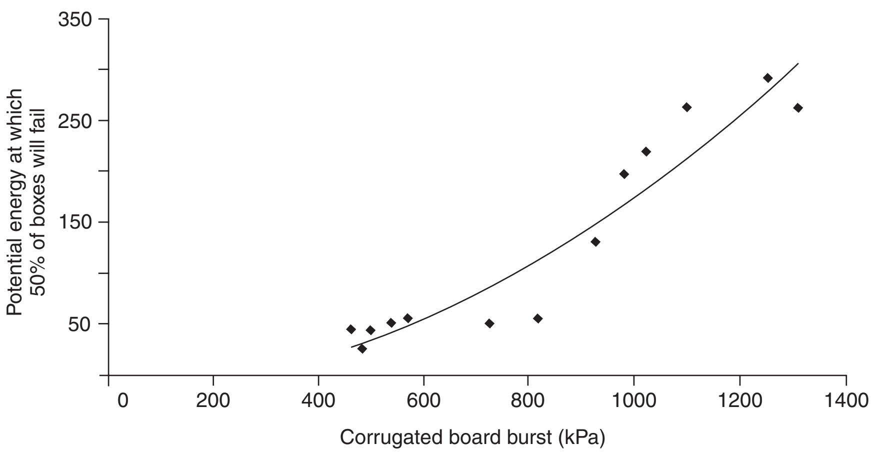

Figure 11.41 Potential energy at which 50% boxes failed by drop versus corrugated board burst (B flute – RSC boxes 40 cm × 30 cm × 30 cm, 15 kg packed).

There are large differences in corrugated board burst strength resulting from the use of papers of different quality (see Figure 11.42). Figure 11.42 also shows the importance of corrugated burst values in relation to the drop height, in particular the difference resulting from the use of test liners with burst index 2.0–2.4 and kraft liners with burst index >3.8. This shows that the maximum drop height for the test liner boxes is 75 cm, approximately, whereas with the kraft liner, the drop height starts at 120 cm and the maximum is 230 cm, approximately.

The conclusion from this drop test research, investigating drop test protection, is that burst strength, measured in kPa, is the key parameter.

Table 11.11 indicates the protection requirements in terms of classification and drop height for dangerous goods.

This classification is the usual recommendation for the transport of dangerous goods indicated in all manuals of practice, for example FEFCO.

11.3.2.3 Puncture protection

Corrugated cases can be damaged by puncturing during distribution both internally by movement of the contents and externally by impact with sharp objects. Puncture resistance of the corrugated board is a requirement specified by some national specifications (France, Germany and Spain).

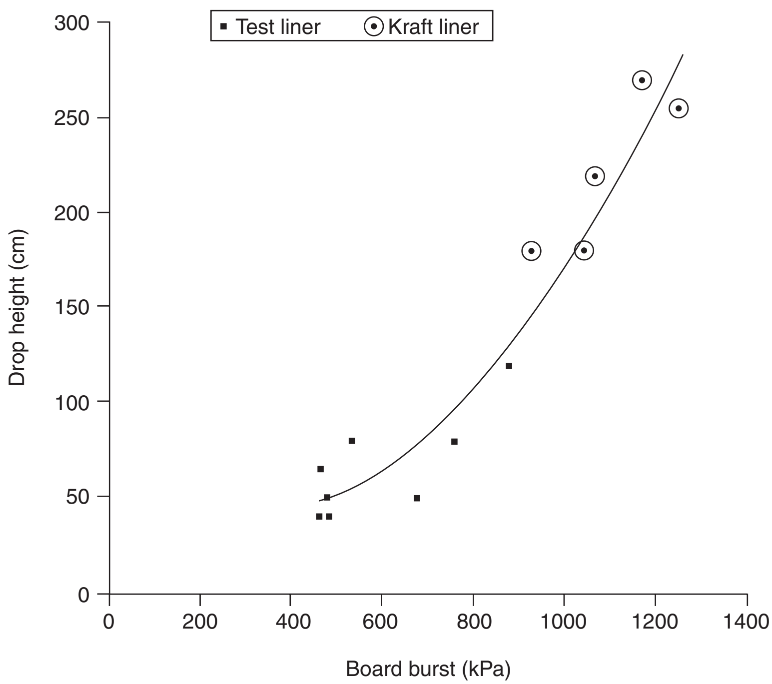

Figure 11.42 Relationship between drop height and corrugated board burst strength.

Table 11.11 Classification of dangerous goods packaging

Group	Danger level	Drop height (cm)
III	Low	80
II	Medium	120
I	High	180

As shown in Figure 11.43, the protection against puncture is provided by the quality of the liners (kraft and test liners), the basis weight of the corrugated board and the structure of the fluting (B or C flute).

11.3.2.4 Preservation of the hardness

Hardness, or softness, is a quantified value. To evaluate the hardness preservation and its relation to the performance of the box, the impact tests on the inclined plane have to be carried out as illustrated below (Fig. 11.44) on the four sides of boxes with a 5 cm × 5 cm transverse hazard. Hardness is evaluated by measuring the BCT before and after impacts – this evaluates the loss of performance resulting from the impacts.

As expected, cushioning properties and box and board performance correlate with board hardness. This can be seen in Figure 11.45 which shows that a significant and continuous drop in BCT is apparent as the board hardness is reduced.

In short, the BCT loss from transportation and handling impacts will not be severe if board of higher hardness is used.

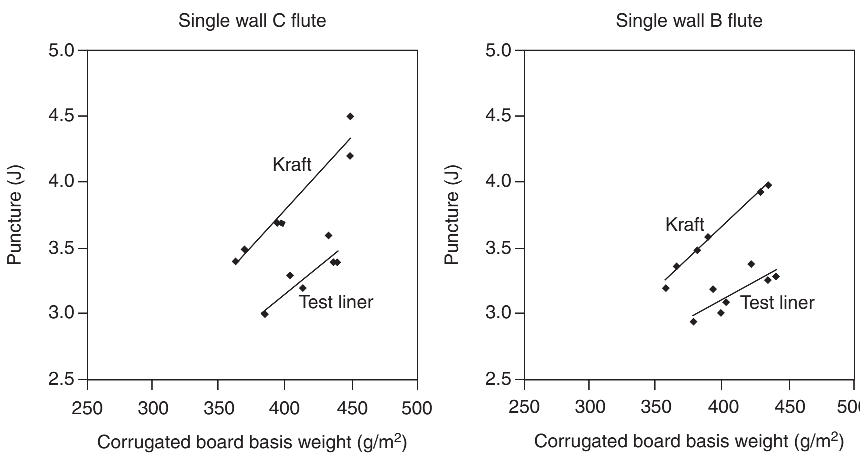

Figure 11.43 Puncture resistance in relation to liner (kraft or Test) and fluting (B and C).

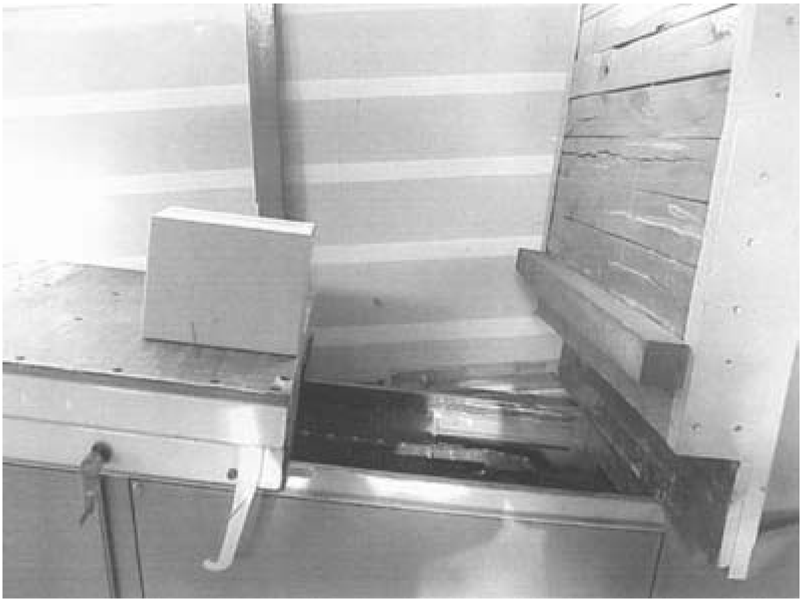

Figure 11.44 Inclined plane test.

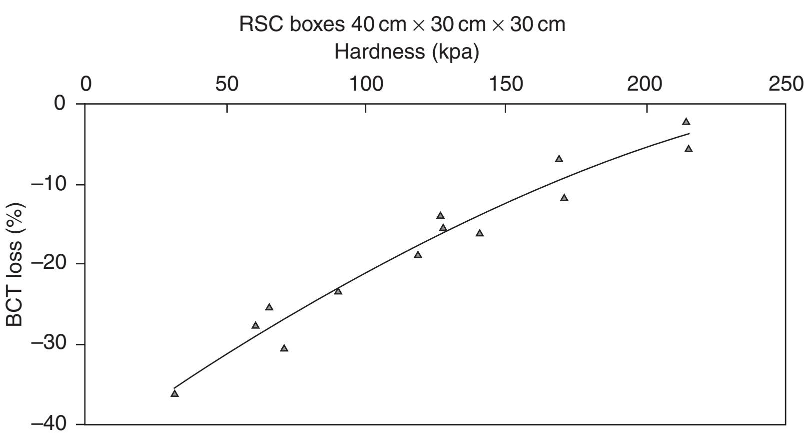

Figure 11.45 Box performance losses versus the hardness of the board (RSC boxes 40 cm × 30 cm × 30 cm).

On several occasions during manufacturing, corrugated board and boxes are prone to be damaged by flat compressive forces exerted by various machines. To understand and control such damage and to implement the experimentation described in the literature, we made similar measurements in one corrugated plant. During these trials, the board was crushed incrementally to create progressive damage and to evaluate the performance of board and boxes made from that board. The extent of damage is expressed as the percentage of initial thickness (calliper).

Decreased thickness (calliper) caused by crushing the board induced increased softness in the board, as can be seen in Figures 11.46 and 11.47. The variation

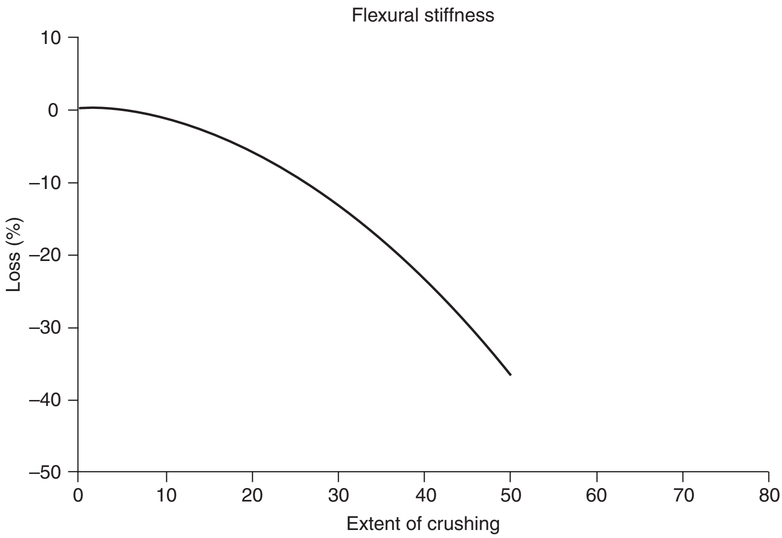

Figure 11.46 Effect of crushing on flexural stiffness.

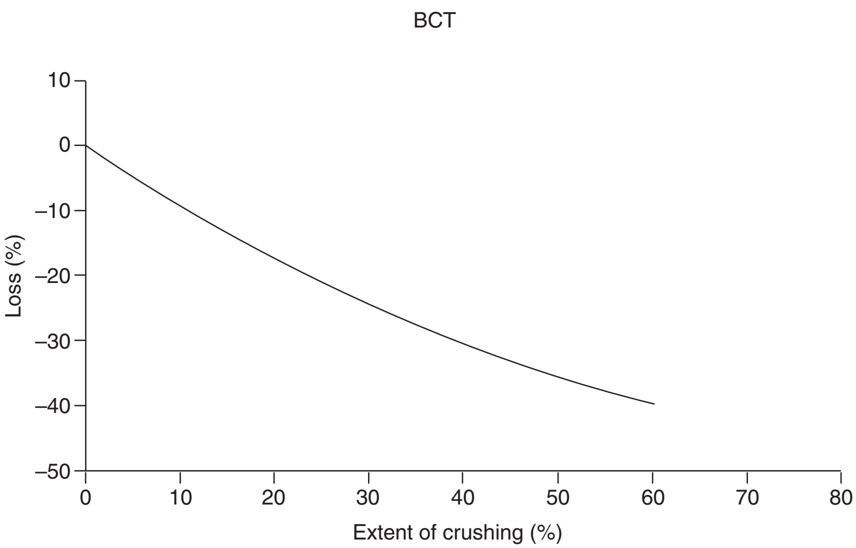

Figure 11.47 Effect of crushing on BCT.

and trends presented in these figures confirm previous findings as found in the bibliography.

11.3.3 Boxboard packing line considerations

Corrugated board boxes (RSCs and die-cut blanks) are packed manually, semi-automatically or fully automatically. The selection of loading method will depend on the product, the package, the line speed and the capacity needs. The packages can be either erected and then filled and closed, or formed around the product and closed.

In general, the filling line speed increases from 5–10 packages per minute to 30 packages per minute in a semi-automatic line and on an automatic line at around one pack per second. To ensure packing line efficiency, the corrugated board blanks and cases have to meet certain requirements:

- flatness and structural stability
- suitability for closure.

11.3.3.1 Flatness of corrugated fibreboard

Corrugated board sheets often exhibit curvature, also referred to as warp or curl which can cause great difficulty in subsequent converting operations and in box set-up in the customer's facility. Hence, flatness or the avoidance of warp is a major consideration in the corrugating industry.

Since warp varies inversely with board thickness, thin boards like F (1.2 mm), E (1.7 mm) and B (2.8 mm) flute are much more prone to warp than C (4.0 mm) flute boards. As production of these thinner flutes and corrugator speed have both increased dramatically, warp has become a much more important issue.

There are different forms of warp:

- normal warp or curl in both MD and CD
- twist warp.

Normal warp across or along the sheet is caused mostly by two factors. These are the differences in both moisture content and hygroexpansivity within or between liners. Figure 1.24 illustrates various types of curl and twist which can occur with paper and paperboard.

Hygroexpansivity, induced by the papermaking process, is often ignored in considerations of warp, but can differ by 50% or more between liners. Control requires adjusting moisture content to compensate for both differences since hygroexpansivity cannot be changed on the corrugator.

A well-tuned corrugator can provide adequate warp control for C flutes and some B flutes, but may fall short of what is needed for thinner flutes.

Curvature along the diagonal of corrugated sheets, usually called twist warp, can be avoided only by specifying liners with polar angles, as it cannot be controlled on the corrugator. (*Note*: The polar angle refers to the proportion of fibre oriented in the MD as compared with the CD.)

A method of measuring warp has been developed, which uses a specific software based on geometric theory to analyse the data.

To control the warp, it has been agreed that acceptable limits of warp for E flute quality are the following:

- MD warp and CD warp: between −2.5 and +2.5% (mm/mm)
- twist warp: between −2 and +2% (mm/mm).

The conventions used with corrugated fibreboard to describe warp are as follows:

- up-curl is away from the print and is positive (+)
- down-curl is towards the back of the board and is negative (−).

MD curl is where the axis of the curl is parallel to the MD of the corrugated board and CD curl is where the axis of the curl is parallel to the CD of the board.

The dimensional stability of corrugated fibreboard is a function of moisture content and the hygroexpansion of the paper components. (*Note*: The hygrosensitivity discussed here is based on a Smurfit developed test procedure.)

The hygroexpansion coefficient expressed in mm/m/%H_2O is a specific characteristic of the papers used (Poustis, Vidal, 1994).

Table 11.12 presents a scale of this criterion which has a close relation with the nature of the paper and its shrinkage.

Warp reduction at the end of the corrugator exit, or delivery, is one of the main preoccupations of the production staff. Warp can have a serious effect on the printing, converting and use of corrugated board. Many studies have been made to investigate the parameters in the manufacture of corrugated fibreboard which are responsible for warp phenomena.

Table 11.12 Hygroexpansion coefficients of different papers

Paper grade		Hygroexpansion coefficient	Maximum shrinkage
Nature	g/m^2	(mm/m/%H_2O)	(%)
Kraft liner	140	2.15	0.79
	200	1.53	0.58
Test liner	135	1.65	0.59
	190	1.40	0.42
	245	1.38	0.80
Fluting medium	112	1.75	0.59

11.3.3.2 Closure of corrugated cases

There are different closure possibilities:

- adhesive
- tape (paper, film or reinforced paper with various adhesive systems)
- strapping (plastic or metal)
- stitching (metal wire based).

Adhesives, which are the most common utilization, can be divided into:

- cold glues, for example PVA emulsion
- hot-melt formulations.

Cold glue application

The important characteristics of a synthetic cold glue, such as a water-based dispersion of polyvinyl acetate (PVA), are the solids content, open time and setting time.

The absorption characteristic of a particular glue on a specific paper surface is studied using a special apparatus. This consists of a precision syringe which can be set, using a micrometric screw, to deliver a drop of glue of a precise volume onto the substrate.

The apparatus is fitted with a vision system consisting of a camera which is able to record the contrast in appearance at fixed intervals of time between the surface of the drop and the background based on a grey level detection ability. Retro-lighting has been installed in order to make the surface of the drop appear in shadow. The position of the light beam must be precise, to avoid both under-exposure and overexposure.

The size of the drop applied can be set using the equipment, and the size chosen is a function of the viscosity of the liquid used. As an example, to characterize a paper in terms of gluing ability, soda is added to water so that it has a pH closer to that of the adhesive. The use of water results in lower absorption times, compared with trials using adhesive and simulates the ability of the adhesive to penetrate into the paper.

