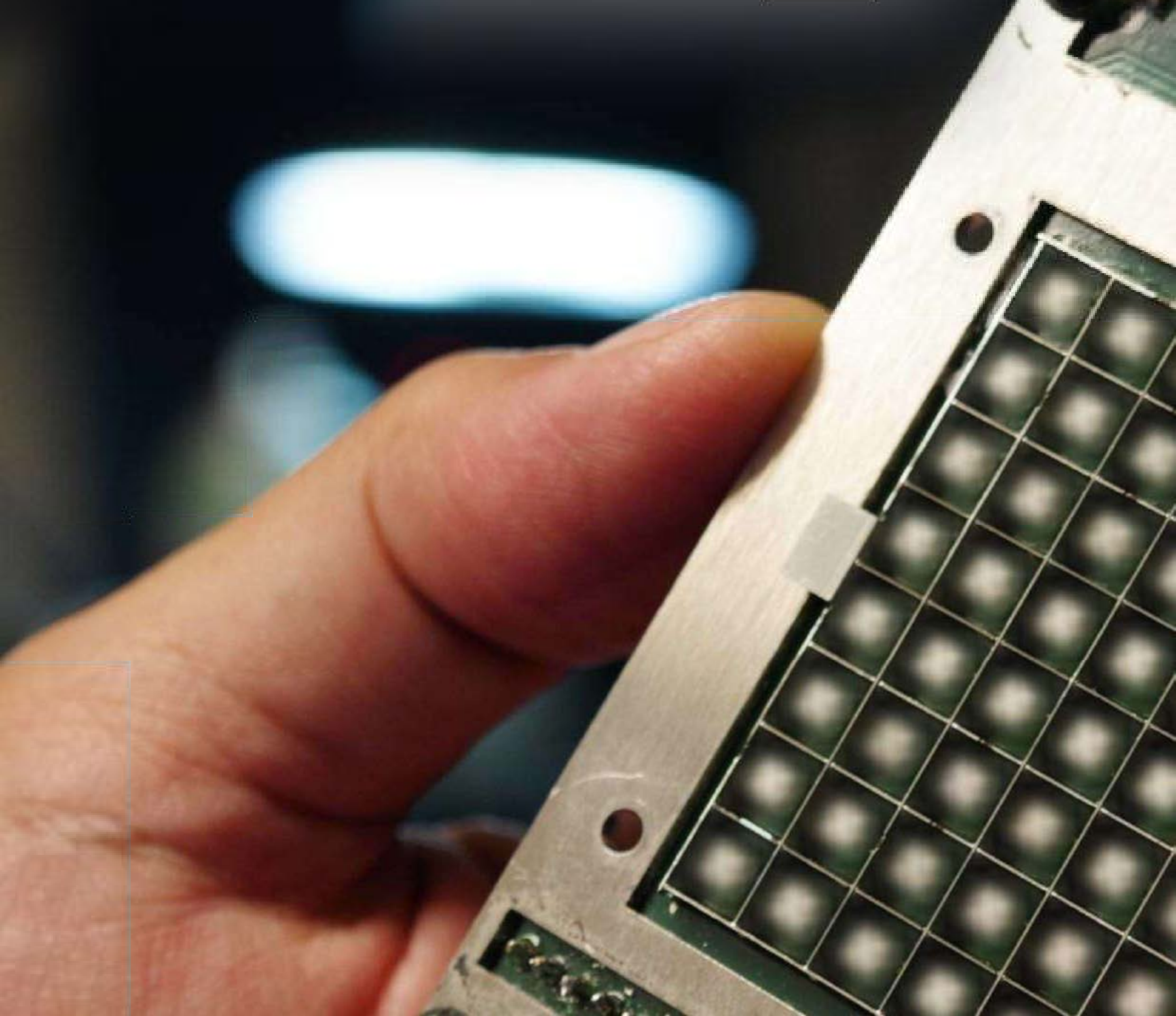
FUNDAMENTALS PACKAGING TECHNOLOGY MATERIALS AND PROCESSES

Nicholas Cameron



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1
Packaging and society

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Abstract: This chapter aims to provide a brief introduction to packaging and an overview of the industry and its development. It places packaging in its context in society and explores some of the major changes that have contributed to the growth in packaging usage. It does not aim to provide a complete view, but to lead the reader to the detailed chapters in the rest of the text.

Key words: history, ancient packaging, Industrial Revolution, brand, ready meals, microwave ovens, supermarket, primary packaging, secondary packaging, tertiary packaging, packaging usage, glass, steel, aluminium, paper, Tetra Pak, jute, cork, wood, pallets.

1.1 Introduction: packaging from a historical perspective

Packaging has been used in some form or other since the first humans began making use of tools. Animal skins and hollowed-out fruit husks were used to carry water, and grasses were woven into baskets and panniers to provide a useful way of keeping together and carrying goods. Probably one of the first examples of 'packaging' to preserve foods was the use of leaves to wrap meat when the tribe was on the move and the source of the next meal was unknown. As tribes became less nomadic and settled to farm the land, there was a need to store the produce. Clay pots met this need and archaeological evidence dating to 8000 BC shows large wide-mouthed jars being used for grains, salt, olives, oils, etc. The discovery that sand could be fused at high temperatures and made into bottles and jars increased the possibilities for storing and preserving liquids such as oils and perfumes. Both clay pots and glass containers were also used for their decorative qualities, as in the painted amphora given as prizes in the early Olympic Games from 700 BC.

As townships and cities developed and men and women became skilled in crafts beyond immediate needs, trade between cities, countries and continents developed, no doubt spurred on by the spirit of exploration which we still see today. Animals were harnessed to carry goods across the trade routes using an assortment of woven grass panniers, wooden barrels and casks and the same types of pack were used in the local markets. Thus the concept of using packaging as a convenient means of transporting goods, and to some extent in protecting and displaying them, was established, albeit that this was at the bulk level rather than with any apparent consideration of what the final consumer wanted.

1.2 Social developments: the changing patterns of consumption and their impact on packaging

1.2.1 The Industrial Revolution

A major influence in moving packaging from this bulk level to addressing the individual's needs was the Industrial Revolution, which began in England in the late seventeenth century. The shift from individual crafts at home or in small groups to mass production in factories brought large-scale migration of workers and their families to towns and cities. Foods and basic commodities previously produced and readily available at home, now had to be transported to shops in the cities to be bought by the workers using their hard-earned wages. This increased the demand for barrels, boxes and bags to bring in supplies on a larger scale than had previously been known, and it also brought a need to supply goods in the small quantities now demanded by the workers. These new 'consumers' lived in relatively cramped surroundings and did not have the large storage facilities previously available on the farms. Thus they needed to make frequent purchases and to carry their goods home, keeping them in acceptable condition as they did so. Goods were often measured out into the purchaser's own container, but gradually this changed to the shopkeeper pre-packing items such as medicines, cosmetics and tea, and having them available for sale in measured quantities, thus offering the buyer some assurance as to the quality and quantity of the goods. Eventually this pre-packing moved back a further stage from the buyer, to the situation we know today, where most goods are packed at the point of production rather than sale.