The drop border (Figure 11.48) is determined and the corresponding surface is automatically calculated by pixel sum. The user may choose to measure:

- contact angle
- critical surface tension
- change of both contact angle and section surface tension with time.

(All measurements are processed automatically using software.)

Figure 11.49 illustrates the behavioural difference of two different substrates. Drop surface has been calculated in percentage terms and does not take into account differences in initial volumes, which cannot be exactly equal.

At a defined time, for example 8.5 s, if the drop surface area on substrate A is 25% higher than that on substrate B, it means that the same liquid quantity will be absorbed by substrate A after a longer period. In this case, it corresponds to

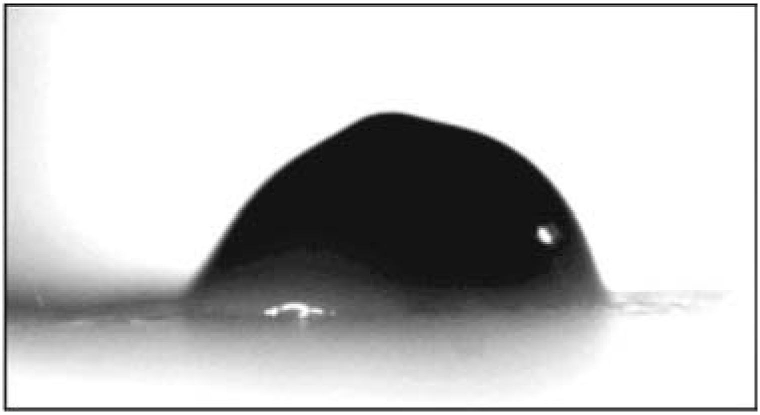

Figure 11.48 Glue drop shape.

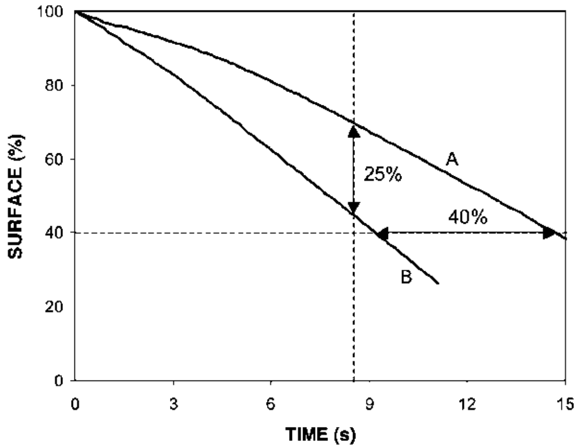

Figure 11.49 Drop surface variation characteristics (kinetics) for two papers (%).

broadly 40% of the time needed to reach a drop surface equal to 40% of its initial value.

To make and close the cases made from substrate A, the operators will certainly have to decrease machine speed and/or apply a higher glue level.

Hot-melt application

Corrugated board gluing is very often carried out using hot-melt glues. Heat is used and the adhesive is applied to the package by extrusion. As compared with vinyl adhesives where the paper absorbance of water is very important, the quality of corrugated board glued with hot melt depends on the paper surface porosity in order to achieve micro-penetration of the adhesive into the paper surface.

Consequently, the corrugated board storage temperature is a very important parameter. After application, the hot-melt joint becomes hard but can soften when the environmental temperature increases.

A reversibility phenomenon exists in relation to temperature. Without any strain, the adhesive joint which has softened will become hard again in few minutes, but with the board, side strains often involve a loss of adhesion. In order to avoid any softening of the adhesive, it is useful to know the softening-point temperature of the hot melt as this must be higher than the storage temperature.

Tapes, strapping and stitching
These technologies are decreasing in use. In all instances, it is important to ensure that the strength of the adhesive will meet the performance needs of the corrugated container. This can be done through both impact-drop and compression tests. In order to ensure the protection of the contents, it is important to know the hazards to which the container may be exposed.

11.3.4 Visual impact and appearance

11.3.4.1 Flexographic printing
Many surface characteristics have to be taken into account in order to achieve good quality flexographic printing (Aspler *et al.*, 1985; Pommier & Poustis, 1986b, 1987; Repya, 1987; Pommier *et al.*, 1989).

The first requirement is the uniformity in appearance of solid areas of print. This mainly depends on the surface finish of the face liner which is determined by porosity, roughness and wettability. The conditions of printing also need to be optimized.

The second requirement is print contrast between printed and unprinted areas. This is best achieved with a white liner having a uniform sheet formation and the ability to retain ink on the surface.

The third requirement is in respect of halftone reproduction. This requires good transfer of ink from the plate to the substrate. Halftones are printed dot by dot. Enlargement of the dot in printing is known as dot gain.

Finally, to achieve a high quality printing result, it is important to note that a good compromise between liner, ink, plate, and printing machine is required.

Some different characteristics which can be measured are:

- optical density of ink
- dot gain.

As far as printing and writing papers are concerned, the IGT printability tester can be used to reproduce flexography-printing conditions. The following illustration, Figure 11.50, explains the modification on the standard IGT apparatus.

The sector is used as an impression cylinder against which one or two printing wheels are applied. The top disc is an engraved roll cylinder with two types of screen: one for solids (80 lines/cm) and one for different halftones (140 lines/cm).

The load is applied between the sector and the cylinder, and can be adjusted very precisely.

The sample of paper is applied to the wheel indicated in Figure 11.50 and the photopolymer plate fixed on the sector, which in our case is 3.2 cm in width. Two different types of plate are used: one for solid and one for halftones.

The photopolymer plates are 5-cm width and present 48° shore A hardness. The engraved disc is inked by a water-based ink modified by the addition of a retarding drying agent.

The optimal conditions of pressure are shown in Table 11.13. A typical test picture is shown in Figure 11.51.

After printing, the samples obtained are inspected visually, for optical density and dot gain, as discussed below.

The values obtained for dot gain, contrast, etc. are checked for agreement with those obtained on samples printed on a flexo pilot printing machine. To evaluate the results of solid print, we measured the optical density with a densitometer. The optical density, OD, is measured in a way which takes the optical density of the base paper into account. The difference between the values gives an indication of the contrast.

$$\text{Contrast} = \text{OD solid print} - \text{OD liner}$$

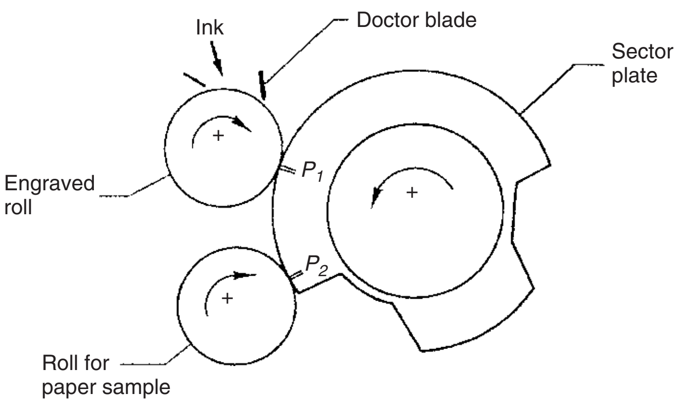

Figure 11.50 Apparatus of IGT (modified).

Table 11.13 Optimum conditions of pressure IGT

	Pressure (kg/cm)	
	Solids	Halftones
*P*1	4.7	1.6
*P*2	6.2	3.1

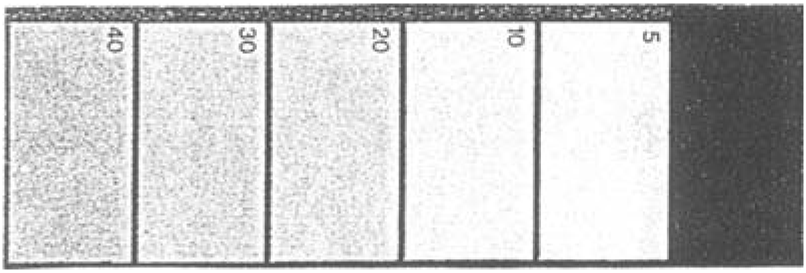

Figure 11.51 Sample printed on IGT modified.

The ink retention on the surface influences the measurement of optical density and it is linked with the quantity of ink applied, the paper, the ink quality and printing machine characteristics.

The weight of ink laid down on the substrate is not easily measured. To determine this parameter, we investigated a method based on titration of a given volume, by atomic absorption of a metal present in the ink. For this purpose, it is convenient to use blue ink because it contains some copper, which is clearly identified by atomic absorption. First, it is necessary to know the solid content of the ink and the proportion of copper in the solids. Then, on a sample of blue printed-paper, ashes are analysed, and knowing the solid content of the ink, it is easy to calculate the weight of ink applied.

In order to compare the halftones with theoretical values, dot gain, which is a consequence of imperfect transfer between plate and support or between ink and plate, is calculated. To do so, a special photopolymer plate manufactured with different ratios of coverage (from 5% screening to solid) is used. Then, using the printing conditions available, samples showing different halftones are obtained. From these samples, the experimental percentage of coverage is calculated with measurements of optical density (P') of each halftone area, using the following formula:

$$P' = \frac{1 - 10^{-\mathrm{DT}}}{1 - 10^{-\mathrm{DS}}}$$

where DT is the optical density of each halftone; and DS is the optical density of solid.

Then the relation between the experimental percentage (P') and the theoretical one (P_t) can be calculated. By plotting this relation on a graph, we can determine the distance (ΔA) between the ideal straight line and the experimental curve, which defines the dot gain for each percentage, as shown on Figure 11.52.

The lower the value, the better the sharpness of the halftones. Through this test, using the same printing conditions, different paper qualities, in terms of

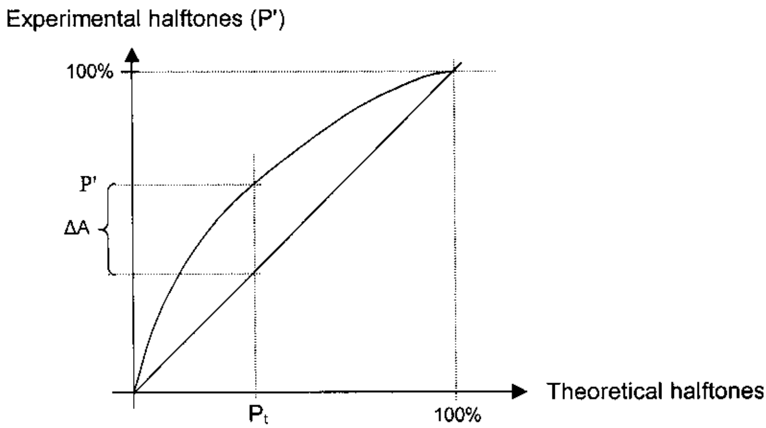

Figure 11.52 Relationship between theory and experience for the measure of the dot.

printability, will give different results. Taking into account the percentage of dot gain, which is a good criterion for printability, we can introduce a new formula

$$R = \frac{100 \times \Sigma_{\mathrm{i}} P_{t_1} \times \Delta A_i}{\Sigma_{\mathrm{i}} P_{t_1}}$$

In the ideal case, ΔA_i is zero because there is no dot gain and consequently, $R = 100\%$. In all cases, in spite of good printing conditions, dot gain is observed.

In Figure 11.53, it is interesting to note that among the different liners white top (bleached kraft) gives the best results.

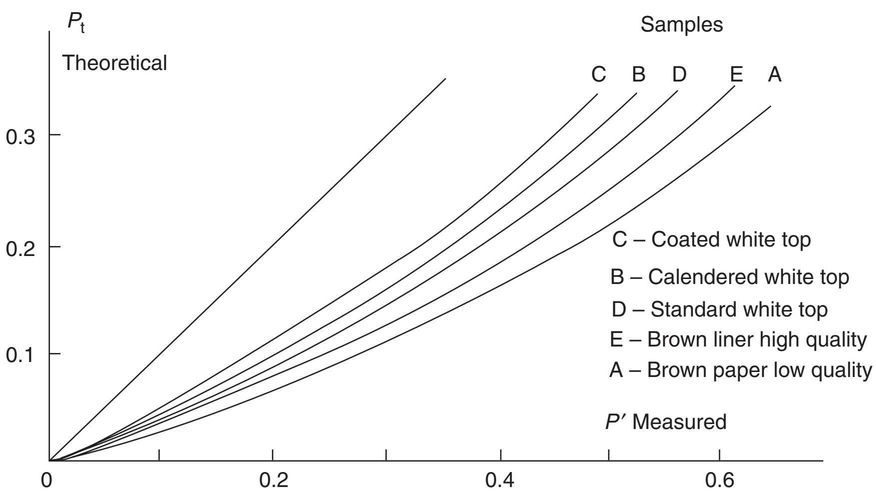

Figure 11.53 Curves of dot gain for different grades of papers.

The surface properties are very important with respect to halftone reproduction. The surface of the white-top liner is specially designed to achieve better printability.

Colour measurement
In order to measure the colour of the print, the CIE reference system as described in Section 1.5.2.1, and shown diagrammatically in Figure 1.18, is used.

Limits in flexo printing
Flexography printing is the most important printing method in the corrugated board industry today, and there are a number of critical stages in the flexography process which need to be considered in relation to printing:

- specifications of the paper substrates (surface, thickness, calliper, etc.)
- inks or varnishes (colour, viscosity, etc.)
- equipment (printing plates, anilox rolls and doctor blades).

And the following are also very important:

- mechanical accuracy of the print machine
- working methods
- operators' skill.

Substrates
Brown papers (kraft or recycled) and white tops (coated or not coated) have been used for printing corrugated packaging for many years.

The main specifications which determine the print quality of these substrates are shown in Table 11.14.

The typical procedure for colour matching is as follows:

- The colour asked by the customer is analysed by the ink supplier, using a spectrophotometer, and the various components (formula) of the base colours stocked by the converter is calculated.
- The ink-blending kitchen at the converting plant prepares the colour using the formula.
- A pre-print on the substrate is made and compared with the original colour (L, a, b and optical density measurements).

Table 11.14 Basic paper specification for flexography

Substrate specification	Importance for printing
Surface strength	X
Smoothness	XXX
Liquid absorption capacity	XX
Liquid absorption speed	XX
Moisture	XX
Surface aspect	XXX
Surface energy	XX
Surface chemistry	XX
Water resistance	XX

XXX = most important.

- If needed, an adjustment of the formula is carried out.
- When the colour on the substrate matches the customer's original, the order is ready for printing.

The important parameters for achieving the required result depend on four different levels:

- method of identifying and matching the colour required
- substrate properties (paper)
- printing machine (every printing press has its own characteristics)
- operators (skill).

Ink–paper interactions
There are two different stages during the printing process that must be considered to understand how ink and paper react together:

- application of the ink to the substrate by the printing plate
- penetration and drying of the ink before the first contact with another sheet or with a part of the machine.

The printing plate applies and presses the ink into the substrate. The ink picked up from the anilox roll is applied to the substrate:

- ink fills the voids at the surface of the substrate
- pressure pushes the ink into the first pores.

The sheet exits the printing unit. Just after the printing plate has deposited ink on the substrate (time $t = 0$), the ink continues to move:

- ink starts to penetrate more deeply and tends to become dry
- ink additives help to retain the pigment at the surface while others remain at the surface to provide gloss, rub resistance, etc.
- water starts to migrate into the paper and to evaporate into the air.

Just before the first contact with a fixed part of the machine, or with another sheet (time = 0.5–1 s), the ink must be dry enough to resist marking and smudging. At that time:

- additives and pigment are re-arranged in the ink film
- quantity of water that remains in the ink is the key parameter for a good rub resistance.

More globally, to evaluate the ink penetration into the substrate and ink drying, we have to analyse:

- the substrate surface characteristics: topography, roughness, porosity
- the substrate surface properties: surface tension, absorptiveness, gloss (Fig. 11.54)
- substrate surface behaviour: smudge, mottling, use IGT modified (Fig. 11.55).

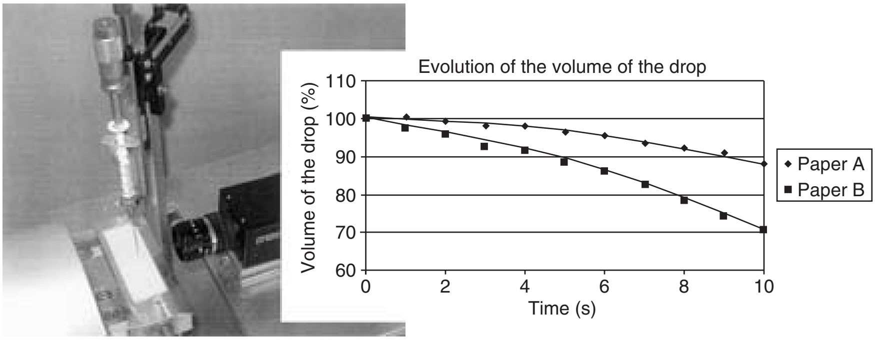

Figure 11.54 Drop test analysed by dynamic camera and analytical results.

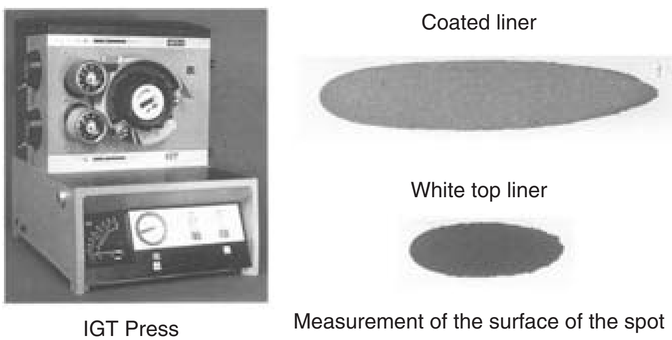

Figure 11.55 IGT modified and print rendering.

Problems may be encountered when printing jobs have to be done on coated papers. Concerning coated papers, we have to mention that the coating:

- smoothes the surface
- produces a gloss effect
- helps to retain pigments and additives on the surface.

But at the same time:

- closes the surface
- decreases the migration potentiality.

Consequently particular adjustments are requested (ink, machine) to make the best use of coated liners and to avoid printing problems.

It is recommended that the paper characteristics are investigated. (This assumes that the plant has investigated the other three key parameters, namely those of the ink, machine and the operators.)

Wash-boarding

Using low grammage papers in the outer liner creates in some cases, but not consistently, a wash-boarding phenomena, as indicated in Figure 11.56.

In post-print, i.e. printing on corrugated board, it is difficult sometimes to obtain good results, especially when it is required to print an illustration in solids and halftone or a bar code.

It is much easier to achieve a high-quality print result by pre-printing white top liners, i.e. by printing reel to reel prior to production of corrugated board.

All printing parameters (consistency, ink consumption for a chosen optical density, etc.), in general, are easily achieved with pre-print technology.

Pre-print versus post-print

A comparison between 39 cm × 35 cm × 22 cm RSC boxes was made with pre-print white top liner and post-print boxes using the same grades of paper liner.

The results obtained are shown in Table 11.15.

In this analysis, no significant difference was observed in BCT performance between pre- and post-print. The customer, however, elected to use the pre-print boxes due to the better print quality.

Corrugated board manufacturing and converting processes are being continuously improved by, for example, the installation of infrared drying equipment to improve the print quality of post-print corrugated board and thereby largely reduce the difference between pre-print and post-print quality.

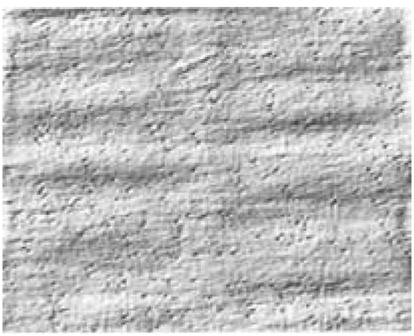

Figure 11.56 Wash-boarding effect of print on corrugated board surface with low grammage white top double face.

Table 11.15 Pre-print compared with post-print

	Pre-print	No print	Post-print
BCT in newtons	2470	2450	2320
Deviation in %	4	4	6
Difference in %		0	6

For the other thin boards (mini-fluted such as E, F, G and N), it will be interesting to evaluate the difference between pre- and post-print.

11.3.5 Packaging for food contact

Foodstuff safety and quality are of paramount importance to consumers, manufacturers and regulators. Both can be influenced by the fitness for the purpose of the packaging and its performance throughout the logistics chain.

Thirty-two percentage of the total European production of corrugated board is used for food packaging, including transport packaging. If beverage packaging is included, this rises to 40%.

A significant proportion of this production is used for direct contact with food but most of the applications are for trays for fruits and vegetables. The volume used for this purpose varies widely across western Europe, but in some areas it may be as high as 20% of total production.

The proportion of corrugated packaging used for other direct food contact applications are much smaller and estimated as follows:

- 1%, approximately, for fatty/aqueous foodstuffs (pizza, burgers, French-fries as fast food, fresh meat, poultry and fish)
- 1%, approximately, for dry/frozen foodstuffs (bread, frozen meat, poultry and fish).

Though a significant proportion of the total tonnage is not covered by the legislation on direct food contact, some of this proportion may still be used in applications where food safety is critical.

European Framework Directive 89/109/EEC – on the harmonization of laws of the member states relating to materials and articles intended to come into contact with foodstuffs – is the Framework Directive and has been transposed into the legislation of each member state of the European Union.

The future Resolution for Paper & Board from the Council of Europe for paper and board for food contact comprises a main section dealing with the general principles and some specifications applying to both virgin and recovered paper. There are three technical documents:

- The Good Manufacturing Practice (GMP) – in order to produce paper for food contact we must apply the GMP. This means implementing good hygiene practices throughout the production process.
- Inventory List – only materials which are on this list may be used in paper and board manufacturing (chemicals, additives, etc.).
- Guidelines on Recycled Fibre Usage will restrict the use of recovered paper in the manufacture of paper for direct contact with fatty/aqueous foodstuffs. This application will require the use of papers not normally used for corrugated packaging.

For the packaging of fruits and vegetables in corrugated packaging, we can use all grades of waste paper for manufacturing paper. However, this packaging does have to meet the required specification on the content of pentachlorophenol (PCP). The PCP level has to be below 150 ppb.

For other dry and non-fatty product contact we can use all grades of waste paper, but we have to comply with the stated maximum levels of PCP, phthalate, polycyclic aromatic hydrocarbons (PAH) and benzophenone.

Until 2004, for direct food contact applications, such as pizza boxes, the recycled papers currently in use in any of the layers of corrugated board are not authorized. This means that for a product such as pizza and similar products which are to be packed in direct contact with corrugated fibreboard, only paper combinations made from virgin fibres may be used (see EU Directives).

This is an evolving situation which should be checked by readers. At the time of publication some 160 000 tons of corrugated fibreboard is currently estimated to be in use in Europe for such applications. In Europe, test conditions and methods of analysis for the specified contaminants and a practical guide are expected to be published at EU Commission level.

11.4 Good manufacturing practice

The International Good Manufacturing Practice Standard for Corrugated and Solid Board was published in October 2003 by the European Federation of Corrugated Board Manufacturers (FEFCO) and the European Solid Board Organisation (ESBO). This is concerned with the manufacturing of corrugated and solid board in a controlled environment as far as quality, hygiene and traceability are concerned. For details see Fefco website.

11.5 Corrugated fibreboard and recyclability

Wood and paper products are part of an integrated eco-cycle based on photosynthesis which involves the conversion of water, carbon dioxide, nutrients and solar energy into renewable woody biomass.

Once consumed and collected separately, wood, discarded packaging and other paper products can be recovered to start a new life as a secondary raw material or bio-fuel.

Concerning resources, virgin and recycled fibre products are complementary. They cannot exist separately. The optimum level of recycling depends on a number of economic, social and environmental aspects, such as the geographical location, the collection potential, the technical limitations to recycling, etc.

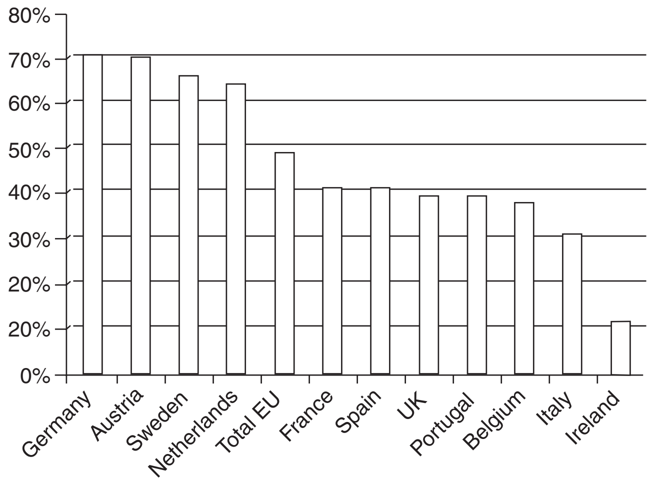

Figure 11.57 Waste management in the Western Europe: paper recovery level. *Source*: Based on the CEPI (European Confederation of Paper Industries) data for 2002.

In addition, the long-term use of wood-based products represents an expanding reservoir of carbon removed from the atmosphere. On an average one tonne of paper contains some 1.33 tonnes of carbon equivalent CO_2.

Recycling is an economic and technical reality for the wood and paper industry which has, as a consequence, become one of the highest industrial recyclers. In the paper industry, recycling rates – measured by the use of recovered fibres as a percentage of domestic consumption – are high, ranging from 35 to 55% in the regions covered.

For packaging papers (corrugated and cartons), the level of recovery can reach 70%, but it is different in each European country, as shown in Figure 11.57.

To improve the environmental performance of packaging products, the European Directive 94/62 allows manufacturers and users to reduce the weight of the packaging but not the weight of the individual papers. However, the vision that for corrugated fibreboard, the two are tied together, i.e. weight of papers = weight of case, is not completely correct. This is because the possibility exists for changing the construction, i.e. replacing BE flute with C flute or applying an alternative professional solution.

Lightweighting is encouraged as it leads to a reduction in the use of resources but with respect to the strength of paper, one has to take into account the fact that repeated recycling leads to lower strength, as indicated in Figure 11.58.

The paper industry fulfills the maximum targets of recovered and recycled rates required in the current EU targets. There are also restrictions in the allowable heavy metal content which has to be below 100 ppm.

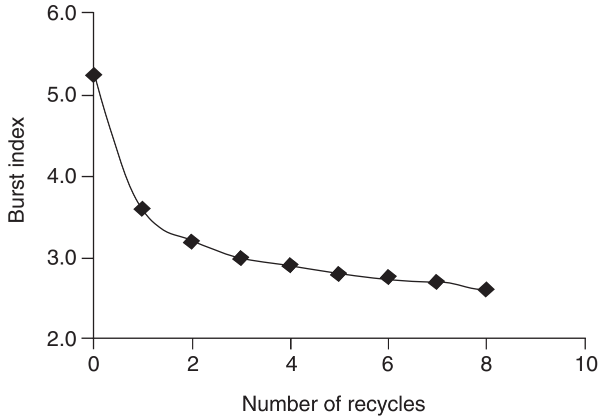

Figure 11.58 Impact of recycling on paper quality (burst index versus number of cycles).

In summary, it must be emphasized that paper packaging, such as corrugated fibreboard:

- is based on a naturally renewable resource
- is easily recycled
- material which is not suitable for recycling is energy recoverable.

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Paper and Paperboard Packaging Technology
Edited by Mark J. Kirwan

12 Solid fibreboard packaging

Mark J. Kirwan

12.1 Overview

Solid fibreboard is primarily used for distribution packaging. It is a rigid, puncture-resistant and water-resistant material, which varies in thickness from 0.8 to 4.0 or 4.5 mm and in grammage from around 550 to around 3000 g/m^2.

Solid board is either made on a multi-ply paperboard machine forming with vats, Fourdrinier wires, or is made by a combination of forming methods. It is also made by multi-ply lamination. The higher thicknesses are always made by laminating two or more layers of paper or paperboard together to provide the strength necessary for the intended use. Additional materials, including polyethylene (PE), may be incorporated to meet specific performance needs. The board is cut into sheets, printed and converted into boxes, trays and other paperboard structures.

Solid fibreboard is used in a wide range of packaging and display applications, such as:

- packaging of meat, poultry, fish and horticultural produce in boxes and trays
- promotional displays in self-service merchandising
- games and games packaging
- slip sheets in bulk distribution and storage
- cell divisions for glass and plastic bottles in corrugated cases
- packaging of engineering products
- export packaging.

In Europe, the largest market for solid board packaging is for poultry, which together with meat account for around 60% of the usage. Table 12.1 indicates the percentage of overall European market usage. However, the actual percentages of the usage of solid board in specific countries for each market will reflect the

Table 12.1 Percentages for typical European market usage of solid board production

Markets	%
Horticulture	15
Meat	25
Poultry	35
Fish	10
Others	15

Source: Kappa Packaging.

relative importance of the various markets in each country. Hence the proportion used, for example, in horticulture may be significantly higher than 15% in some countries and lower in others.

Standard quality solid fibreboard is more resistant to water and damp conditions than standard corrugated fibreboard. The water resistance of solid fibreboard can be significantly improved during manufacture to meet the needs of differing wet environments. Performance needs can be met for packing and storage in frozen, chilled, ice-packed, wet or humid conditions. Higher levels of moisture resistance are achieved by internal treatment (sizing) of the board during board manufacture and by the use of kraft facing, or liner, extrusion coated with PE on one or both sides.

Inevitably, solid fibreboard packaging is compared with corrugated fibreboard packaging. At equal *grammage*, a case made from corrugated fibreboard will have a higher box compression strength as a result of its higher thickness.

At equal *box compression strength*, the solid fibreboard box will be heavier and as the weight of the material has a major influence on the cost, the corrugated fibreboard container is preferred.

The solid fibreboard container will, however, be specified where its strength, toughness, puncture and water resistance are essential for a satisfactory packaging performance in specific conditions of use, which can include rough manual handling in cold and wet environments.

Though both solid and corrugated fibreboard containers are normally thought of as one-trip packages, where it is feasible to specify multi-trip usage then solid fibreboard is a better choice. This is because, it is less easily crushed than corrugated and where it is damaged, it is easier to repair with self-adhesive tape.

Solid fibreboard packaging is manufactured primarily from recycled material. It is both recyclable and biodegradable at the end of its useful life. It can be either collected from households and businesses, or from ‘bring’ systems, to be returned to a mill which uses recovered paper and paperboard to be recycled in the manufacture of solid fibreboards.

12.2 Pack design

A wide range of packaging designs has been published in the International Fibreboard Case Code (www.fefco/ESBO.org). The European Solid Board Organisation (ESBO) has collaborated with the European Federation of Corrugated Board Manufacturers (FEFCO) in the preparation of the Code. It is a structured presentation of existing box designs with a code number assigned to each design. The Code is used worldwide and has been adopted by the United Nations. It has also been adopted by the International Corrugated Case Association (ICCA).

In addition to the designs in the Code, individual solid fibreboard packaging manufacturers can extend the design range with customised packaging solutions to meet specific market needs.

Solid fibreboard packaging is supplied flat to save space in storage and distribution. It can be erected by the packer manually or with mechanical assistance. Where product volume is high, and a high packing speed is required, fully automatic machinery is used for erecting, packing and closing. The solution in any given application depends on the volume of usage and the packaging environment.

Typical packaging designs are as follows:

- separate base and full depth lid both based on a 4-point glued blank (Fig. 12.1)
- integral full depth hinged lid and tray based on a 6-point glued blank (Fig. 12.2)
- double end wall self-locking tray (Fig. 12.3)
- tray with ledge at each end with stacking and holding features, based on 8-point glued blank (Fig. 12.4)
- stackable tray with clipped-in plastic corner supports (Fig. 12.5).

12.3 Applications

12.3.1 Horticultural produce

Fruit, vegetables and flowers are packed by the grower, or in co-operatives, for supply to the markets on a daily basis. Natural produce is best packed in

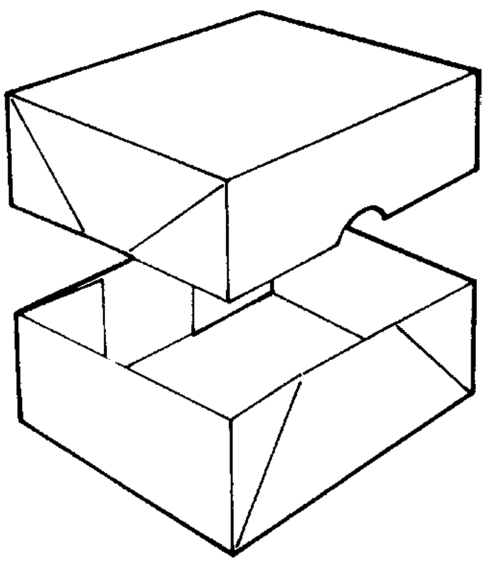

Figure 12.1 Separate base and full depth lid, both based on a 4-point glued blank. (Reproduced, with permission, from Alexir Packaging Ltd.)

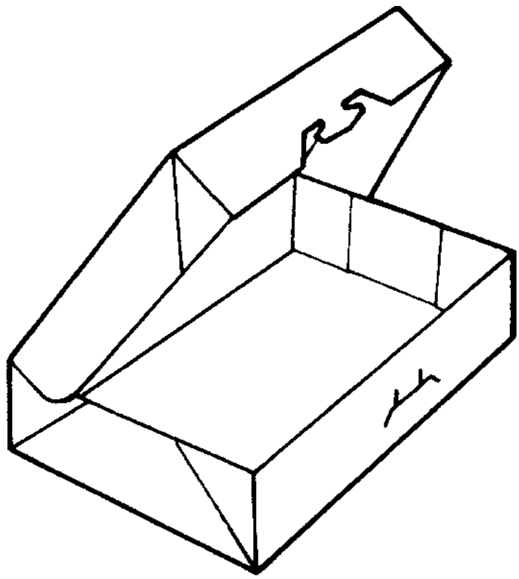

Figure 12.2 Integral full depth hinged lid and tray based on a 6-point glued blank. (Reproduced, with permission, from Alexir Packaging Ltd.)

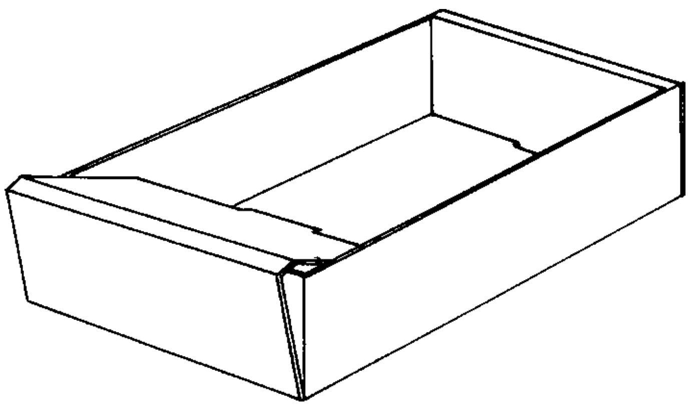

Figure 12.3 Double end wall self-locking tray. (Reproduced, with permission, from John Wiley & Sons, Inc.)

water-resistant solid fibreboard to keep the product fresh during storage and transportation.

Flowers are frequently packed in lidded trays, i.e. cartons comprising a base and a lid. Fruit and vegetables are packed in machine-erected trays that include stackable features, which enable packs to be stacked 10 high on a pallet. Some products may be packed wet.