Whilst we have scant evidence to support this, it is reasonable to assume that there was a limited choice of goods available to the new consumer and little information about who had supplied the goods. If butter was wanted and butter was available in the shop, the consumer bought it, with no options from which to choose and no knowledge of its provenance. It was not until the nineteenth century that we started to see the rise of the 'brand name' used as a mark of quality by producers who wanted to make sure the buyer knew which product they were buying and were not misled by inferior goods. The word 'brand' comes from the identifying mark farmers burned into the hides of their cattle, as a stamp of ownership to deter others from stealing. The same burning process began to be used on wooden barrels and boxes as producers faced competition. Some of the oldest brand names are still with us today, for example, Schweppes (1792), Perrier (1863) and Quaker (1901).

1.2.2 Modern packaging

The move from packing goods at the point of sale to packing at the point of production brought about a shift from bulk to consumer packs, which had to survive the journey not just from shop to home, but, more importantly, from factory to shop, a journey which today may span countries and even continents and will include intermediate storage stages en route. It also gave producers the opportunity to develop their own style of packs to promote their own products, and this has brought us to the modern-day pack. Now, unlike our ancestors, we expect to have a range of goods from which to choose when we shop and the packaging plays a significant role in helping us to differentiate between the options available from various companies. We also expect our products to be free from damage, and in the case of foodstuffs, wholesome and safe and, again, the packaging makes a major contribution to meeting these expectations. Brand owners now expend their resources in developing packs which attract the attention of the would-be purchaser and at the same time provide the product with the protection needed. These different roles of packaging will be expanded and discussed in detail in the next chapter, although it is inevitable that reference will be made to them here.

1.2.3 Lifestyle changes and their impact on packaging

Since the middle of the twentieth century there have been significant changes in lifestyle in the developed countries and these have had, and continue to have, a major influence on how goods are packed. This applies particularly to food and drink, but also to all other fast-moving consumer goods. The following is not an exhaustive list, but presents just some of the relevant lifestyle changes.

- Reduction in the size of the family unit, due to decreased birth rates, increased number of one-parent families and increased longevity. There are now many more single- and two-person households than there were in the 1950s and 1960s and this means a requirement for smaller packs, thus more packaging per kilogram of food.
- Growth in the number of households in which all adults are in either full-or part-time work, outside of the home. This means less formal meals where everyone sits down together; meals are required at different times, and with minimum preparation. This brings a higher than ever consumer demand for convenience in terms of portion size and food which can be made ready-to-eat at short notice. Ready meals and the packaging formats in which they are presented make a key contribution to meeting this demand.
- Growth in ownership of domestic appliances such as the fridge and freezer has allowed consumers to buy larger quantities of 'fresh' foods, which are expected to remain in good condition for prolonged periods of time. The development of the low-cost domestic microwave oven brought with it a requirement for microwave-suitable packaging.
- More disposable income means more money to spend on food, especially luxury food and drink.
- More international travel and exposure to other cultures, leading to interest in 'ethnic' foods, but with minimal preparation time.

1.3 Business developments: the effects of globalisation and modern retailing

As well as the societal changes mentioned above, changes in the way businesses operate also strongly influence the need for and the types of packaging used. For example, the growth of the modern supermarket brings a highly competitive retail environment, with different versions or brands of the same product all displayed together. The time-pressed shopper relies on the subliminal cues of the packaging to make a selection, usually based on almost instant recognition of familiar features such as colour, graphics or shape.

Other ways in which business changes have influenced packaging include the following.

- The globalisation of manufacturing, with products being shipped over long distances and through different climatic conditions places strong emphasis on packaging to provide protection against likely hazards.
- Modern supermarkets demand fast stock replenishment with a minimum of manual effort. This has brought a requirement for secondary packs which can 'double up' as shelf-ready display packs, with no handling of the individual primary packs. One of the first companies to introduce this concept was Marks and Spencer in the 1970s. The 'straight-on tray', as it was then called, was initially used for food, and then extended to other goods such as toiletries.
- Modern supermarkets also demand rapid service at the checkout, and here the ubiquitous bar code provides a quick and reliable means of identifying the product and its price. Importantly, this data is also used for stock control purposes, often linked to automatic ordering to replenish supplies.

A further aspect to consider is concern about health and hygiene, on the part of the consumer and business. Sellers, producers and consumers alike want reassurance that a product, especially a food product, is fit for consumption and will not cause illness or injury. Packaging contributes to providing such reassurance, via fully sealed containers, often with some measure of tamper evidence. A related aspect is that packaging can be used to provide authenticity to a product, giving assurance that it is the genuine article and not a substandard alternative.

1.4 The different levels of packaging: primary, secondary and tertiary

Packaging exists at different levels and the following definitions are used throughout this text.

- *Primary* packaging includes not just the materials in direct contact with the product, but all of the packaging which surrounds the product when the consumer takes it home. For a multipack of crisps, for example, the primary packaging will be the individual bags and the large bag into which the separate packs are packed. A useful way to define primary packaging is to think of it as all the packaging which eventually finds its way into the domestic waste stream, once the product is used up.
- *Secondary* packaging is used to group packs together for ease of handling. In the example above of the crisps, several multipacks are packed into printed corrugated cases. The case is the secondary packaging. Other examples of secondary packaging

are shrinkwrap film, and the corrugated board and thermoformed plastic trays used for shelf-ready packaging.

- *Tertiary* packaging is used to collate secondary packs for ease of transport. One of the most common forms of tertiary packaging is the pallet, along with stretchwrap film and a label, to secure the secondary packs to the pallet and provide a ready means of identification. Roll cages and crates are also examples of tertiary packaging.

1.5 Packaging materials usage and development

Around 70% of packaging is used for food and drink, but other sectors such as healthcare, beauty products, chemicals, clothing, electrical and electronic equipment all need packaging to ensure they stay in an acceptable condition from manufacturer to consumer. Today's global packaging industry is valued at over $400 billion, roughly broken down into 36% paper and board, 34% plastics, 17% metals (steel and aluminium), and 10% glass, the remainder being made up of materials such as wood and textiles.

Of these major materials, glass is probably the oldest in its use as a packaging medium, dating back to its use for hollow vessels, in about 1500 BC. These were made by layering molten glass around a sand core and then removing the sand once the glass had cooled and solidified. Glass blowing started to develop around the first century BC and brought with it the ability to make glass containers of many different shapes and sizes, as the formability of molten glass was exploited. This property continues to be exploited in the modern, fully automatic glass-forming machines of today, demonstrated by a visit to the perfume counters of major stores where there is a vast range of intricately-shaped bottles on display. Glass remains an important packaging material and studies have shown that in the mind of today's consumer it is associated with features such as cleanliness, inertness and high clarity. Such properties engender its high-quality image and account for its continued use in market sectors such as beers, wines and spirits, perfumes and some pharmaceuticals.

Metal packaging is reported to date back to Napoleonic times and the development of metal containers for food has gone hand-in-hand with the introduction and development of food sterilisation systems such as those used in canning. Steel continues to be used for heat-sterilised cans for food and drink and for large containers such as drums and intermediate bulk containers (IBCs). Aluminium was first used for cans in the 1950s and today is widely used for drinks cans, especially for carbonated soft drinks. Both steel and aluminium are used for aerosol containers.

Papermaking is thought to date back to China in the second century AD and originally used woven strips of wet papyrus, laid down by hand and then dried. Papermaking machinery developments in the nineteenth century brought the ability to build up layers of cellulose fibre (initially obtained from rags and then from trees) into a continuous web, thus allowing a wide range of materials of different thicknesses and performance to be made. As the data shows, paper and board are the most widely used materials in today's packaging, and applications vary from labels to that workhorse of secondary packaging: the corrugated board case.