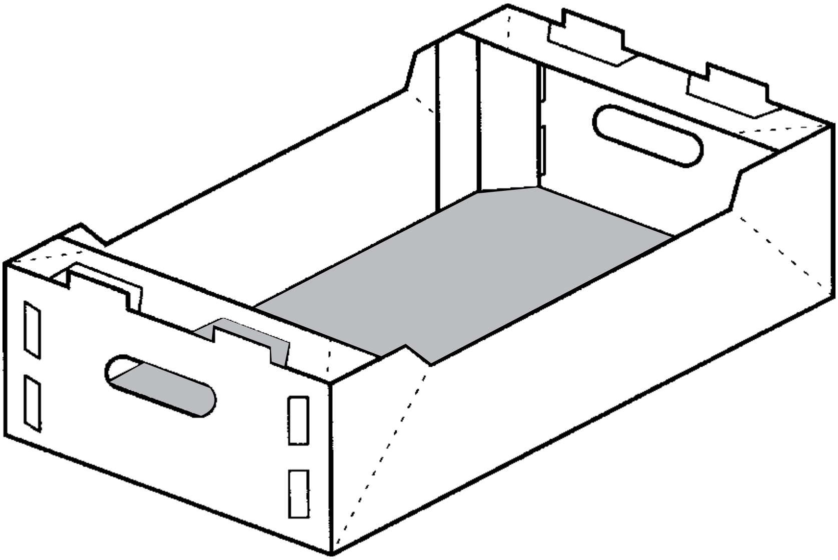

Figure 12.4 Tray with ledge at each end with stacking and holding features, based on 8-point glued blank. (Reproduced, with permission, from Papermarc Merton Packaging.)

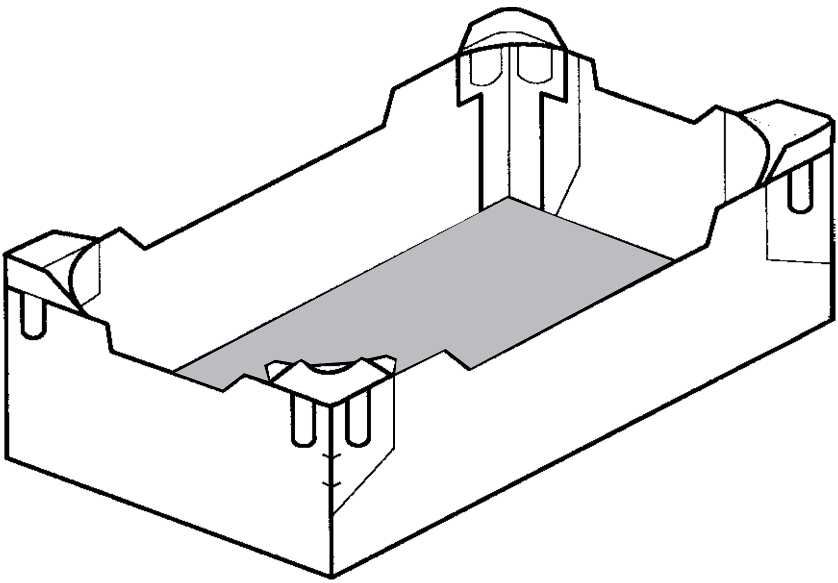

Figure 12.5 Stackable tray with clipped-in plastic corner supports. (Reproduced, with permission, from Papermarc Merton Packaging.)

12.3.2 Meat and poultry

These products are packed in trays with full-depth lids. Where PE lined solid board is used, it must not be corona discharge treated as this would cause wet products to stick to the PE. Such designs can be glued using hot-melt adhesives. These packs can be used for a product weight range of 3–6 kg.

12.3.3 Fish

Fish may be packed wet, chilled or iced. The trays need to be in a leak-proof style, in which the corner design is described as ‘webbed’. Two-side PE-coated solid board with additional hard sizing provides the maximum protection for this type of packaging.

12.3.4 Beer (glass bottles and cans)

The wrap-around litho-printed multipack is the standard specification for this application.

12.3.5 Dairy products

Compartmentalised machine-erected trays are typically used for multipacks of plastic yoghurt pots. The solid board design is preferred as the corrugated fibreboard equivalent has a larger area on account of the thickness of the sides. This difference can be critical in supermarket shelf display.

12.3.6 Footwear

Solid board is used in shoe box packaging, alongside folding cartons and corrugated-fibreboard packaging.

12.3.7 Laundry

In some European markets, large solid board cartons are used for detergent and soap powders.

12.3.8 Engineering

Products which are heavy, liable to be shifted in transportation, require moisture protection, and possibly, with protruding parts need the protection of a puncture-resistant solid board. These boxes can provide rustproof packaging to the Ministry of Defence (UK) Standard.

12.3.9 Export packaging

Solid fibreboard packaging is robust and both puncture and moisture resistant. Where boxes are to be shipped in containers, the box dimensions are designed to ensure optimum use of the available volume.

12.3.10 Luxury packaging

Litho-printed solid board is used for luxury packaging of products, such as chocolates, cosmetics and whisky. (Solid board as a material in sheet form is also used by rigid-box manufacturers, see Chapter 9.)

12.3.11 Slip sheets

Slip sheets can be used in place of wood or plastic pallet bases. The items are assembled on a sheet of solid board, known as a slip sheet, shown in Figure 12.6. In order for a fork-lift truck to move such a unit load, it has to operate with a system, known as a Quick Fork Mount (QFM) which grips a protruding edge of the slip

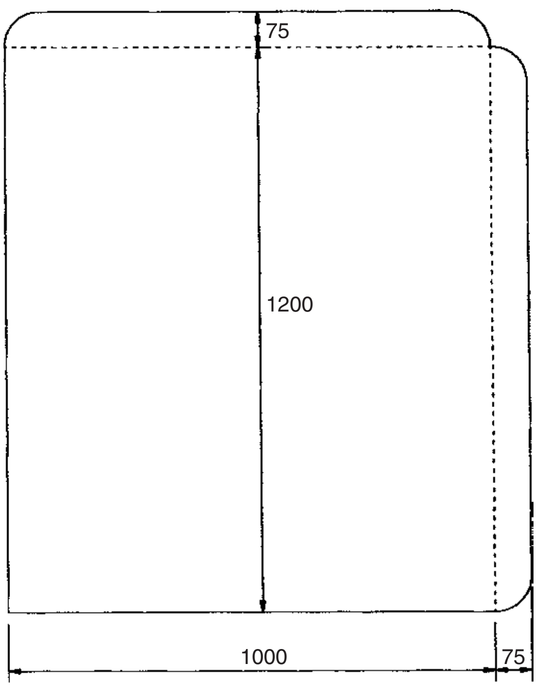

Figure 12.6 Slip sheet. (Reproduced, with permission, from Kappa Packaging.)

sheet so that it can pull, and subsequently push, both the sheet and the stacked load onto a platform attached to the truck (FOPT, 1996).

For a unit load size of 1000 mm × 1200 mm, the protruding edge needs to be between 75 and 100 mm wide. This flap is pre-creased so that it can be easily folded against the side of an adjacent load. Depending on customer requirements, protruding edges can be specified on one side, two sides opposite, two sides adjacent, three sides or four sides.

Slip sheets can be made from three plies of kraft with a combined grammage of 960 g/m^2. They are also made using 100% recovered fibre at a grammage of 1200 g/m^2, and with kraft outer liners and recovered-fibre middle plies. The use of kraft provides a stronger sheet and one that is possible to re-use.

Polyethylene-lined board and hard-sized board can be specified for use in wet/damp conditions. The presence of PE improves load stability by increasing the coefficient of friction of the surface of the slip sheet.

An anti-skid varnish can be applied to the slip sheet to assist load stability, but this is only effective where a similar varnish is applied to the cartons forming the unit load.

Similarly, thinner sheets, without flaps, are used as layer sheets, to assist the sweeping of cans, plastic and glass containers at the container in-feed on packing lines. It is superior to corrugated board for this purpose as it does not indent with the shape of the upturned container. Solid board sheets are also used as pallet top boards.

12.3.12 Partitions (divisions and fitments)

These are interlocking pieces, divisions or partitions of solid fibreboard, which are used to create cells in a case or a box wherein individual items of packaging and packaged products can be placed. The solid board is cut and the fitments or divisions are interlocked and folded flat for storage and shipment.

Divisions used in this way protect the products by restraining them from movement rather than by cushioning. Typical examples, including sheets which fit over bottles to restrain movement, are shown in Figure 12.7. Restraining in this way is particularly important for glass packaging, for example glass containers and bottles of wines, spirits, liqueurs, beer, etc. Divisions also protect labels on glass and plastic bottles from damage due to scuffing during transportation.

Divisions are also used in the packaging of pharmaceuticals, cosmetics, ceramics, confectionery, fresh produce and electronic and engineering components. Divisions can be erected and inserted by hand as shown in Figure 12.8. They can also be erected and inserted on high-speed packing lines in a sequence shown in Figure 12.9.

Whilst corrugated fibreboard partitions and dividers can also be used, they are less preferred as they are thicker and require larger dimensions in transit cases. Another important advantage of solid fibreboard dividers is that they can be cleanly cut and are, therefore, free from excessive edge dust or fibreboard slivers and trimmings.

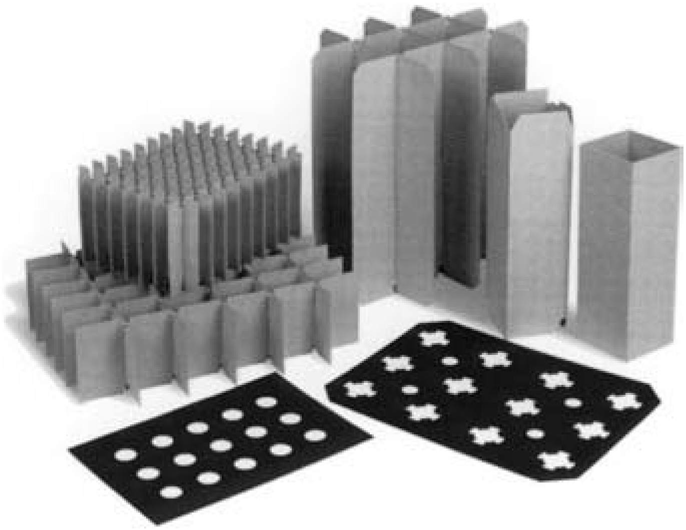

Figure 12.7 Typical solid fibreboard fitments and divisions. (Reproduced, with permission, from Kappa Lokfast.)

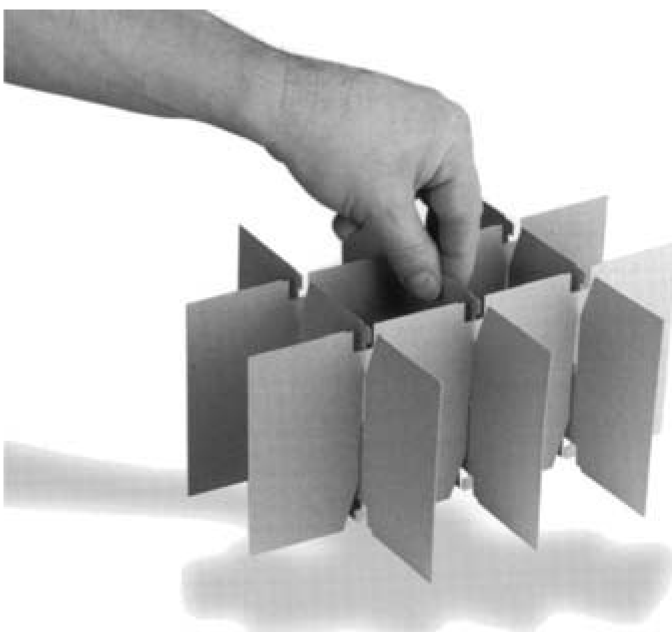

Figure 12.8 Divisions being inserted by hand. (Reproduced, with permission, from Kappa Lokfast.)

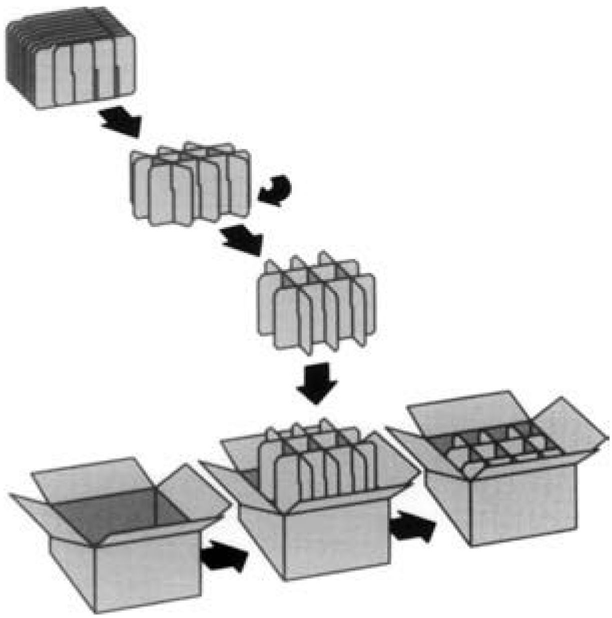

Figure 12.9 Sequences in high-speed packing for the glass and other industries. (Reproduced, with permission, from Kappa Lokfast.)

12.3.13 Recycling boxes

Waterproofed boxes, with lids, can be used for the collection of waste paper and paperboard. They are used by some local authorities in UK instead of plastic boxes. The boxes can be attractively printed to encourage their use and display the collection calendar dates. They can be used in a variety of situations, for example kerbside collection schemes and in offices, homes and at supermarkets. The boxes themselves are recyclable.

12.4 Materials

As already noted, solid board can be made on multi-ply paperboard machines. The higher thicknesses are made by lamination on a paster. This is a machine which takes reels of board, usually up to six reels in line, glue laminates them and cuts them into sheets at the end of the paster machine.

The middle layers are made from recycled paper fibre and are grey in colour. The moisture resistance is increased by hard sizing. Starch is used to increase strength.

In addition to the use of hard-sized middles, one or both outer surfaces can be laminated with PE-coated kraft to achieve the best water and water-vapour resistance. The typical weight of PE applied in this way is 15 g/m^2. White lined, folding boxboards and solid bleached (white) board can also be used as required.

12.5 Water and water vapour resistance

Figure 12.10 shows the superior wet resistance of water-resistant solid board compared with standard solid board and corrugated fibreboard measured over a 24-hour period.

Other key data, supplied by Papermarc Merton Packaging, which demonstrates that water resistant solid board is significantly better than alternative materials is shown in Table 12.2.

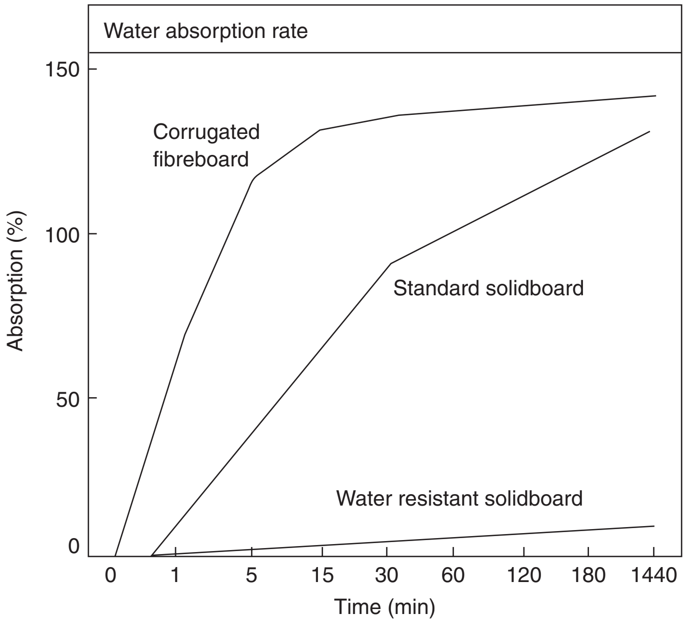

Figure 12.10 Graph showing comparison for water absorption over 24 h for water resistant solid board compared with standard solid board and corrugated fibreboard. (Reproduced, with permission, from Papermarc Merton Packaging.)

Table 12.2 Comparison of various solid boards

	Corrugated	Standard solid board	Water-resistant solid board
Effect of relative humidity on rigidity at 90% RH	60% loss of strength	40% loss of strength	20% loss of strength
Effect of water immersion on strength	80% loss after 5 min	80% loss after 60 min	10% loss after 60 min
Effect of water immersion on puncture strength*	Reduced from 6 to 2.5 J	Reduced from 6 to 5 J	—

* The boards with a puncture resistance of 6 J are immersed in water for 15 min.

As already noted, the water resistance of standard solid board is increased by hard sizing the middle plies and by PE coatings on one or both outer surfaces.

12.6 Printing and conversion

12.6.1 Printing

Depending on the quality required, printing is carried out on sheets by either letterpress, offset litho or flexo.

12.6.2 Cutting and creasing

Three methods are available:

- rotary bending machine bends and slots simple designs, such as 4-flap cases and slotted bases and lids
- flatbed cutting and creasing forms using a make-ready
- rotary cutting and creasing forms have the advantage of incremental cutting and creasing, and hence does not need the high pressures used with an auto platen.

12.7 Packaging operation

Solid fibreboard packaging can be supplied either for easy make-up by hand or by machine.

12.8 Waste management

As noted, solid fibreboard cases are usually one-trip containers after which they can be recovered and the fibre recycled. Where special conditions apply, such as box cleanliness and appropriate return transport, solid fibreboard cases can be folded flat after use and returned to the packer for re-use.

12.9 Good manufacturing practice

The International Good Manufacturing Practice Standard for Corrugated and Solid Board was published in October 2003 by the European Federation of Corrugated Board Manufacturers (FEFCO) and the European Solid Board Organisation (ESBO). This is concerned with the manufacturing of corrugated and solid board in a controlled environment as far as quality, hygiene and traceability are concerned. For details, visit Fefco website.

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www.fefco/ESBO.org (site includes International Case Code).
www.kappapackaging.com.
www.papermarcmerton.com.

Paper and Paperboard Packaging Technology
Edited by Mark J. Kirwan

13 Paperboard-based liquid packaging

Mark J. Kirwan

13.1 Introduction

The story of paperboard-based liquid packaging over the last century is a classic business case study. It contains all the elements from the concept to a successful worldwide business based on vision, motivation and entrepreneurial drive, utilising skills in science, technology and commerce.

Technically, the concept perceived around 1900 sought a leak-proof paper-based container to match the glass and metal containers in common use and to replace the traditional distribution of milk, whereby it was ladled out into the consumers' own ceramic containers from churns in the street. In this instance, according to Gordon Robertson's account of the early development of paperboard-based beverage cartons (Robertson, 2002, pp. 46–52) there appears to be no dispute about where the credit lies for the first successful solution. Though earlier attempts to solve the problem have been recorded, it was in 1915 that a US patent was granted to John Van Wormer of Toledo, Ohio, for what was described as a 'paper bottle' and which he called Pure-Pak®. It was a folded carton blank, which would be supplied flat to dairies for the packaging of milk. The concept offered several important advantages which still apply today – those of savings in delivery, storage and weight compared with glass bottles.

Glass packaging for milk was well established by this time with equipment for washing, filling and capping. There were systems for the distribution and recovery of the bottles. The machinery for forming, filling and sealing the paper bottle still had to be invented.

The carton blank had to be made into a container with the help of adhesives. It was then made leak-proof by dipping it in molten paraffin wax. The container was then filled and the top closed by heat, pressure and stapling, as described in the articles in *Modern Packaging* and *Popular Science Monthly* from the early 1930s. Clearly, considerable engineering development work was necessary to accomplish the forming, filling and sealing and to do this at reasonable speeds added to the complexity of what was required. Ex-Cell-O Corporation emerged as the owner of Pure-Pak® and the successful machinery producer. Milk was packed in Pure-Pak® cartons at 24 quart, i.e. 2-pint, cartons per minute in bulk from 1936.

Pure-Pak® was used in Europe after World War II. Initially, the cartons were imported from the USA for filling. Elopak (European Licensee of Pure-Pak®) was formed in 1957. In 1987, Elopak bought the Ex-Cell-O Packaging Systems Division and the Pure-Pak® Licence (Fig. 13.1).

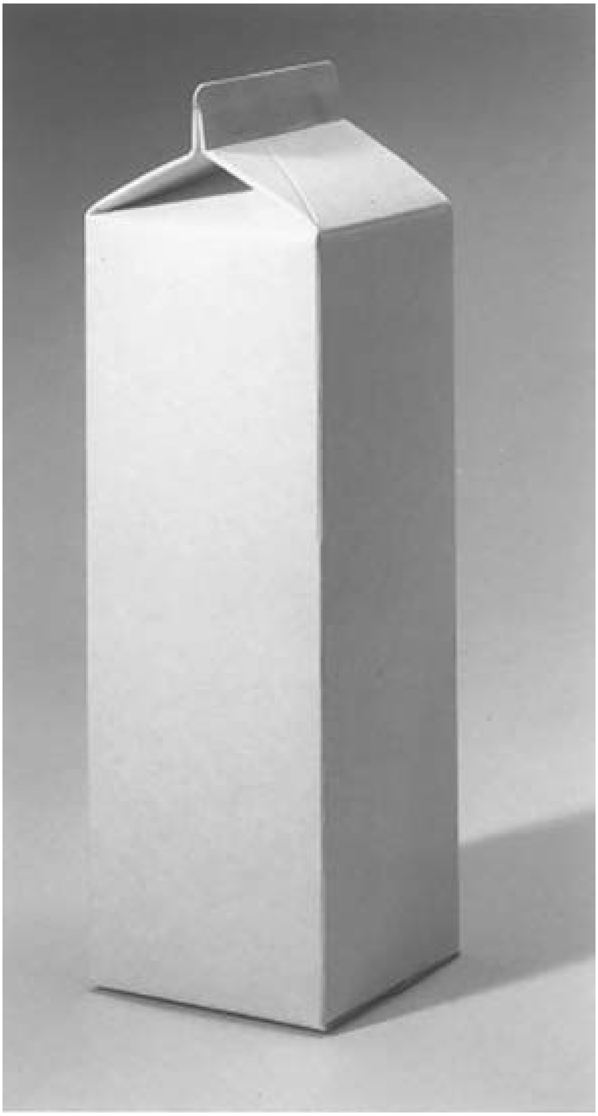


Figure 13.1 Pure-Pak® gable top carton. (Reproduced, with permission, from Elopak.)

There were alternatives launched in the US – some ten companies had launched a paper-based package for milk, by the 1930s. In Germany, Jagenberg had introduced Perga, which was also waxed. It had a circular base and a square top. Perga developed quickly and by 1939, there were 26 factories in 8 countries including Germany, England, Sweden, US, Canada and Australia. Jagenberg founded PKL in 1958 and introduced a package known as Blocpac.

Meanwhile, from 1943, a different approach was in development in Sweden. The company of Åkerlund and Rausing had been formed in 1929 to manufacture consumer packaging. This company developed Satello, during World War II. This was a wax-coated cylindrical container produced during the time when glass and tinplate containers were in short supply. Satello was used to pack jams and marmalade. The company then set out to develop a milk package which would be formed from the reel by cutting and sealing a tube of moisture-proofed paperboard at alternate right angles below the level of the liquid. This produced a tetrahedral-shaped package and a patent was applied for in Sweden in the name of R. Rausing in 1944 (Leander, 1996, p. 27).

It did not have an auspicious beginning. Ruben Rausing afterwards said that it was 'a package (shape) which you only ever saw in geometry classes, to be manufactured by a machine of whose appearance nobody had even the faintest idea, made from a material which did not exist and intended for one of our most vulnerable foodstuffs'. Of the person who invented the package, Rausing said that 'this was what you get for hiring people who have no idea how a package is made and what it ought to look like' (Leander, 1996, pp. 25–27) – clearly, a justification of lateral thinking!

As with Pure-Pak®, the development of a forming, filling and sealing machine together with that of a suitable packaging material took several years. The name Tetra Pak was registered in 1950 and a subsidiary company of Åkerlund and Rausing, AB Tetra Pak, formed in 1951. Tetra Pak became an independent company under the ownership of Ruben Rausing in 1965.

Several plastic materials had been tried by Tetra Pak and a polystyrene blend had been successful. The first packaging machine was installed in a dairy in Lund, Sweden, in 1952. This produced a tetrahedral-shaped package. Today, it is known as Tetra Classic (Fig. 13.2).

Polyethylene (PE) had been invented in England in 1933 by ICI and was given the brand name 'polythene'. Its use as a packaging material was not envisaged. Subsequently, DuPont with a licence to manufacture PE encouraged the firm of Frank W. Egan to develop an extrusion coating machine in 1954/55. Tetra Pak began coating paperboards with PE in 1956 (Leander, 1996, p. 53).

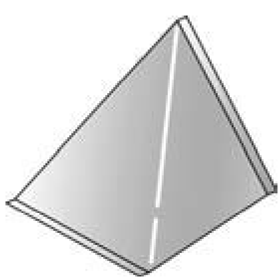


Figure 13.2 Tetra Classic. (Reproduced, with permission, from Tetra Pak.)

A brick-shaped PE-coated paperboard pack was introduced by Zupack (subsequently bought by Tetra Pak in 1982) in 1959 and, slightly earlier, PKL had introduced Blocpac with a similar shape. As noted already, the Pure-Pak® gable top from Elopac was being sold in Europe since the 1950s. These developments prompted Tetra Pak to develop a brick-shaped pack and this was achieved by 1963. The main advantage of a brick-shaped pack called Tetra Brik, with a square or rectangular cross section, is that it makes the best use of storage volume and is easier to handle mechanically in the dairies and in distribution (Fig. 13.3).

In addition to developments in machinery, materials and pack shapes, it was also recognised that it would be a major benefit to develop an *aseptic* paperboard-based packaging system for milk. Aseptic packaging requires the separate sterilisation for the package and the product, for them to be brought together in an aseptic environment, i.e. one from which micro-organisms are excluded, and for the pack to be hermetically sealed. Sterilising food, particularly liquid food, in this way achieves its objective with a shorter exposure of the food to heat thereby minimising the loss of nutritional content and flavour. This process would also result in an extended product shelf life. It was demonstrated by Tetra Pak on tetrahedral-shaped packs in 1961 and on the Tetra Brik in 1969.

In 1970, Tetra Pak bought an Austrian company, Selfpack, which had also introduced an aseptic system. PKL replaced Blocpac with Quadrobloc, and offered an aseptic system. About the same time, this company changed its name to Combibloc, and is SIG (Swiss Industrial Company) Combibloc, today. Later, the aseptic Pure-Pak® was launched using aseptic processing licensed from Liquipak.

In 1989, an expert panel on food safety and nutrition at the Institute of Food Technology, Chicago, ranked the aseptic process and packaging as the most significant of ten food science innovations of the previous 50 years (Asepticpackaging, 1989).

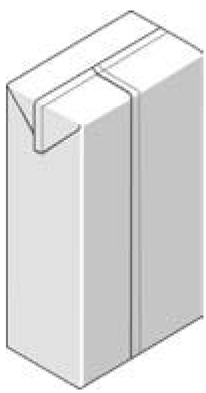


Figure 13.3 Tetra Brik. (Reproduced, with permission, from Tetra Pak.)

The leading companies in both aseptic and non-aseptic paper-based liquid packaging today are Tetra Pak, Elopak (with Pure-Pak® cartons) and SIG Combibloc. Despite the fact that Pure-Pak® was initially the leading paperboard-based liquid package for many years (1915–1955), Tetra Pak is by far and away the dominant company worldwide today with over 80% of the market. Speculation on the reasons for the market developing in the way that it did is beyond the scope of this book, but they are discussed in detail in INSEAD (2003).

The market expanded significantly from 1960 onwards. Initially, only milk and cream were packed in paperboard-based packaging; then juices were launched and from the 1980s, soups, sauces, cooking oil and, more recently, water. The range of pack sizes is extensive – from Tetra Classics of 12–65 ml through the popular range of packs with square or rectangular cross sections from 200 ml to 2 l. Even larger 4 and 5 litre pack cartons are available in the Pure-Pak® range. Pack shapes have expanded beyond the brick and gable-topped cartons to include multifaceted, wedge, pouch and hexagonal designs.

The range of products and the shelf life requirements have extended the types of packaging materials to include aluminium foil, high barrier and ionomer plastics – the latter providing easier heat sealing, product resistance where required and excellent adhesion to aluminium foil.

A major feature of pack development in recent years has been the attention paid by the manufacturers to open, pour, reclose and tamper evidence. In 2001, a fully retortable paperboard-based carton called Tetra Recart was launched to compete with the processed food can. A major component of the success of these forms of liquid packaging has derived from the attention paid to logistics – the science of material flows. Various designs of brick-shaped *transit* packaging have been developed to fit the pallet bases in common use. This in turn fixed the dimensions of the individual package to minimise the volume required in storage and distribution. Mini pallets and roll cages were developed to minimise handling and provide suitable displays at the point of purchase.

In addition to the liquid packaging so far discussed, there are other ranges of liquid packaging on the market. These include the bag-in-box pack with a corrugated fibreboard outer and a high-barrier plastic inner, which is used for wine, in sizes of 2–3 l. The commercial use of the bag-in-box concept has been reported handling 30 gal semi-skimmed milk, for the retail chain Pret-A-Manger, where capacity in storage and transportation savings were claimed (Paperboard, 2001). This type of packaging has been extended to dry products, for example catering products in large Pure-Pak® gable cartons, and also, to a limited extent, non-food liquid products.

A major feature of paper-based liquid packaging, in Europe and North America, has been the attention paid to environmental issues in terms of minimising the use of materials, energy savings in the packaging chain and to the recovery and recycling of the paperboard, plastics and aluminium.

In 1996, the aseptic package received the Presidential, US, Award for Sustainable Development – the first package to receive this environmental award (Environ, 1996; Asepticpackaging, 2000).

13.2 Packaging materials

13.2.1 Paperboard

Paperboard provides strength, structure, a hygienic appearance, and a good printing surface for liquid packaging cartons. The basic construction is multi-ply paperboard made from virgin fibres to ensure a high standard of odour and taint neutrality. The outer layer is always made from bleached, i.e. white, chemical pulp. (*Note*: This is also referred to as bleached sulphate pulp as the chemical separation of the cellulose fibres from wood is carried out by the *sulphate* process.) This outer layer may be white pigment coated to give the best print reproduction. The other layers may comprise either bleached or unbleached, i.e. brown, chemical pulp.

It is also possible to incorporate chemically treated thermomechanical pulp (CTMP) which has a lighter shade than ordinary thermomechanical or refiner mechanical pulp but is not as white as bleached chemical pulp. Where it is used, it is sandwiched between layers of bleached chemical pulp in the paperboard. CTMP provides more bulk and hence more stiffness than chemical pulp of the same grammage, or basis weight, and is lower in cost. The thickness and hence grammage or basis weight used depends on the size of carton and whether CTMP is used in the construction.

The main difference between liquid packaging board and board used for folding cartons is in the type of internal sizing applied at the stock preparation stage. Even though the pack design ensures that neither the edges nor the flat surfaces of the paperboard are exposed to the liquid product, because dairies have high humidity and wet environments, it is necessary to ensure that raw edges of board which are exposed to that environment do not readily absorb water or product.

Liquid packaging paperboard has developed into a mature product with capital-intensive large-scale production from relatively few producers (SPCI, 2002).

13.2.2 Barriers and heat sealing layers

The basic construction requires compatible heat sealing polymers on both the face, top, or print side, and the reverse side. This is usually provided by extrusion coatings of low density polyethylene (LDPE). In some designs, as we will see later, PE is sealed outside surface to inside surface and hence the PE on the two surfaces must be heat-seal compatible; and in other designs, the sealing is inside to inside. Most designs also require outside to outside sealing. Figure 13.4 shows a 2-side PE lined paperboard.

This construction will provide liquid tightness and humidity protection. It is mainly used for fresh products requiring a relatively short shelf life in chilled distribution.

The thicknesses of PE used depend on the size of carton. The outer layer may be either 14 or 26 g/m^2 and the inner layer 26, 41 or 56 g/m^2, the latter two

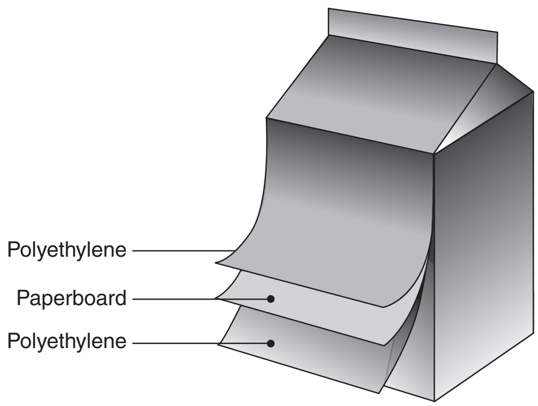


Figure 13.4 2-side polyethylene-lined paperboard. (Reproduced, with permission, from Elopak.)

being applied in two or three consecutive applications to achieve the total PE thickness required.

Polyethylene, as with most plastics, should not be thought of as a single material in the way, for instance, that we think of a specific inorganic chemical compound. There is a large family of PEs of different densities and molecular structures, which are controlled by the conditions under which the ethylene was polymerised – the conditions referred to concern pressure, temperature and the type of catalyst used. The recent introduction of metallocene (cyclopentadiene) catalysts has had a major impact on the properties of PE and other plastics. Hence this is an active area of development for the manufacturers of PE. The LLDPE (linear low density polyethylene) is superior to LDPE in most properties such as tensile strength, impact and puncture resistance.

It is also possible to blend these and other compatible polymers to enhance or vary the properties. In this connection, ethylene vinyl acetate (EVA) should be mentioned. As an extrusion coating, EVA improves heat sealability. In films, such as in the laminates used in the bag-in-box applications, EVA improves strength and flexibility as well as heat sealability.

For higher barriers in liquid packaging, it is necessary to use other materials in addition to PE. Ethylene vinyl alcohol (EVOH) and polyamide (PA) are good oxygen barriers and they also provide flavour protection and oil/fat resistance. EVOH and PA are not particularly good barriers to moisture vapour, the barrier for which is provided by the PE. These structures are used for medium and long-term shelf-life products in ambient and chilled distribution and provide an alternative to the use of structures which include aluminium foil (Fig. 13.5).

Aluminium foil is a well-established high-barrier material, which provides a barrier to light, oxygen and moisture vapour. It provides excellent protection to flavours and has oil/fat resistance. It may be laminated to either side of the paperboard. When laminated to the outside (top side) of the paperboard, it provides the carton with a metallic finish. In the majority of the cases, aluminium is used solely for barrier properties and an additional layer of PE is applied as

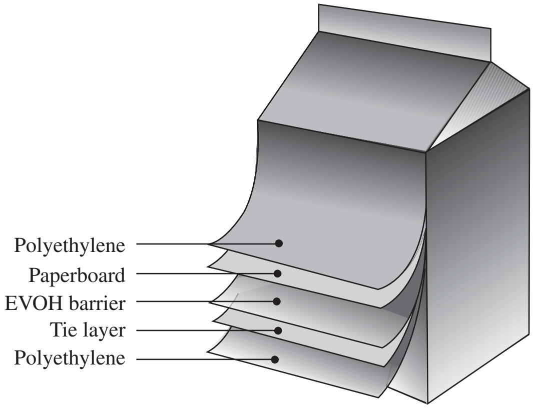


Figure 13.5 2-Side polyethylene-lined paperboard incorporating ethylene vinyl alcohol (EVOH). (Reproduced, with permission, from Elopak.)

indicated in Figure 13.6. These laminates are used for aseptic and hot filled products, requiring a long shelf life in ambient distribution, and fresh juices in chilled distribution.