With regard to plastics, while the first materials date back to the nineteenth century, the major developments which have resulted in today's plastics packaging industry have taken place only since the 1940s. Plastics packaging has seen the most significant growth since then, of all the packaging materials, due to the development of low-cost processes and materials with a wide range of different properties, and, probably most significantly, the ability to tailor those properties to suit a range of different needs. For these reasons plastics have replaced the more traditional materials such as glass and metal in some applications, such as:

- the change from glass to polyethylene terephthalate (PET) containers for bottled water and soft drinks
- the change from glass to high-density polyethylene (HDPE) containers for milk
- the change from metal cans to flexible plastics pouches for pet food, soups and sauces.

Of course, this is not meant to imply that such changes are complete; some notable brands of bottled water retain glass for its high-quality image, and the vast majority of 'canned' foods remain in the traditional food can. What plastics have brought is the ability to offer alternatives and brand owners have seized these opportunities to differentiate their product offerings. Importantly, they have also brought reductions in pack weight, often with associated reductions in the total cost of the packed product and, not surprisingly, product manufacturers have welcomed such changes.

Another significant packaging development relying on plastics is the reel-formed 'carton' typified by the Tetra Pak and Combibloc containers. Although primarily constructed of paperboard, this type of pack relies on plastic layers for heat sealing (and thus forming leak-tight containers) and for barrier to moisture and gases (often along with aluminium foil). Despite its many detractors, this pack format is now ubiquitous in the fruit juice and milk sectors, providing a distinctive, lightweight, regular-shaped container. Most of the criticisms aimed at the pack have been related to its opening characteristics, leading to the development of a range of caps and opening devices.

Wood has been used for barrels for bulk products such as butter, and is still used for crates and boxes for fresh produce and for heavy engineering items such as machinery parts. However, the most significant use of wood in packaging is probably in the form of pallets, still the most common way of moving goods from manufacture to seller.

Other materials used in packaging include cork (wine bottles, albeit challenged by plastics) and textiles such as jute, used for sacks and bags. Jute sacks are used for agricultural products, due to their breathability, and for commodity food products such as sugar and rice. Jute bags are available as shopping bags and gift bags, often by companies wanting to project a 'green' image by using this natural fibre.

1.6 The environmental perspective: responsible use of resources

With regard to environmental impact, packaging has attracted criticism as a squanderer of valuable resources and an environmental pollutant. This criticism is rarely justified: far from wasting resources, packaging can and does deliver significant benefits in reducing product waste by containing, protecting against physical damage, and preserving against spoilage. Indeed, modern society could not function without packaging and the potential environmental damage of not using packaging is far greater than that caused by its use. It is estimated that supply chain losses are of the order of 40–60% in less developed countries, vs. around 3% in Western Europe.

Packaging reduction projects have long been important in modern manufacturing companies; no commercially sound organisation deliberately uses more packaging than is necessary for the safe delivery of the product and its acceptance by the market. To do so is not only environmentally irresponsible; it is economically disastrous and bodes ill for the financial health of the organisation. Legal compliance is a further issue, with widespread legislation concerning packaging use and disposal.

It is irresponsible to ignore the environmental impact of *any* decisions today, not just packaging decisions. Responsible manufacturers now consider how best to reduce the total amount of packaging used, whether it can be reused or recycled and how best to recover used packaging from the waste stream. There are no easy answers and no one material which can be held up as indisputably more ‘environmentally friendly’ than any other.

2
The packaging supply chain

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Abstract: This chapter examines the supply chain as a total system for the delivery of goods from the packing line through to the retail environment and the consumer. The conventional approach to envisaging the supply chain is integrated with considerations of sustainability. The central theme is the use of packaging to prevent damage and the benefits to be derived from bringing all stakeholders together in the supply chain to deliver optimum results.

Key words: testing, distribution, sustainability, shrinkage, damage, design, specification, manufacturing, packing, supply chain walk, order picking, pallet, primary, secondary, tertiary, roll cages, shelf ready, retail ready.

2.1 Introduction

This chapter describes not just the supply chain for packaged goods but also shows how our conception of that supply chain has changed over the years and will continue to change into the future. Exploring this change will bring in key elements of sustainability that are becoming interwoven with our understanding of the supply chain.

Within this chapter we will be referring to a 'package', so we should first consider what is meant by that term in the context of the supply chain. The focus of the supply chain is the product; the role of the 'package' is to get that product safely through the supply chain and on to the customer's home. Given that context, it is then self-evident that within the supply chain by 'package' we must be referring not just to the primary package but all of the elements, primary, secondary and tertiary, the 'packaging system', that come together at different stages to assure the safe delivery of the product to the consumer's home.

Each element of that system of combined packages plays both distinct and synergistic roles within the supply chain, each element being of key importance at a particular phase in the supply chain. The primary pack achieves key importance at two points in the chain, firstly during the filling process and secondly at the point of purchase and use by the consumer. During the intervening processes it is playing a synergistic role both in keeping the product intact and in good condition and very often contributing to the combined strength of the packaging system.

The fundamental role of the secondary pack is to provide collation and to enable shelf loading. As order picking from pallets into roll cages has become the norm, so the secondary pack has come to take over many of the roles previously ascribed to the tertiary pack. Indeed as the conditions within a roll cage can be significantly more stressful than in a pallet and so much of the damage that occurs is generated during this phase, it can be argued that the secondary is now more important for protecting the product than the tertiary pack.

Another change, to shelf-ready or retail-ready packaging, has significantly changed the role of the secondary pack. It is now expected to open easily, facilitate easy shelf loading and provide a good shelf fill. Designing a pack that will contain and protect a number of primary packs during stressful distribution, but then provide what is sometimes called 'one touch' opening, is far from a trivial task.

Traditionally tertiary packaging was designed to get the total package system and contained product through the supply chain with minimal damage. The extent that it fulfils that role today varies widely. Clearly for long distance journeys overseas or through long road or rail journeys that fundamental role is little changed. However, modern modes of transport including containerisation and air suspension on lorries have greatly reduced those stresses.

In many instances also goods are only sent relatively short distances as pallet loads before being broken up in order-picking centres. Despite this, many tertiary packs are still designed as if long distance palletised travel direct to the customer were still the norm. It is well worth investigating to establish the reality before setting out to specify design.

Returning to the theme of synergy, designers have got ever smarter at getting these individual units to work together so that we can be focused on the performance of the whole packaging system and not just its parts. Put another way, if a unit of a packaging system is not working synergistically with the other units of packaging, it is time to carry out a design review.

Our starting point in any development must be the relationship between a package and its contents and those contents must be the focus of any activity. We have over time moved from the idea of the package as being complementary to the product to being an integral part, in effect another component of that product.

The whole development of first environmental and then sustainability thinking on packaging started with the issue of packaging as litter. This view of packaging as an isolated item needing to be disposed of properly led to the development of the cradle-to-grave approach to packaging; realisation that recovered packaging waste was potentially a valuable resource led to the cradle-to-cradle approach and that thinking renders the product and packaging supply chains as one. Sustainability thinking and the imperative within it to prevent and eliminate waste then gave prominence to the role of packaging in preventing that waste and hence finally to the concept of the combined supply chain, where product and packaging are treated as being one.