Ionomer (Surlyn™) is a moisture vapour barrier like PE and, additionally, has oil/fat resistance. It has very good hot-tack and heat-sealing properties and is used as a tie layer (process aid) on aluminium foil on which PE can be extruded. Ionomer can be extruded onto aluminium foil at lower temperature than PE and thereby avoid potential odour from PE extruded at the temperatures necessary to achieve good adhesion to aluminium foil.

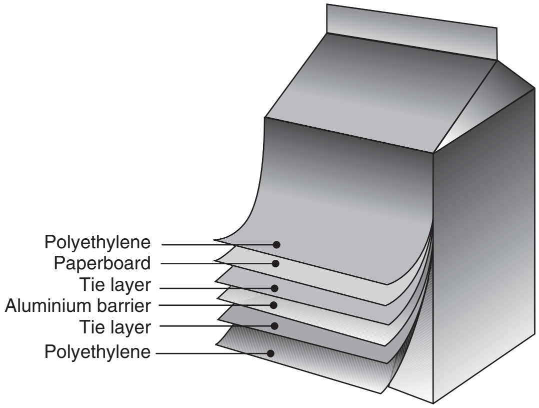


Figure 13.6 2-Side polyethylene lined paperboard incorporating aluminium foil. (Reproduced, with permission, from Elopak.)

An alternative tie layer for PE/PA would be one of the Bynel® range of coextrudable adhesion promoters from DuPont (Tampere, 2000; DuPont website).

Polyester (PET or PETE) film vacuum metallised with a thin layer of aluminium can be a good barrier to oxygen and moisture vapour. It can be laminated to paperboard. Other films such as polypropylene (PP) and polyamide can also be metallised. Another high-barrier film construction has a plasma-coated layer of silicon oxide (SiO_x) on polyester film which also provides a completely non-metallic barrier which can be extrusion-laminated to paperboard.

There are many possible combinations of extrusion coating and laminating. For example, PP, with resistance to essential oils, is extrusion-coated onto paperboard for cartons used to pack orange juice. The PP is overcoated with a blend containing PP plus 20% LDPE and 4% tackifier to improve the heat sealing of the inner layer (TAPPI, 2001). PP also has higher heat resistance than PE.

In practice, the product, the shelf life required and commercial considerations will all have a bearing on what is used in any specific liquid packaging application.

Another possible approach to barrier coating which may find a place in future developments is by way of size-press application on the paperboard machine of polymers in water-based dispersions. Both Surlyn™ and Nucrel® are thermoplastics from DuPont with oil/grease resistance and low seal-initiation temperature properties, which are available as dispersion coatings. Lower costs are favoured by the treatment which takes place on the paperboard machine (SPCI, 2002; Tampere, 2000; DuPont website).

Another reported development involves the production and use of polymer nanocomposites in which nanoscale particles of surface-modified clay are dispersed in the polymer. Enhanced barrier properties are claimed, making the material suitable for the packaging of oxygen-sensitive beverages such as fruit juices (Krook & Hedenqvist, 2001).

A relatively new material in production from Ecolean (www.ecolean.com) comprises calcium carbonate mixed with PE plastics (Packaging, 2002).

13.3 Printing and converting

13.3.1 Reel-to-reel converting for reel-fed form, fill, seal packaging

The paperboard is printed reel to reel by flexo or gravure. The printed reels are then either PE extrusion coated on both sides or, if an additional barrier layer is required, the reels are PE extrusion laminated to aluminium foil, or PE extrusion coated on both sides. With the heavier PE extrusion coatings on the inside of the package, a second PE application is required. As noted above, an alternative barrier layer may be applied – sandwiched between the paperboard and the outer coating of PE. The reels are then creased and slit to size and sent to the packer where the reels are formed, filled and sealed. An exception to this is Tetra Classic which is not creased during conversion.

13.3.2 Reel-to-sheet converting for supplying printed carton blanks for packing

There are options possible for producing flat carton blanks from extrusion coated and laminated paperboard. These materials are printed and cut and creased in-line. The printing process would most likely be gravure or flexo. In order to achieve good print adhesion to the PE, it is necessary to treat the surface of the PE after extrusion coating with an electric corona discharge, or direct gas flame, which oxidises the surface of the PE, making the surface molecules more reactive. Where printing is applied to the outside surface of the PE, the inks must have good wet and dry rub resistance.

Polyethylene and barrier coatings can also be cut into sheets before printing, usually by offset litho. The printed sheets are then cut and creased to produce individual carton blanks. The print must also be product resistant.

The design includes a narrow fifth panel on the side of the blank about 15 mm wide. The edge of this panel is then 'skived'. In this process, most of the paperboard from a 4-mm wide strip on the edge is removed. This leaves a narrow strip, 4 mm wide, of the inner layer of material, i.e. PE + aluminium foil + residual fibre, which is then folded over through 180°, so that it is then in contact with PE on the remaining 10 mm wide panel. As this is completed, the carton panels are folded over, and the 10 mm wide side seam of the carton is formed using hot air or gas flame. Skiving enables efficient folding and a side seam which is restricted to two thicknesses of the paperboard. This construction seals the inner surface of the narrow sealing panel to the inner surface of the joining panel and ensures that when the carton is filled, the liquid does not have any contact with a raw or exposed edge of paperboard, as shown in Figure 13.7. The side seam sealed carton blanks are then ready for dispatch to the packer.

13.4 Carton designs

13.4.1 Gable top

The original Pure-Pak® (from Elopak) carton was a gable top as shown in Figure 13.1; this is also available with a screw cap. Gable-top cartons have been available from other suppliers for many years. Tetra Rex, as shown in Figure 13.8, is a gable top

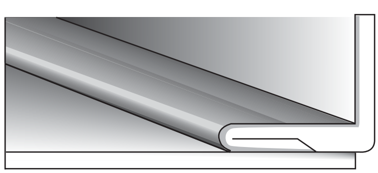


Figure 13.7 Heat sealed side seam. (Reproduced, with permission, from Tetra Pak.)

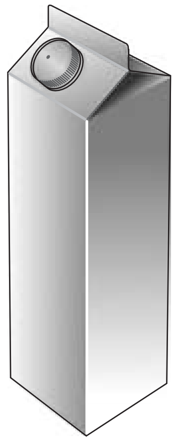


Figure 13.8 Tetra Rex gable top. (Reproduced, with permission, from Tetra Pak.)

carton produced by Tetra Pak. These cartons are produced from carton blanks. Other gable tops are Bowpack (Elopak from 2003) and Biopack (Field).

13.4.2 Pyramid shape

This is the shape of the first liquid pack launched by Tetra Pak. It is known today as Tetra Classic and is shown in Figure 13.2. The board is supplied uncreased in reel form. The pack is formed over a shoulder and around a vertical tube where the side seam is heat sealed. Prior to sealing, a thin ribbon of PE is fed and heat sealed across the raw, or exposed edge, of the longitudinal seal. This ensures that the liquid is not in contact with the raw edge of the paperboard. The product is fed into the tube where it enters the folded side seam–sealed tube. The horizontal seal is made intermittently through the product. As succeeding heat seals are made at right angles to each other, the resulting pack is shaped like a pyramid.

13.4.3 Brick shape

The Tetra Brik is made from reels and the Combibloc (SIG Combibloc) is made from carton blanks. In the case of Tetra Brik, the side seam is also covered with a strip of PE film to prevent the product from contacting the raw edge of the overlapping seam. This style results in ears formed when the horizontal heat seals are made. They are folded flat against the pack and lightly sealed. Tetra Brik Aseptic 200 ml is Tetra Pak's first resealable portion pack. It has a square profile and features a screw cap (Corrugated, 2002). Another brick shape is Quadrobloc.

Most of the brick-shaped packages have a rectangular cross section, as shown in Figure 13.3, but it is possible to have a square cross section, as shown in Figure 13.9.

13.4.4 Pouch

Tetra Fino is a paperboard-based pouch (Fig. 13.10). This pack and the associated packaging machinery provide a low cost and low investment system. It also places a lower demand for personnel, training and spare parts compared with other systems.

13.4.5 Wedge

The wedge shaped is a stand-up pouch (Fig. 13.11). An example is the Tetra Wedge which, with a straw, is a convenient-to-use drinks pack.

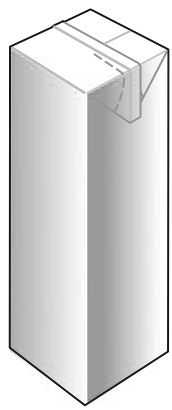


Figure 13.9 Tetra Brik – Square. (Reproduced, with permission, from Tetra Pak.)

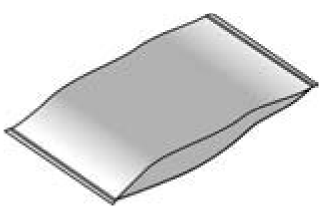


Figure 13.10 Tetra Fino – Pouch shaped liquid package. (Reproduced, with permission, from Tetra Pak.)

Figure 13.11 Wedge shaped paperboard-based package. (Reproduced, with permission, from Tetra Pak.)

13.4.6 Multifaceted and curved designs

Designs have emanated from all the leading companies in paperboard-based liquid packaging in order to meet specific needs with respect to life style and product differentiation. Designs have been produced for people on the move which fit easily into bags, into their hands and have both convenient to open and drink from features. Elopak has issued a pack with a hexagonal design named Diamond Pure-Pak®.

Other examples are as follows:

- Tetra Prisma is an eight-faceted design as illustrated in Figure 13.12
- Combishape is the concept that can be customised to meet specific customer and market needs – see three alternatives in Figure 13.13.

Figure 13.12 Tetra Prisma. (Reproduced, with permission, from Tetra Pak.)

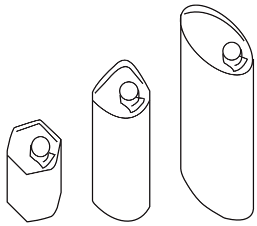


Figure 13.13 Combishape designs. (Reproduced, with permission, from SIG Combibloc.)

13.4.7 Square cross section with round corners

Tetra Top (Fig. 13.14) is a container with a square cross section modified with rounded corners and a plastic top.

This design is differentiated by the range of tops which are discussed in Section 13.5 and shown in Figure 13.22.

13.4.8 Round cross section

The Walcican 250 Aseptic is a round cross section container manufactured by Lamican Oy. It is a 'drink from the can' container, with a foil ring-pull or peel-tab opening (Fig. 13.15). An aluminium-free specification is also available. A well-known tea company has marketed 12 flavours of iced tea in this container.

Figure 13.14 Tetra Top. (Reproduced, with permission, from Tetra Pak.)

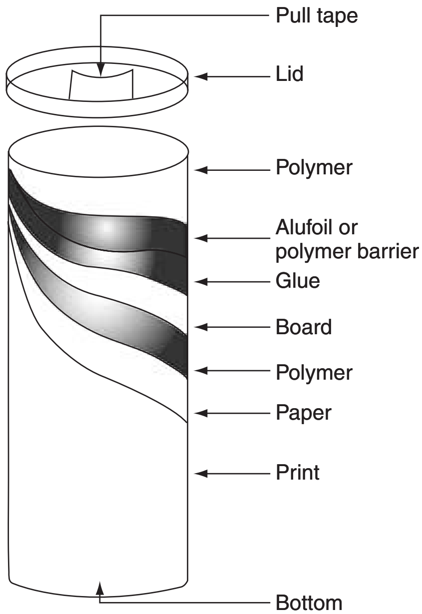


Figure 13.15 Walcican 250 Aseptic. (Reproduced, with permission, from Lamican Oy.)

13.4.9 Bottom profile for gable top carton

This is not a carton design as such, but a modification to an existing design with a technical or performance-related benefit. This is the Sahara bottom which reduces water absorption by the raw edge in the bottom design of the Tetra Rex carton.

It is a feature which can be applied on the forming and filling machine. It has the effect of raising the uncoated paperboard edge in the sealed bottom of Tetra Rex away from contact with the surface, which may be wet, on which the bottom of the carton is resting. The raised area of the base is shown in Figure 13.16. It is

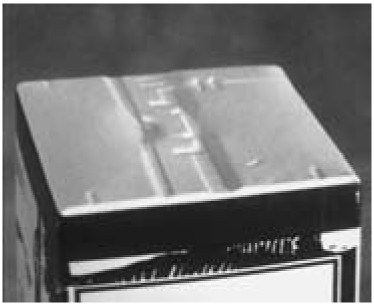


Figure 13.16 Modified carton base profile – Sahara design for Tetra Rex. (Reproduced, with permission, from Tetra Pak.)

claimed that raising the exposed edge by 1 mm reduces the uptake of water by the raw edge of paperboard by 80% and prevents the bottom of the carton from becoming saturated with water, i.e. soggy (Packaging, 2000).

13.5 Opening, reclosure and tamper evidence

The main disadvantage of liquid food and beverage cartons has, until comparatively recently, been the absence of convenient and safe ways of opening them. Though many packs, particularly the smaller ones, were considered to be one-shot packs, reclosure was a poorly addressed feature, particularly for the larger pack sizes, and this became a barrier to developing the use of these containers in some product markets.

The early gable top cartons from Ex-Cell-O were to be opened ‘with a knife or scissors’. Clips were used to reclose gable tops. In 1955, the ‘Pitcher Pour’ built-in pouring spout concept replaced the perforated tabs and openings covered by paper patches (Robertson, 2002, p. 48).

The sequence of recommended steps that should be taken to open a gable top carton are shown in Figure 13.17, where one is advised to ‘press back two of the wings and compress them to form a spout’.

It is also likely that the advent of aseptic liquid-packaging cartons actually set back concerns about opening liquid food and beverage cartons, as a balance has to be struck between the opening convenience and the integrity of the contents. There were also the questions of what sort of closure is needed, how it would be applied and what would it cost.

One is invited to open brick-shaped packs with the aid of scissors. In another example, a pull tab is sealed across the access point, as shown in Figure 13.18.

The simplest approach to drinking the contents of paperboard-based liquid packaging is by means of a straw, wrapped in film, attached to the body of the carton. A hole is punched in the paperboard prior to applying aluminium foil and PE. This provides an easy entry point for pushing the straw into the carton. The position of the hole is covered with a pull tab. The straw is packed in a film sachet and attached to the carton with a spot of hot-melt adhesive (Fig. 13.19).

The Tetra Prisma, described in Section 13.4.6, is fitted with a pull-tab closure, which when removed reveals a large drinking aperture that also is excellent for removing the contents by pouring (Fig. 13.20).

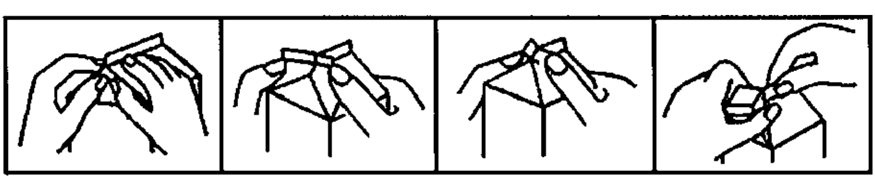


Figure 13.17 Opening a gable top carton. (Reproduced, with permission, from Elopak.)

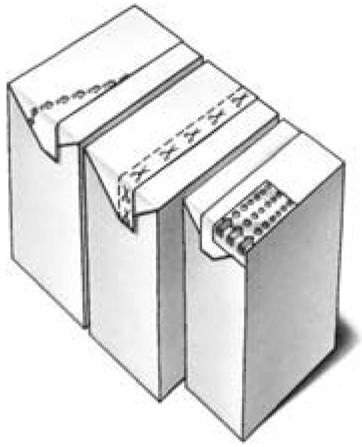


Figure 13.18 Opening indications on brick shaped cartons. (Reproduced, with permission, from Tetra Pak.)

Figure 13.19 Drinking straw attached to carton. (Reproduced, with permission, from Tetra Pak.)

In recent years, a wide range of recloseable injection-moulded plastic closures has been launched with built-in tamper evidence.

Figure 13.21 shows Recap 3 from Tetra Pak. This has a flexible aluminium foil-based diaphragm seal over the carton opening. This has to be removed in order to access the product and is therefore a tamper-evident feature. The hinged overcap can be used to reclose the container with a sharp click.

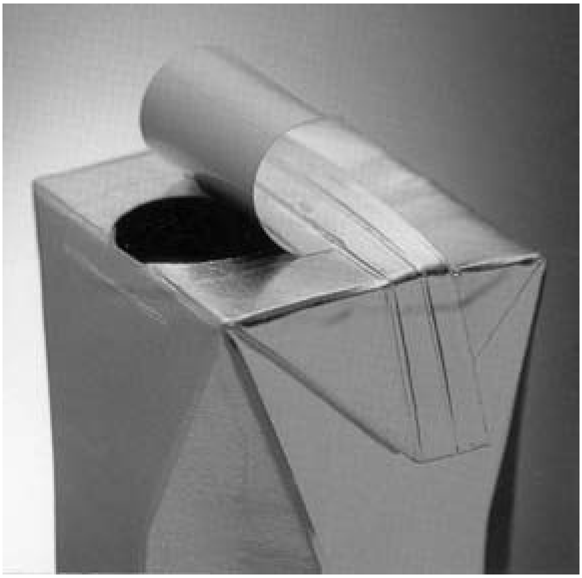


Figure 13.20 Pull tab closure and wide drinking aperture. (Reproduced, with permission, from Tetra Pak.)

There are several types of screw-type closure. CombiTop from SIG Combibloc was the first, launched in 1994. There are designs which are applied over an area of the carton from which the paperboard was removed prior to extrusion coating and laminating with aluminium foil. When this cap is removed for the first time, the foil/plastic material is perforated and pushed away from the opening. Others have external tamper-evident security plastic rings, which have to be broken in order to remove the cap, as shown in Figure 13.22. Improved pourers and wide apperture closures have been incorporated where they are considered appropriate (Ayshford, 2001).