This approach to the supply chain still concentrates on what we now know as the environmental pillar of sustainability and from there it is a natural step to examine how the other two pillars relate to the supply chain. The economic pillar has, most will agree, been with us longer even than the environmental pillar, cost and material optimisation being but two sides of the same coin. The social pillar is much newer in terms of recognition as such, but many of its component elements have been recognised for a long time. Understanding and control of the supply chain gives us understanding and control of each of these pillars. Addressing each of these pillars raises its own set of challenges not least because today it is hard to conceive of a purely national supply chain. Materials markets and sources are global, product purchasing by retailers is now primarily organised on a regional or global basis and the location of packaging manufacture is in turn closely linked to that of the product source.

One consequence of this geographically dispersed supply chain is that decisions about what elements to include within the supply chain boundaries become the subject of challenging decisions of balance. Good practice says that the specifier should at least have an overview of where the significant choices within their supply chain are made and seek to influence and change those that lie at the heart of issues and problems. Inevitably the practical problems of monitoring and controlling increase rapidly with distance. On top of this, it is now the norm for responsibility for individual segments of the supply chain to be subcontracted and the specifier may have no direct link to or authority over those subcontractors. These important issues of distance, system boundaries and exercising of adequate controls bring us on to the next part of this chapter.

2.2 Development, structure and inter-dependence of the segments of the global packaging supply chain

Although we speak of the packaging supply chain as if it were a single entity, in reality it is a series of sequential processes, the managers of which (the stakeholders) all view the package in a different light. Therefore before anything can be achieved within the supply chain, any new development or optimisation attempted there needs to be a process of stakeholder engagement.

How easy that will be depends on how effectively the supply chain has been mapped. If the supply chain has been achieved through a long chain of sub-contractual obligations, it can be difficult to establish a complete overview. That difficulty will increase the further back down the chain one moves and, as packaging sourcing by definition lies close to the start of the chain, it is also likely to be hardest to view.

In many instances that remoteness of supply can be extremely off-putting. Language barriers, sheer physical distance and the cost of establishing these links can be major obstacles. In practice, many do find these barriers insuperable and, as long as essential legal, health and safety requirements are met, decide to live with the situation. There is a clear downside to this in missed opportunities; the choice is for each individual to make.

Once the supply chain has been mapped then at each stage there will be a key stakeholder who needs to be identified. Supply chains will vary to some degree from product to product, so some stakeholders may be different according to the exact product concerned. That difference in stakeholders will be most evident between those that are manufactured in-house and those manufactured by third parties.

One valuable approach to stakeholder identification is the ‘supply chain walk’, a concept developed by ECR Europe[1] and used in addressing issues such as ‘shrinkage’ (product loss through theft, damage or process failure in the supply chain). This supply chain walk was conceived as a physical process whereby a project team actually visits each part of the supply chain to learn in some detail about its functions and what its capabilities and limitations are. This same principle can be applied, at the very least as a mental discipline, to stakeholder identification.

Whilst no two companies are alike, and responsibilities can be quite different even where individuals share similar job titles, a typical stakeholder list might look as follows:

- *Marketing* – will have clear views on the product and how it is presented, merchandised and used. They should also have a clear view of sustainability issues, real and perceived, surrounding the product and how customers and consumers are prioritising those issues.
- *Product/packaging design* – by working together can ensure that the overall sustainability of the product is maximised.
- *Purchasing* – plays a major role in identifying suitable suppliers and identifying the economic parameters within which it is acceptable to operate.
- *Packaging manufacturer* – where involved as a partner will act as a valuable source of advice and provide assurance of sustainability in their own processes and back down their supply chain.
- *Raw material suppliers* – by no means all companies will have the resources to work with even the major suppliers of raw materials used in their packaging. However, a clearly written policy setting out acceptable and unacceptable practices in respect of raw materials and their sources that has been agreed formally with suppliers will make a major contribution to establishing sustainable practices.
- *Manufacturing* – packing processes, manual or automatic, impose significant stresses on packaging that limit the scope to reduce resource usage in packaging. An in-depth understanding of how packaging and filling machinery interact and the key relevant performance parameters is essential for a successful outcome of any project. Joint work to identify and moderate those requirements and stresses can do a great deal to reduce resource usage.
- *Packaging technical development* – will provide the skills required together with the supplier to create and test a sustainably optimised specification.
- *Storage and distribution logistics* – Pira International[2] in 2003 calculated that loss through damage in the European fast-moving consumer goods supply chain cost industry €3.5bn each year. In addition, up to 3% of food is lost through spoilage before it reaches the consumer, whilst for fruit and vegetables distributed loose that loss can reach 25% according to retail industry research. Taking steps, such as 'supply chain walks' to identify points where damage occurs is a key first step towards the elimination of such damage.
- *Merchandising* – the *Global Retail Theft Barometer* report for 2010[3] shows that on average theft is equivalent to 1.36% of retail sales. In Europe that costs industry $41 billion. Prevention of theft and other losses in the retail environment can make a significant contribution to sustainability.
- *Consumers* – although consumers are not involved directly as stakeholders, their interests must be recognised. Between 3 and 6% of purchased food is discarded and food waste comprises 10–20% of food consumed[4]. According to WRAP, in the UK, food that was not but could have been consumed totalled 5.3 million

tons. Packaging cannot tackle all of this but much can be achieved through shelf life extension, portion control and the use of packaging in the home to slow deterioration of food.

2.3 Packaging as a means of delivering cost effective solutions

As already set out above, waste remains a significant issue in the supply chain. Cost has always had a profound influence on our ability to choose and specify packaging. Today financial impacts are recognised as one of the three aspects of sustainability alongside environmental and social impacts, each of which can in fact be viewed as a form of cost in its own right. Some might say that waste is a fundamental measure for all three. Waste after all involves loss of resources, unnecessary costs and avoidable environmental impacts. The social costs of waste are harder to calculate, but in a global society where many lack access to key goods, wasting products represents at the very least an opportunity cost to those peoples.

It has become common to view the environmental impact of packaging in the light of the weight of material used. In reality, as long as the packaging is being used in the best way to protect goods, that view is erroneous. None the less it persists.

Packaging weight reduction, much more constructively viewed as packaging optimisation, had long been a feature of the packaging development process long before it became fashionable to adopt it as an 'environmental' target. If we view the process as one of optimisation rather than straight reduction, then it should become clear that consistent product damage is a clear indicator that the process has been pushed too far.

Unfortunately no research exists to show how much cost would be involved in eliminating the €3.5 billion of damage mentioned above but we can get some indication of how we might benefit from a consideration of the analogous balance of resource usage and losses. From research we know that overall the packaging used to protect a product consumes only one tenth of the resource consumed in making that product.[5] Given that there is a clear relationship between resource usage and cost, that must surely imply that spending the right amount on packaging could produce a disproportionate benefit in overall cost. Whatever that balance might prove to be, it should be clear that it can never be a correct approach simply to reduce packaging as a standalone exercise without being assured that there will be no offsetting or oversetting losses elsewhere.

Concerted efforts to reduce packaging really started in the 1970s and have continued steadily ever since with packaging overall having more than halved in weight in that time.[6] Companies that have been applying packaging optimisation over that period, and that includes all major packaging users, are reaching the limit of the 'salami slicing' process that has traditionally been applied and now look to significant innovations to reduce their packaging usage. Whilst in the past a company following this approach is likely to have achieved overall around a 5% per year packaging reduction, that is now becoming increasingly difficult to achieve. One sign of that slow down is that the Courtauld 2 Commitment in the UK had a target to reduce packaging by 5%

over three years from 2009 to 2012 (See www.wrap.org.uk), a reduction that in the past might have been targeted in a single year.

Whether or not potential still exists to make significant packaging reductions can depend heavily on the source of the packaging. One example of a very significant opportunity for reducing packaging in this way was found in respect of the secondary packaging for goods imported from the developing world. Due most often to a wish to avoid damage in transit, a significant proportion of goods susceptible to breakage from such countries can be overpackaged. According to informed sources interviewed during a study in 2010, this overpackaging is up to 100%.

Identifying where other opportunities arise is a less simple process. Distribution systems report by default and hence do not have mechanisms to detect or report where a package may be overspecified. One way that professional packaging teams will guard against such eventualities is by reviewing packaging every two years against a packaging utilisation key performance indicator (KPI). As a consequence, overspecifying is unlikely in companies with such teams; on the other hand, there is a much greater possibility of overspecifying by companies that do not apply such regular checks. Packaging technology moves forward steadily so even if looking for large improvements per year may be too challenging, given the history of packaging optimisation the chance of finding improvements in packaging over a slightly longer period is still high.

Specifying performance for primary or retail packaging brings into consideration additional factors such as shelf appearance, food contact safety and consumer appeal. The choice of packaging is still influenced by price and the best balance between performance and an acceptable end cost.

There is a trend for packer fillers and retailers to augment in-house packaging teams by working collaboratively with their suppliers. However, such companies still need to have the expertise to review and challenge supplier specifications and brief those suppliers on performance requirements. Otherwise there is a tendency to employ conventional weight-based specifications because this makes the process of price comparison easier. A company that applies this weight-based approach is not in the best position to optimise performance and thereby is likely to overspecify. This latter point is why increasing numbers of people regard performance specifying as the way forward in resource optimisation.

There can be hesitancy on the part of a supplier to suggest a change of a material grade based on performance specifying to a customer, even if their expertise indicates that an alternative grade material could provide the required performance. This is because, if the packaging fails, they may run the risk of being deemed to be responsible and be charged for any product losses incurred by the customer. What can happen then is that the supplier may recommend that a customer trial an alternative material but leaving it to the customer to make the final decision.

Smaller packaging suppliers may also experience difficulties in working with performance specifications. The resource and expertise levels required to work with such specifications are not inconsiderable and unless their customer base strongly demands such an approach their supplier may not regard the investment as justified. Even for large packaging suppliers providing the necessary level of resources to support performance specifying can be an issue. Only if a customer is large enough to place significant orders may the supplier feel justified in devoting the amount of resources needed to create a performance specification.

Packaging should be assessed primarily in its role to reduce waste either through product protection or through process optimisation. There is still a significant amount of waste in the supply chain, referred to as 'shrinkage'. Chapman and Templar[7] define shrinkage as: intended sales income that was not and cannot be realised, retailers include within this 'malicious shrinkage' (external theft, internal theft, inter-company fraud) and 'non-malicious shrinkage' (spoilage, damage, data errors, pricing errors, delivery errors and scanning errors). Around 1.4% of sales disappear in this way[1] costing retailers around one-third of their profit margin. About 0.8% of goods are known to arrive damaged in the store. Only through performance specification and process optimisation can such losses be prevented.

Process optimisation involves re-examining the role of the packaging and specifying it according to its actual function. A good example can be seen in a 2009 retailer initiative to ship wine from the southern hemisphere in bulk and only pack it once it reaches the UK. During long distance shipping the container is unnecessary so its performance is zero or indeed negative as shipping it occupies space and consumes energy. The actual performance of the bottle is in retailing and consumer use and ageing in the bottle where relevant and so bottling in the country of consumption makes great sense whilst the package only plays a role where it is essential.

Given that packaging reduction on its own is not an effective means of cutting overall cost and even liable to be counterproductive because of damage increase, how do we set about delivering cost effective packaging? Clearly, as we have seen, the first step is to characterise the supply chain in all of its elements and then to decide what the governing KPIs are going to be. The next stage must be to look at the requirements of the product.

In an ideal world the supply chain will have been designed with the product in mind. However, we have to accept that the supply chain as a whole will have represented a major investment that has to be amortised over a significant period whilst products and packaging technology tend to evolve quite rapidly. In practice, most often it is the product and its packaging that have to do the adapting to the essentially fixed supply chain requirements.

For the purposes of this chapter we will assume that the primary package has been so designed as to provide the immediate protection of the contents in terms of barrier, light, etc., and focus primarily on physical damage protection and supply chain interactions. That is not to say, however, that the influence of product shelf life on supply chain efficiency is not worthy of serious consideration.

One interesting illustration of the type of challenge from product and packaging evolution faced by the supply chain comes from the growth in the sales of short shelf life, primarily chilled, products. Firstly, the product has to arrive in the store with sufficient remaining shelf life to allow for consumer selection and the consumer's own storage requirements in the home. Secondly, products near to the end of their saleable period are frequently discounted and may need to be destroyed. Such losses can approach 20%.

Given these changes, how can process and packaging optimisation be applied to reduce those losses? There are two potential process optimisation roles for packaging to play. First of all, barrier technology continues to improve and, perhaps more importantly, so-called 'active' packaging (first mooted in the 1930s) is becoming a reality. So we can see significant potential there to increase shelf life and give more time during which the product can be purchased and consumed. The second theme to this optimisation involves improving the ability to actively determine the real remaining shelf life of a product through the application of shelf life indicators. Currently shelf life determinations must necessarily be made on a conservative basis, allowing for the possibility that conditions in transport may be less than ideal. Monitoring the packaging in transit allows a much more precise determination to be made of available shelf life once the goods arrive in store.

Some monitoring devices travel with the load, recording conditions in the vehicle and individual pallets or tertiary packs. They are more often used analytically to determine weak points to be addressed in the distribution system, although they can be used to inform a receiving store what the in-store shelf life should be set to. Monitors specifically designed to be incorporated into packaging tend to take the form of labels that react either to time/temperature effects or to a buildup of substances in the package known to relate to spoilage. This approach provides staff within a store with specific information regarding the safe residual time for the product to be displayed, cutting down on unnecessary disposals.

Both of these approaches to shelf life monitoring add to packaging and distribution costs whilst enhanced barrier protection contributes to packaging costs. Clearly, therefore, those costs need to be justified. Such a justification can only really be made based on a total supply chain cost approach, illustrating once again the importance of involving all stakeholders in decisions regarding supply chain enhancement through packaging.

Other critical factors that relate to process optimisation within the supply chain are related to the physical strength and stress-resistant factors of the packaging and its constituent materials. Here we should still continue with the theme of understanding and respecting stakeholder priorities within each section of the supply chain and through that supporting the best overall performance for the whole.

We still cannot escape from the overall impact of cost controls on packaging decisions. The first consideration and the last will be the combined cost of the units of the package system within the product as a whole. Establishing an optimum overall cost for a packaging system may sound straightforward; often it is not. A primary reason for that difficulty lies with the buying process, where very often each unit of the packaging system for a product is bought separately and each is assessed separately in respect of its contribution to the overall cost, and apparent savings that may be available for each individual unit of the packaging system.