Tetra Top, the pack with the square cross section and rounded corners, is offered with a family of alternative plastic closures integrated with the fibreboard-based body of the container. Each closure is designed to meet specific market needs. The closures are described below and are shown in Figure 13.23:

- grand tab, a lift-off closure for a container, which is easy to drink from directly
- total top, fitted with a ring pull which removes the entire top of the container making it suitable for foods which are eaten from the container such as soups, yoghurt and other desserts
- screwcap, with a tamper-evident seal
- ringpull, which is easy to open and close effectively.

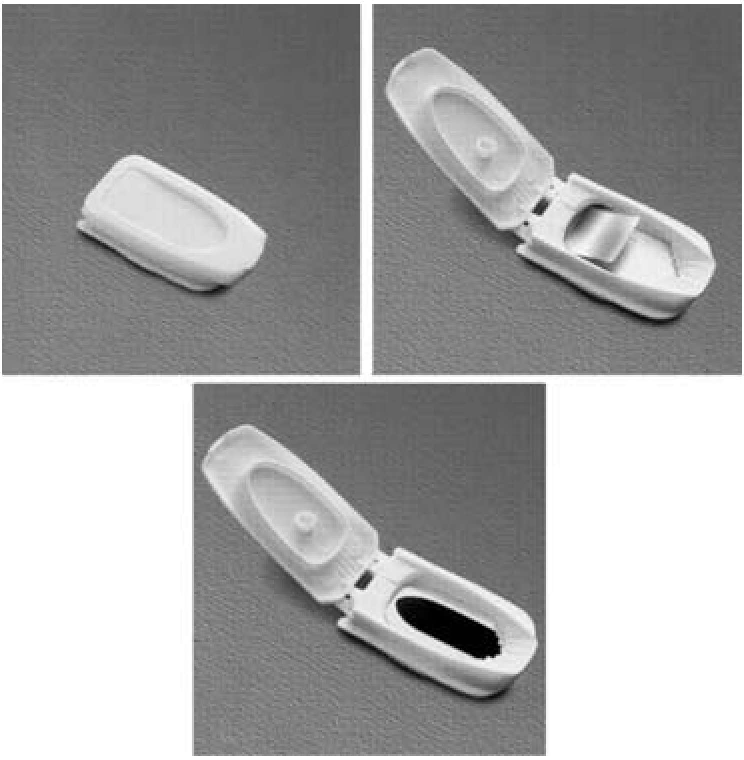


Figure 13.21 Tamper evident closure with reclosure, Recap3. (Reproduced, with permission, from Tetra Pak.)

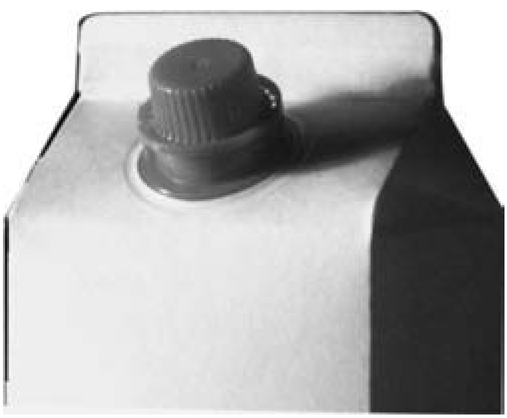


Figure 13.22 Screw cap with security ring. (Reproduced, with permission, from Tetra Pak.)

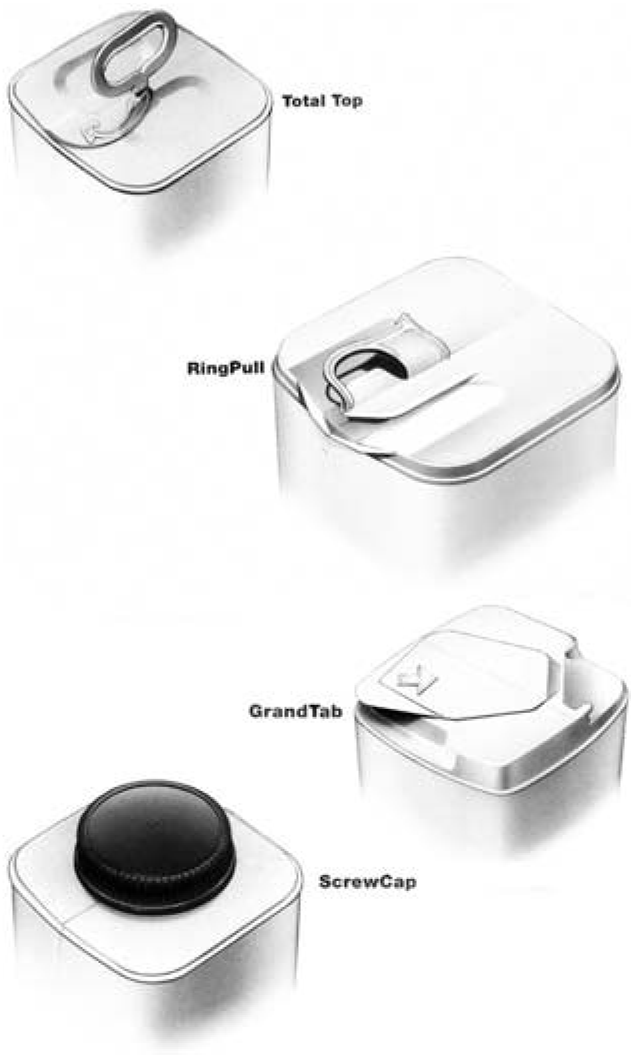


Figure 13.23 Four closure designs for Tetra Top. (Reproduced, with permission, from Tetra Pak.)

13.6 Aseptic processing

In the aseptic packaging process, ultraheat treatment (UHT), in-line food sterilisation thermal processing is followed by packing in a sterilised container whilst still *within* the sterile environment, also known as the aseptic zone. The liquid food or drink is sterilised or pasteurised in a continuous process as it travels through a heat exchanger, after which it is cooled and filled. Meanwhile, the packaging machine shapes the container and sterilises the packaging material.

This is significantly different to the procedure adopted when sterilising food *after* it has been packed in a sealed container, such as a processed food can. This difference is demonstrated in Figure 13.24.

Typical temperatures and holding times in a UHT process are of the order of 140 °C for a few seconds, for example 3–15 s (Tucker, 2003). Sterilisation of the packaging is carried out using hydrogen peroxide, UV and sterile hot air. The system is purged with an overpressure using a sterile air system. A typical flow line is illustrated in Figure 13.25.

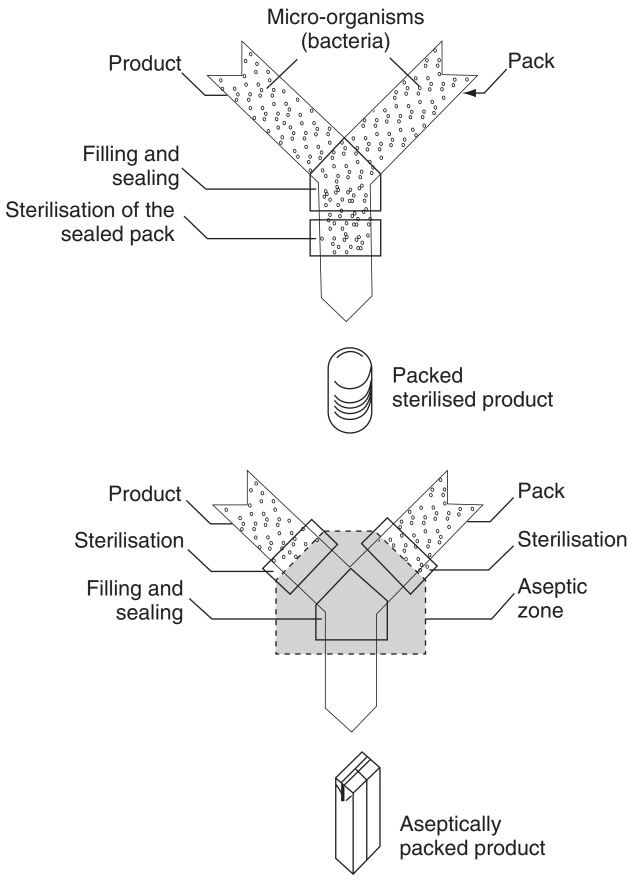


Figure 13.24 Comparison between aseptic packaging and sterilising a packed product. (Reproduced, with permission, from SIG Combibloc.)

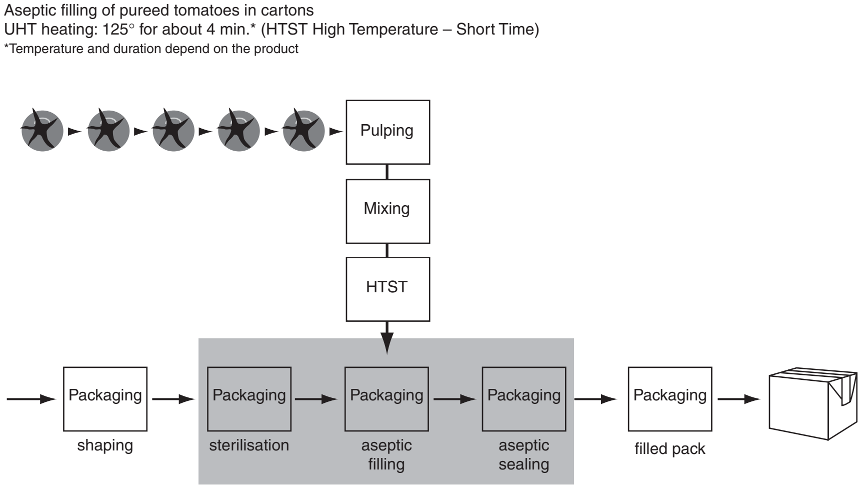


Figure 13.25 Aseptic filling of pureed tomatoes in cartons. (Reproduced, with permission, from SIG Combibloc.)

The main benefits of aseptic packaging are:

- food safety – harmful bacteria and other microbiological contaminants are eliminated from liquid food and drinks
- no refrigeration necessary – cost and environmental impact reduced
- convenient – lightweight, shatterproof and convenient for distribution
- better taste and nutrition – retains natural taste and colour, less damage to heat-sensitive constituents, such as vitamins, and reduced use of chemical preservatives
- longer product shelf life.

13.7 Post-packaging sterilisation

Tetra Pak launched a retortable brick-shaped carton known as Tetra Recart in 2001 (Packaging, 2001). The material is a 6-layer laminate including paperboard, aluminium foil and polyolefin, i.e. polypropylene, with heat sealing adequate to withstand retorting at temperatures around 130 °C.

This package is an alternative to the heat-processed can and glass jar. It is suitable for the packaging of a wide range of foods, such as vegetables, fruit, soups, ready meals, sauces, pastas, salsas and pet food.

A form, fill, seal machine erects cartons from flat blanks and, after filling, seals the bottom. This machine is capable of handling 24 000 cartons per hour, i.e. similar to that of a modern canning line.

The main benefits are:

- food safety – harmful bacteria and other microbiological contaminants are destroyed in the retorting process
- long shelf life comparable with processed food cans and glass jars
- no refrigeration necessary – cost and environmental impact reduced
- convenient to handle and open, lightweight and shatterproof
- more efficient distribution, storage and merchandising compared with cylindrical cans and glass jars.

13.8 Transit packaging

The needs of transit packaging, storage and merchandising at the point of purchase have all been addressed by the suppliers of liquid-packaging materials. Packs are collated or grouped for sleeving, placing in trays, and shrink or stretch wrapping. Special packaging formats are used for boxing the tetrahedral, wedge and pouch-shaped packs. Plastic crates have been designed which also serve as merchandising units at the point of purchase. Figure 13.26 shows three presentations of stackable distribution packs.

These packs are designed for efficient stacking, i.e. best use of the pallet volume and with alternate rows having a different pattern to give pallet stability (Fig. 13.27).

For the large retail groups selling large volumes of products in paperboard-based liquid packaging, the usual package for distribution is the roll container as illustrated in Figure 13.28.

Delivery lorries have been designed to handle crates and facilitate loading/ unloading.

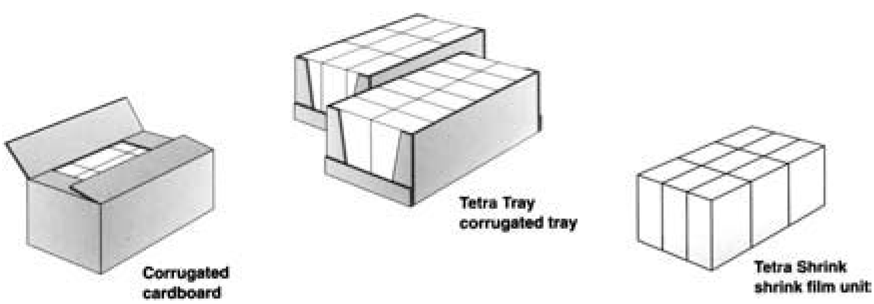
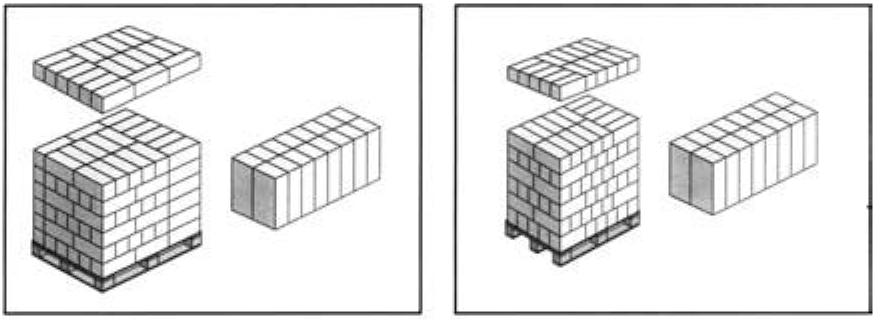


Figure 13.26 Distribution packs. (Reproduced, with permission, from Tetra Pak.)



UK Pallet (1000 x 1200 mm) Euro Pallet (800 x 1000 mm)

Figure 13.27 Efficient palletisation in use of space and stability of the pallet. (Reproduced, with permission, from Tetra Pak.)

Figure 13.28 Roll cage container for use in distribution and at point of purchase. (Reproduced, with permission, from Tetra Pak.)

13.9 Applications

The main application area in volume terms is for the packaging of dairy products, such as milk and cream, and utilising both refrigerated non-aseptic and aseptic packaging. This has been extended to a wide range of juices. Wine and mineral water have been packed in liquid cartons. Ice lollies are packed in Tetra Classic and Tetra Classic Aseptic packaging.

Other examples are as follows:

- Cooking oil in 1.5 l Pure-Pak® (Packmark, 2000a).
- Liquid egg range of products in Pure-Pak® (Paperboard, 2000).
- New Covent Garden Soup Co. in 2 l cartons (Packmark, 2000b). (There are many examples of soup cartons in smaller sizes.)
- In the non-food area, softener products used in washing clothes have been packed in cartons as a refill pack for plastic containers.
- Gable top cartons can be used for dry food. For example, Tetra Rex, 750 g in 2-litre cartons, has been used to launch a range of high fruit content muesli recipes by Capespan International, under the Fyffes, Cape and Outspan brand names printed on six colours litho (Packaging, 2003). Freeze-dried vegetables have been packed in large Pure-Pak® cartons for the catering and institutional markets.

13.10 Environmental issues

The liquid-food packaging industry has invested much effort into promoting the environmental benefits of liquid-packaging cartons through industry-wide associations. In general, this has concentrated on aspects which apply to paper and paperboard packaging as a whole, and as such will not be discussed here.

Environmental issues which are specific to this form of packaging concern are discussed in the following sections.

13.10.1 Resource reduction

The material used in beverage cartons has been reduced by 21% since 1970 (www.drinkscartons.com/docs/packaging10.htm). This has been made possible by new carton design and use of CTMP (SIG Combibloc).

An average beverage carton weighs 28 g, which is 3% of the total pack weight in the case of milk and juice (www.drinks.com/doc/packaging10.htm). (A 1-pint glass milk bottle in UK weighed approximately 220 g, which is roughly 26% of the total pack weight.) On the journey to the filler's plant, 600 000 empty 1-litre beverage cartons fit into one truck. The same number of glass milk bottles would require the use of 22 trucks (www.drinks.com/docs/packaging4.htm).

After filling, beverage cartons are easily stacked and take up less space. The overall effect in transportation is significant in reducing emissions of nitrogen oxides, carbon monoxide and carbon dioxide. In connection with this subject, a US report stated that the lightweight of the carton and the rectangular shape meant that over 50% more cartons could be packed on a truck compared with comparable glass containers (Clydesdale, 1990).

13.10.2 Life cycle assessment

A major debate has taken place in Germany about the environment comparison between packaging, such as glass, which is recovered and reused and one-trip packaging, such as the beverage carton. A Life Cycle Assessment (LCA) in 1993 had failed to reach a definite conclusion on this comparison and another was commissioned at the Fraunhofer Institute in 1999 to be undertaken in accordance with ISO14040 (Fraunhofer, 1999).

The report was submitted to an international panel for review (Critical review, 1999) and the conclusion was that there was 'No clear and unambiguous preference for non-reusable or reusable packaging'. The glass bottle came out better in respect of:

- lower generation of municipal waste
- lower water consumption
- lower total-energy consumption.

The beverage carton was superior in terms of:

- lower greenhouse effect
- less hazardous waste
- lower use of mineral resources
- lower use of non-renewable energy
- lower acidification of the environment
- lower eutrophication of the environment.