In the early days when a product is being launched such costing inconsistencies should be easy to detect within an overall budget. At this stage there should be clear balanced KPIs for the total system including costs that simplify the establishment of an optimised overall cost. As time passes, however, there is a risk that each item within a packaging system will be cost optimised individually without necessarily taking full cognisance of the cost impacts on other parts of that system. Here the same point needs to be made as was made in respect of optimising physical performance of packaging. If you do not consider the whole when changing just a part, then the risk of losing as much or more than you are gaining must exist.

We have talked about KPIs being determined for each stage of the supply chain and there are two ways that can be done; one is through factory trial and the other through technical investigation. In essence whilst a factory trial accompanied by careful observation and recording can achieve a great deal, in particular regarding where and how failure occurs, a technical investigation will reveal much more about the underlying reasons for failure and how they may be addressed. The next section will go into greater depth on the types of test that can be applied and the results that can be expected.

A technical investigation is unquestionably more resource and time consuming but it does give a much better basis for decision making and the eventual establishment of performance-based specification. On the other hand, a factory trial tends only to point to materials that worked and hence to lead to the type of specification that primarily describes a structure and combination without giving clues as to why. A performance specification based on a technical investigation reveals much more about what aspects of a package are critical and why, hence allowing much more freedom to look creatively at generating solutions for the future.

Another benefit that the analytical approach combined with performance specifying brings to packaging is that it tends to expose and thus help to eliminate preconceived notions about which elements of a package's design and specification are critical. Such preconceptions about the reasons for packaging failure and solutions are quite common in the absence of a technical analysis, but in many instances they will be found to have grown over time and in reality to be erroneous.

In addition, by enabling real underlying causes to be established, a technical analysis approach will encourage questioning about whether a packaging change is the right solution or whether a machine change would be more effective. In the absence of such technical understanding, it is normal for the inherent cause to be assumed to lie with packaging. Determining the solution from that point may well require going back to first principles to find whether the machine requirement can be met realistically and cost effectively through packaging and if not whether instead changes to machine components or settings would produce a more effective result.

Choosing the right form of technical analysis to represent what is actually happening in a process is a challenging task that requires a significant degree of expertise and experience. That may be one reason why so many specifications avoid defining performance parameters for packaging and instead focus on simple physical measurements of parameters such as the grammage or caliper of materials that factory trials have shown to work. Whilst it may be more difficult and time consuming there is no substitute for observation first hand of the process to find the critical points and then finding a test or tests that will allow accurate prediction of whether a material and construction will be optimum.

Simulated transit testing is one example of such an underutilised form of test that is an accurate indicator of performance and hence comparator of potential solutions. Standard transit tests where loads are sent on a journey as part of a load of standard products are a classic example of the act of observation changing the outcome. Such simple factors as a pallet being marked for observation or returned to base for analysis in an otherwise empty vehicle will change the result. Cost is also a consideration here; standard transit tests over intercontinental distances are prohibitively expensive and often omitted for that very reason. Simulated testing that does not involve lengthy and costly shipping can be much more cost effective and, with the use of instrumentation, much more repeatable.

Transit test simulators allow the load to be subjected to the same critical stresses they will experience during their journey but in the laboratory. Some models even allow stresses recorded during an actual journey to be played back into the test load. Thus the tests are reproducible when applied to alternative packaging systems and, where failures occur, the reasons can be observed and used to give precise feedback to designers and specifiers.

This kind of performance-related testing and specifying has the potential to reduce cost in the longer term, even when it is more expensive in the short term. Down time in the factory is expensive, eliminating the problem through trial and error is time consuming and there is no guarantee that any changes made will not have knock-on impacts elsewhere. The underlying causes of product damage will remain unknown and require a fresh solution each time without the benefit of fundamental knowledge. This difficulty of resolution will tend to lead to overspecification as a means of avoiding further problems. Purchasing options also remain constrained through being based on material rather than performance parameters.

2.4 Challenges of the supply chain

We have already seen above how significant shrinkage is to the supply chain. Were shrinkage to be eliminated, then retailer margins would be increased by 62%. Packaging can play a significant role in preventing this shrinkage. Just how has been explored in great depth by ECR Europe and the reader is referred to their report *Package Design for Shrinkage Protection*.[8]

Poor basic packaging design significantly increases the risk of shrinkage. Badly designed packs are more likely to:

- allow their contents to become damaged in transit
- cause contamination through leakage
- experience product spoilage or damage
- contribute to product loss through misidentification
- lose their contents
- become too unsightly to sell
- suffer decreased shelf life and consequent reduced sales.

The primary drivers of shrinkage other than through theft are:

- *Spoilage*: products that have reached their expiry date or gone beyond agreed temperature parameters and are no longer safe to sell to consumers or staff.

- *Damages*: refers to products that have been damaged during the journey to the shelf and in the general store environment.
- *Data errors:* errors in the recording of product details on company systems.
- *Pricing errors*: losses caused by errors in the way in which goods are priced and sold in the business.
- *Delivery errors*: losses caused by incorrect quantities booked to the store inventory but not physically delivered or transferred.
- *Scanning Errors*: errors occurring at the point of sale leading to a discrepancy in the store book stock.

ECR Europe also identified these packaging related factors in being critical in the prevention of shrinkage:

- placement and readability of bar codes
- robustness of inner and outer packaging
- marking and design of break packs
- clear identification of at-risk items
- packs that are difficult for a would-be thief to hide
- packs that cannot be covertly opened, tamper-evident packs
- packaging that is protectable by electronic article surveillance (EAS)
- barcode usage rules that minimise reading error
- product shipment, distribution and assortment controls
- use of testers and samplers
- fixture and secondary display design
- store layout, design and lighting
- returns policy.

There are also a number of solutions in respect of supply chain processes that in some degree relate to packaging:

- robust documentation systems for orders and deliveries
- secure storage, dispatch, transit, delivery, receipt and in-store storage
- shelf replenishment and range change processes
- procedures for damaged and returned merchandise.

There is a tendency to picture the supply chain between factory and customer in terms of pallet loads of goods travelling together between warehouses by road, rail, air or sea. There is a great deal of knowledge and expertise built up to support that concept regarding matters such as optimised pallet fill and package top-load strength. On that basis one can expect optimised and damage-free pallet loads to be the norm. In fact, we do indeed find that most packaging-related issues in the supply chain now occur after the palletised phase.

We have already addressed the importance of understanding problems through technical analysis prior to specification. If that is done properly, then damage should be minimised, but what do we mean by 'minimised'? Originally it would be said that damage has been minimised when the following conditions have been met:

- All legal requirements relating to the package and its contents have been

- There are no health or safety issues emerging from the damage.
- The damage is not causing significant knock-on effects in other parts of the business.
- Performance issues in the supply chain related to packaging fall within agreed norms.
- Consumer complaints related to failures caused through packaging fall below the threshold acceptable level set by the producer.
- Levels of packaging-related loss at the commercial customer fall below the threshold level established with that customer.
- The cost of rectifying the problem is such as to make it economic in terms of the product value.

In addition to the above, we need today to consider carefully the impact of product loss on the sustainability of a business. We have already seen that on average the environmental impact of packaging is only one-tenth of that of the product it protects. So there is a question that needs always to be addressed whether the resource implications of upgrading the packaging are justified by the reduction in resource loss in the product. In practice the answer will very often be yes and the challenge then becomes, as we have seen before, justifying the cost of that upgrade.