A further LCA study was set up by the German Federal Environment Agency (*Umweltbundesamt*) and was carried out by Prognos, IFEU Institute, GVM+ Packforce. Title: *Ökobilanz Getränkeverpackungen für alkoholfreie Getränke und Wein*. Phase I published in August 2000. Phase II published in October 2002 (Texte 51/02, ISSN 0722–186X, Forschungsbericht 103 50 504). This is available at www.umweltbundesamt.de/uba-info-daten/daten/bil.htm (SIG, 2004).

13.10.3 Recovery and recycling

Of the liquid food and beverage cartons placed on the EU market in 2002, 27% were recycled and 29% were used in energy-to-waste plants (ACE, 2004).

The fibre recovered from paper-based liquid packaging is of high quality and therefore is useful to maintain the quantity and quality of recovered fibre. Usually the separated plastic material which is separated is used for energy recovery.

The UK has been slow in seeking to recover beverage cartons from mixed paper waste. Technology is, however, available to segregate different qualities of waste paper. The alternative, i.e. to segregate different types of household waste at source with kerbside collection, is being encouraged and a plant at a paper mill became fully operational in November 2003 in UK with the capacity to recycle 20% of the UK's used liquid food and beverage cartons (LFCMA, 2003).

Corenso, a mill (joint ownership of StoraEnso and UPM-Kymmene), which makes the base papers for reel cores, at Varkaus in Finland has commissioned a plant built by Foster Wheeler, which recovers aluminium in addition to fibre and plastic materials. A gasifier turns the flammable plastic material into gas which fuels a gas boiler. The heat generated is equivalent to burning 16 500 tonnes of fuel oil per annum. Ash containing aluminium is collected in oxygen-free conditions – this is cast into blocks and sent to an aluminium foil production plant (Metal, 1999; Usine Nouv, 2001).

13.11 Systems approach

Today, there are many examples of a total system approach involving one packaging company acting in partnership with manufacturers, particularly in the food industry, in developing, installing and maintaining the whole system from the point of packaging to the point of sale.

In the case of liquid packaging, this has tended to go one step further and includes the food processing. This is inevitable if, as with aseptic packaging, the processing and packaging is inevitably closely integrated. This has led to liquid packaging manufacturers being closely associated with food processing, and this in turn has led to packaging solutions which are highly cost effective.

In another way, the manufacturers of liquid packaging have also gone further than most packaging manufacturers in studying and getting involved with solutions for the logistics of distribution from the end of the packing line to the point of sale at the supermarket. This has resulted in maintaining, developing and expanding liquid packaging in paperboard-based packaging.

Solutions have been developed with the worldwide market bearing in mind the serious wastage of food which occurs in the developing world as a result of the lack of suitable technology that can be adapted to local needs.

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Tetra Pak at www.tetrapak.com.

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14 Moulded pulp packaging

Chris Hogarth

14.1 Introduction

Amongst the largest volume of mass-produced, moulded pulp packages in Europe and North America are egg trays, Figure 14.1, instantly recognisable by consumers, and egg boxes.

As the name implies, this type of packaging is made from pulp which is moulded into a shape designed to hold and protect the product to be packed.

The primary function of moulded pulp packaging is to provide impact protection against breakage, chipping, etc. This is achieved in the design, which locates and stabilises the product. The structural design can also provide a degree of springiness and therefore shock amelioration.

14.2 Applications

Moulded pulp packaging includes the following:

- trays – such as those for eggs, Figure 14.1, fruits, ampoules and vials and also punnet-style trays with handles for mushrooms. Top and bottom trays are used to locate and protect bottles and jars, Figure 14.2.
- clam-shell–style containers in which the product is enclosed as for eggs or bottles (Fig. 14.5)
- corner or edge protectors for ceramics, radiators and furniture (Fig. 14.6)

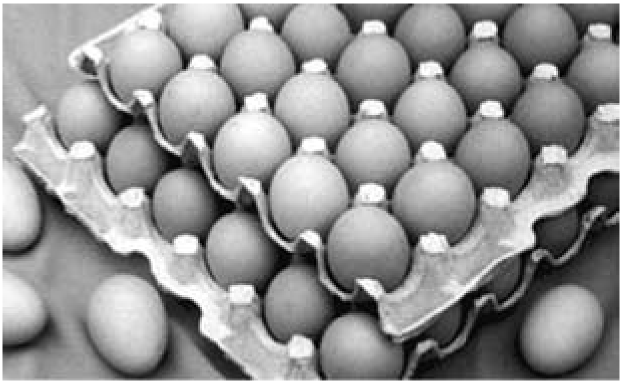

Figure 14.1 Egg trays.

Figure 14.2 Bottle protection with top and bottom fitments.

Figure 14.3 Typical tray shapes.

- locating fitments to assist the packaging of non-rectangular products, for example elliptically shaped chocolate boxes, where several products are packed in a corrugated box container for distribution.

Recent new applications of moulded pulp packaging include trays for the location of collapsible tubes, e.g. in foods and toiletries, and for electronic products

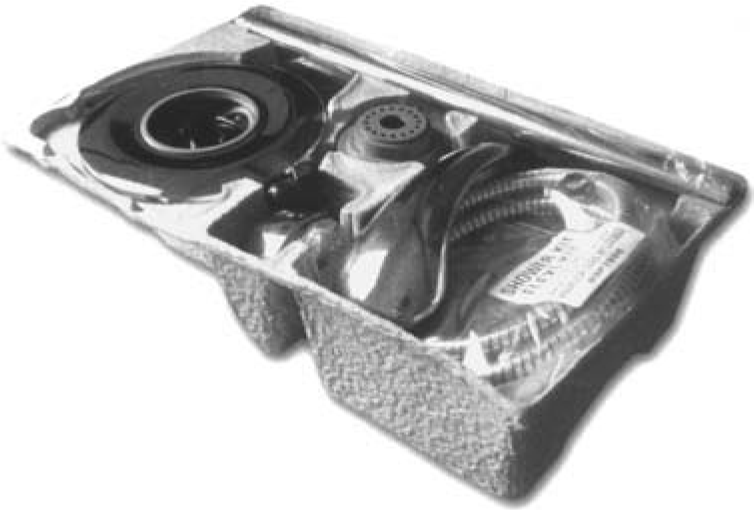

Figure 14.4 Complete kit of shower fittings.

Figure 14.5 Glass bottle protection suitable for postage.

Figure 14.6 Examples of edge and corner protection.

Figure 14.7 Protection of laptop computer.

e.g. car radios and, computer-associated products, e.g. flat screens and laptop computers – Figure 14.7.

The main end-use industries served are:

- food and drink
- chemicals

- electronics and IT equipment
- furniture
- ceramic wares and radiators.

Moulded pulp packaging is used in retail, wholesale, industrial and mail order applications. It can be used for disposable containers in hospitals.

14.3 Raw materials

Every moulded pulp item is produced by mixing water with either wood pulp or pulp made from recovered waste paper/paperboard to a consistency of normally 96% water and 4% fibre. Where required, a waterproofing agent such as rosin or a wax emulsion is added. Dyes may be added to produce specific colours.

The fibre used is predominantly made from specific grades of recovered paper and paperboard. However, where required, virgin fibre, either chemical or mechanical, bleached or unbleached, may be used. Baled recovered paper or pulp is hydropulped and is diluted to the correct consistency.

14.4 Production

Initially, there were two moulding processes – pressure moulding and suction moulding. In the former, the pulp mixture is fed into the mould and the product is formed using hot air under pressure. This process is semi-automatic and therefore of lower output. Additionally, mouldings made by the pressure-forming process have a thicker and more variable wall thickness. The pressure-moulding process is also less suitable for producing more complicated designs and it has been superseded by the suction moulding process.

In suction moulding, pulp is pumped into a perforated mould where water is removed by vacuum forming. The moulded item is then dried. An illustration of forming tools is shown in Figure 14.8.

A mould is essentially in the ‘shape’ of the product required. All tool sets are of two pieces – ‘male and female’ type. This results in the moulded pulp product having one side which is smooth and the other which is rougher. The mould is perforated to allow the removal of water by suction. It is covered, or lined, depending on the shape and which side is required to have a smooth surface finish, by gauze, Figure 14.9. This gauze is made from strands of stainless steel wire of 50-microns thick and with a 50-micron gap, or pitch, between parallel strands. It imparts a smooth surface to the surface of the moulded product.

For an egg box produced by this process, the outside surface is required to be smooth so that a printed self-adhesive label can, subsequently, be applied. The die set would comprise a smooth, female tool mould, for the outside and, correspondingly, an inside male demould. This results in a rough finish on the inside of the egg box.

If we require a tray with a smooth *inside* surface, then the inside will be in contact with a smooth male mould and the outside, with a female demould which imparts

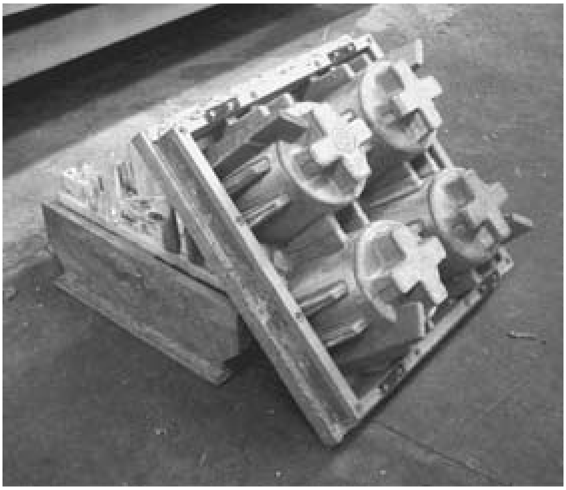

Figure 14.8 Forming tools.

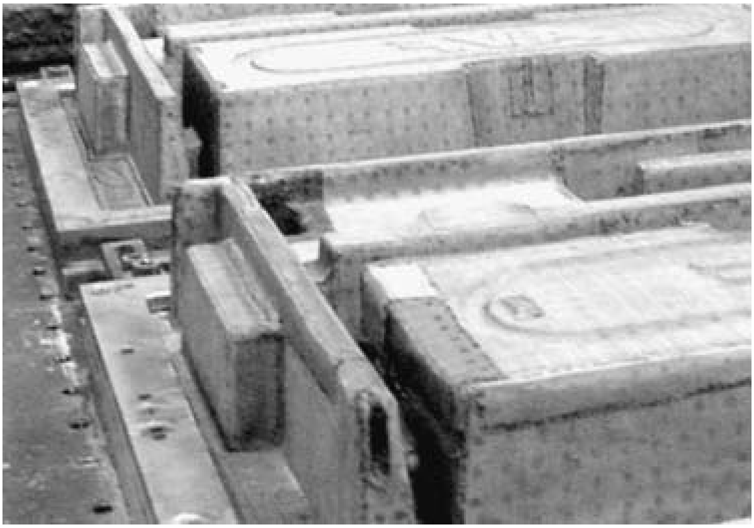

Figure 14.9 Gauze used to mesh the mould tool surface.

a rough finish to the *outside* surface of the moulded product. Figure 14.10 shows all the components which are needed to make a full tool set, i.e. aluminium baseplate, retaining plates, etc.

The forming mould is a complex piece of engineering. It is expensive. It is designed by specialist engineers and is normally made from aluminium, though

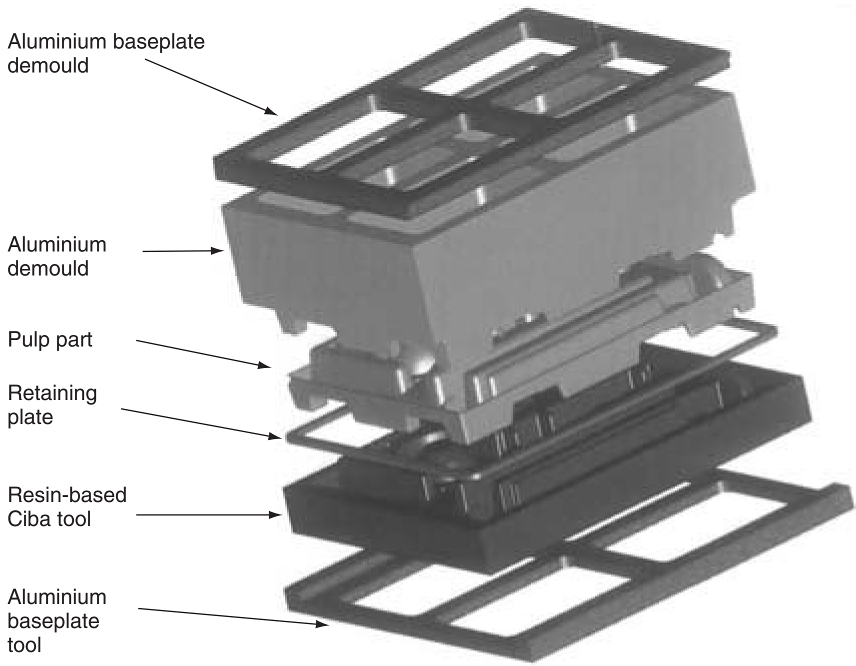

Figure 14.10 Components of a die.

resin-based tooling, for example 'Ciba' indicated in Figure 14.10, can also be used. The use of computer aided design (CAD) has facilitated mould design and enabled much more complicated designs to be produced than hitherto.

The tool set is made in a milling machine using computer numerical control (CNC). This is based on the output from the CAD tool design and a computer aided manufacturing (CAM) toolpath. After CNC machining and manual drilling, the face of the mould used to form the product is covered manually with the fine mesh gauze. It is a specialised skill acquired after years of training. Once the product is formed by vacuum (suction) on the mould, it is transferred to the drying process using a transfer mould, which is a mirror image of the forming mould and is made from aluminium or epoxy resin. Reverse airflow is used to eject the formed piece of pulp from the suction forming mould onto the transfer mould. Machines used for pulp moulding range from inexpensive hand-operated machines to fully computer-controlled automatic machines capable of producing thousands of tonnes of moulded pulp packaging per annum.

14.5 Product drying

The product is dried in one of two ways. It is dried by either the circulation of heat inside long aluminium gas burning driers or in-mould thermoforming which uses additional heated moulds to further press and dry the product. This in-mould drying results in a very high quality finished product, which rivals vacuum and thermo-formed plastic mouldings in both aesthetics and geometrics.

Along with its low environmental cost in real and life cycle senses, this new in-mould pressed pulp packaging is now the most popular choice for packing in the electronics and mobile communication industries (Figs 14.11 and 14.12), for example for the packaging of products such as modems, mobile phones and computer printers.

14.6 Printing and decoration

As already noted, coloured moulded pulp packaging can be produced by using a dyed pulp. Decorative finishes can be applied by spray gun. Text, such as brand and end-user names, symbols such as the recyclable logo or trademarks, and

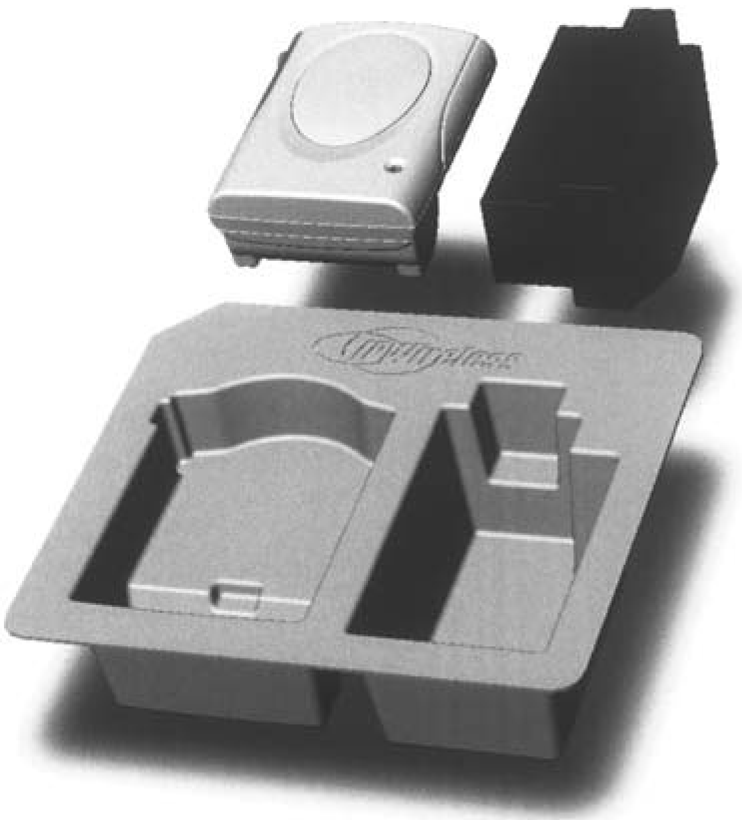

Figure 14.11 Electronics tray pack.

Figure 14.12 Wireless satellite modem packaging.

decorative patterns can be incorporated in the mould to produce an embossed or debossed effect. Multi-coloured self-adhesive labels provide the best option for high-quality printing. Direct printing is also possible on moulded pulp surfaces; and whilst the better result is achieved on the smooth side, it is also possible to print a small font size adequately on the rough side, for example inside of egg boxes.

14.7 Conclusion

Moulded pulp packaging provides a cost-effective solution for the packaging of a wide range products, many of which are fragile. There are ancillary benefits, in the sense that multiple cavities can be customised for the collation of difficult-to-handle products. The environmental benefits include features shared by all paper and paperboard-based packaging, namely those of being recyclable, biodegradable and by being based on a naturally renewable resource. Moulded pulp packaging provides an important use for recovered paper and paperboard, and by the application of innovative design techniques, it provides protection with a minimal weight of material.

Whilst tooling costs are high and order sizes need to be relatively high to spread the cost over a large number of units of production, it is also the case that many of the products protected also have a high unit cost. With many of the other products where the item packed has a relatively low cost, for example eggs and fruit, the tooling cost is spread over vast numbers of packs and therefore the cost of the tooling is a lower issue. The use of CAD has significantly extended the complexity of pack design for which tooling can be produced.

Website

www.cullen.co.uk.

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