As always it is the social aspect of loss and damage that is hardest to address. In a world where food shortages are a fact of life and many people are deprived of necessities, can it ever be right to allow damage and wastage to occur? On the other hand, should we balance that by considering that had that wastage been prevented, it is unlikely that the goods saved would somehow have reached the needy? Can the fact that more goods were produced potentially generated additional work for those in society needing it be regarded as a social benefit? There are no easy answers to questions of this type, but it is no less important to keep on addressing them.

If despite all precautions damage higher than the acceptable levels set out above is occurring, how should it be addressed? First of all the likely source needs to be established, ideally by following the supply chain walk approach set out above for packaging development and optimisation.

At the start of the chain production and palletisation line, damage such as crushing, impact, poor closure or scuffing tends to be characteristic and the source should be straightforward to identify. Beyond the production line and palletisation, the next likely cause is from truck handling of pallets. Trucks can impact loads, pierce packaging and even drop or topple pallets. Such incidents are, or should be, sporadic and a combination of often tell-tale damage characteristics and warehouse logs should eventually run these down. Of course, the further along the supply chain the incident occurred, the harder the task of identifying the cause will be.

Damage in modern lorries or containerised sea or air transport is relatively rare and most likely will have been caused by some one-off incident. Deliveries from more remote locations may well have travelled by less modern transport and over poorer roads, so the damage may be more systematic. Often this problem of poor local transport conditions will be offset by overpackaging. Whether or not, despite this overpackaging still failing, the receiver of the goods is willing and able to undertake an investigation in a far-off location is up to the individual. Rightly or wrongly often accepting this overspecification or damage may be perceived as the lesser evil.

Today a great deal of the product damage that is found occurs after the palletised section of the supply chain where individual units, primary, secondary or tertiary, travel mixed together with other products in some form of cage or trolley. In many instances loading of these cages is random and it is easy for items to be loaded at an angle, inverted or with heavy items superimposed on fragile ones. If loading of products is found to be the source of the problem, then there needs to be consideration of making the product more cage friendly in terms of its package dimensions, appearance (to make its fragile nature more evident) and protection. It is critical once an incident has happened to visit the order-picking operation when in full operation and seek out points where damage can happen. Such visits, if they have not been carried out previously, are invaluable for picking up information to support design and specification.

2.5 The importance of training

Nobody seeking to work effectively on supply chain topics can afford to be so much of a specialist that they cannot get a perspective on the priorities and goals of others. Arguably the most effective form of training for this is 'on the job'. Just as the supply chain walk is the most effective means of understanding the supply chain, so it is the most effective way of understanding the perspectives of the people who manage it.

Clearly having identified and formed an understanding with key stakeholders, the next stage is to weld them into teams to tackle specific problems. From what has been said above it should be apparent that persuading individuals with quite different and even conflicting goals to work to a common goal is a significant skill. Training in team building is important for anybody who is involved in forming a project team, even if they are not leading it.

Knowledge of specifying is of course fundamental to any packaging manager but performance specification may be less familiar. At the same time defining performance KPIs at each point of the supply chain is clearly logical, for those performance KPIs should be captured in the form of performance specification. Anybody unfamiliar with performance specifying will clearly gain an advantage from studying the technique.

Performance specifying needs to be backed up by testing. Some tests will be familiar, others much less so. There is a skill involved in selecting the correct test that most accurately reflects the real-life situation under study and it is well worth while having training to gain that skill. Overall it is probably true to say that instrumented transit package testing is the least well understood and least widely applied area of testing technology, despite its significant potential to cut cost and wastage. From a technology point of view, this is potentially one of the most fruitful areas to gain knowledge through training.

2.6 Sources of further information and advice

- *Packaging for sustainability: Packaging in the context of the product, supply chain and consumer needs*[9]
- *Effective Packaging Effective Prevention*[10]
- *Packaging Reduction – Doing More with Less*[11]
- *Shrinkage – a collaborative approach to reducing stock loss in the supply chain*[1]
- *Environmental Impact of Products*[12]
- *Shelf Ready Packaging (Retail Ready Packaging) Addressing the challenge*[13]

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3
Packaging functions

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Abstract: This chapter examines in some detail the different functions of packaging. Emphasis is placed on understanding the properties of the product and the hazards it will face in the supply chain, including the demands of the consumer. There are different and sometimes conflicting requirements and expectations at each stage of the life of the product, and these must be understood before appropriate packaging solutions can be sought.

Key words: functions, containment, protection, physical damage, shock, vibration, compression, humidity, water, light, oxygen, pilferage, tampering, tamper evidence, journey hazards, preservation, biotic spoilage, abiotic spoilage, shelf life, water activity, pH, MAP, vacuum packaging, convenience features, information, selling, product cost.

3.1 Introduction

It is difficult to imagine life without packaging, and yet in many cases the consumer barely notices it is there, let alone thinks about what functions it is performing. The delivery of basic commodities such as coffee, tea, sugar and jam from factory to consumer relies on efficient use of packaging, and highly perishable foods such as fresh meat and fish, ready-prepared meals and salads would not be so readily available without the packaging which plays a key role in preventing spoilage, thus extending shelf life and minimising wastage. Electronic equipment such as televisions, personal computers and DVD players, along with domestic appliances such as irons, kettles, toasters and microwave ovens all rely on packaging to protect them against the potential damage encountered in the distribution chain. The growth in Internet shopping brings a need for packaging to be robust enough to survive the mail order delivery system, and to readily identify the product throughout the handling processes.

But packaging has to fulfil more than these functions of containment, preservation, protection and identification. It also influences the convenience in use of a product, and, just as importantly, it is instrumental in selling the product, by attracting the consumer.

Each of these functions will be discussed in the rest of this chapter. Many of the points being made will apply not only to consumer goods, but also to all other ‘products’ such as raw materials and ingredients for food, pharmaceuticals and cosmetics, components for the automotive and aeronautical industries, and packaging materials being shipped to their point of use. The functions of containment, protection and identification are just as important for the safe and efficient movement of such materials, and examples will be given where appropriate.

In all cases, to understand the functions of the pack and to ensure that they are adequately met, it is essential to define the product in terms of its nature, critical properties and value. This should always be the starting point; packaging does not have a 'life' of its own and without a product it has no reason to exist. The packaging designer/specifier needs to work closely alongside the product developer to gain a full understanding of the product and what can cause it to deteriorate to the point of being unacceptable. Only then can appropriate packaging be specified and sourced.

3.2 Containment

Properly designed, constructed and sealed packs provide complete containment for the contents, preventing unsightly or dangerous leakage, or loss of parts. This containment must be assured throughout the expected life of the product, including the numerous handling stages from the end of the packaging line to the final consumer use. Containment also means keeping a number of different or the same items packed together, and this applies to primary, secondary and tertiary packs. Examples include:

- packs of different varieties of crisps assembled into one bag, or the various parts needed in a hair colouring 'kit' such as colour, developer, gloves and comprehensive instruction sheet
- filled bottles of shampoo collated in a display tray
- stretch wrap film used to secure goods to a pallet.

If leakage or loss occurs, the consequences can vary from a minor inconvenience to a major and potentially catastrophic incident. A leaking bottle of bath foam is likely to result in a failure of the selling function, as no one wants the leaking pack on the shelf, and it may also have affected neighbouring packs so that they are also unsaleable. It may also fail to inform, if the type matter has become obliterated, in which case it may be illegal, and this also applies if it is underweight due to loss of contents. If, instead of a relatively innocuous bath product, the product is an aggressive or corrosive liquid, such as some household and industrial cleaning chemicals, the implications of leakage can be much more serious. If a vital part is lost, for example an instruction leaflet, the product may be rendered unusable.

3.2.1 Evaluating the containment function

A key step in evaluating the risk of leakage is to identify the factors which can affect the efficient containment of the product. Consider first the potential leakage points of a pack, including not just the obvious opening points, e.g. a screw threaded cap, but all other points where the pack could fail. Then consider how and why failure could occur at each of these points. Some examples to stimulate thought are given in Table 3.1.

Once the potential leakage-causing factors are identified, it is the role of the packaging technologist to ensure that the required performance characteristics are designed-in at the development stage, carefully specified on component and process

Table 3.1 Examples of containment failure

Pack type	Potential failure points/ mode of failure	Typical possible causes
Cartons	Glue seams split	Wrong adhesive for board and conditions of use; poor control of adhesive application conditions
	Tuck-in flaps work loose, tear	Wrong board weight for the weight of the product; poor cutting and creasing of the carton
Bottles/caps	Leakage at neck, misalignment of cap	Dimensional inaccuracies in bottle and/or cap finish; wrong cap application force; wrong wadding material
	Leakage at mould part line and/or injection point (plastic)	Poor control of moulding conditions
Sachets	Leakage in seal areas	Wrong sealing layer; poor control of sealing conditions; product in seal area
	Leakage in body of sachet	Puncture by product or by external means
Tubes	Leakage at neck, misalignment of cap	Dimensional inaccuracies in tube and/or cap finish; wrong cap application force; wrong dimension of orifice
	Leakage at base of tube	Wrong sealing layer; poor control of sealing conditions; product in seal area

specifications, and that checks are in place to ensure specifications are followed. Leak testing should be carried out during development, making sure that the likely conditions of use are taken into account. For example, a product intended to be carried around in the handbag requires a different test protocol from one which will be stored in one place for most of its useful life. Leak testing can be carried out by a variety of methods, including simple inversion of packs or by applying pressure to seals, in both cases observing the effects over time.

3.3 Protection

Protection means the prevention/reduction of physical damage to the product, during all stages of its life. This includes manufacture and packaging operations, storage and handling in warehouses, transport to the merchant, distributor or store for sale, display, and moving to the final usage point. It also includes storage and use of the product, e.g. in a kitchen, garage or garden, and any other handling operations which the final user may be reasonably expected to carry out on the product.

Damage can occur at any of these handling stages, although most physical damage happens in the warehousing and distribution environment, due to dropping (from pallets, and during order picking and transit), jolting, vibration (in vehicles), compression (when stacked in warehouses) or puncturing (often due to use of poor quality pallets). Damage can also result from environmental factors such as dust, dirt, birds, insects and rodents. See Table 3.2 for a list of typical hazards, their causes and effects.

Protection against physical damage is important for all products, not just the

Table 3.2 Typical hazards in the supply chain, their causes and effects

Hazard	Causes	Possible effects
Shock	Falls from conveyors, pallets, vehicles, possibly due to poor stacking; shunts due to irregular movement along conveyors; drops due to manual handling; impacts in transit due to driving over poor road surfaces	Breakage; deformation
Vibration	Vibration occurs naturally in all types of transport. In road transport the effects are enhanced over the rear axle of the vehicle, and by any imbalance in the load. Irregular road surfaces also increase vibration	Breakage; scuffing; product separation and/or settlement; loosening of screw caps; garments falling from hangers
Compression – static	Stacking in storage, made worse by damp conditions	Breakage; crushing; load collapse
Compression – dynamic	Clamp truck pressure; severe vibration during transport	Breakage, crushing, stack resonance
Puncture	Poor quality pallets, bad handling practices	Breakage; product spoilage; load collapse
Changes in relative humidity	Loads left outside; goods stored in damp warehouses, or where climatic conditions are not controlled; goods shipped via and to different climates	Product spoilage, e.g. corrosion; packaging failure, e.g. damp corrugated board cases
Changes in temperature	As above	Product spoilage; drying out of paper/board materials;
Exposure to light	Retail display	Fading of product and/or pack; product spoilage, e.g. rancidity
Insects, rodents, birds, dust, dirt	Goods stored in warehouses not cleaned or treated for pest control, or where doors/windows are left open or badly fitting	Product spoilage due to poor hygiene; contamination of product and pack
Pilferage and tampering	Goods exposed to uncontrolled personnel access; display on shelf	Loss of products; damaged packs and products; contamination; counterfeit products

obviously fragile such as glass and ceramics, or electronic components, but also for plastics, textiles, paper and board items, etc., whilst the unacceptability of damaged product may be obvious, aesthetic damage to the packaging, such as scuffing of labels/cartons, or scratches on plastic tubs, may also be causes of rejection.

3.3.1 Evaluating the protection function

To understand the level of protection required for a product, a simple equation to bear in mind is that the inherent ruggedness of the product plus the protection provided by the pack must be equal to the likely hazards encountered in the journey from factory to consumer and ultimate use of the product (Fiedler, 1995). The key steps to follow to decide what type of packaging will provide the product with the appropriate level of protection are:

- define the product
- define the environment to which the product is likely to be exposed
- investigate the properties (including cost) of available protective packaging materials (this step will be covered only in outline here).

Only when armed with the relevant information from each of these three steps will it be possible to propose possible packaging materials and pack formats which will match the defined characteristics. These proposals must then be tested in conditions which simulate 'real life' before packaging specifications can be agreed and the proposals implemented and monitored.

When developing solutions, remember it is the combined performance of all levels of packaging which is important. There will potentially be several different solutions, perhaps using a relatively weak primary pack which relies on its secondary pack for physical strength. Or it may be possible to design a sturdy primary pack which dispenses with the need for any secondary packaging, and is stacked directly onto a pallet. Therefore it is essential to consider not only the primary packaging when carrying out a development programme, but to combine this with an investigation of possible secondary/tertiary options. This combined approach will almost certainly result in the most cost effective solution.

3.3.2 Defining the product

As already stated, understanding the product is the key to any packaging development process and product development or research departments are likely to be the source of this information. The data may have to be developed from 'scratch' by carrying out actual tests, or there may be similar products with proven performance which can be used for guidance.

The aim is to define the product type (physical form) and how 'rugged' it is in terms of what conditions it can withstand before damage occurs, for example what level of shock, what vibration frequency, what top load, what range of temperature and humidity?

The product value will also have to be considered as it will decide the level of protection which can be afforded, and it will have a bearing on its attraction to the pilferer and/or the counterfeiter. Also at this point, any applicable legislation must be noted, e.g. legislation concerning hazardous goods.

3.3.3 Defining the environment

How the product is destined to be stored, moved, displayed and sold needs to be identified and clearly understood, as each of these stages has its own inherent hazards. This includes all operations, both internally within the premises and externally when the goods are outside of the direct control of the producer. One of the results of globalisation of manufacturing amongst large producers is that the distribution chain has become more complex, with multiple handling and exposure to a range of different climatic conditions. The more control which can be exercised, the more the risk of damage can be reduced and the less protection will be required from the packaging. Conversely, if control is poor, packaging requirements – and costs – will be high.

The common hazards will now be considered in more detail. In this section, refer again to Table 3.2 for possible causes and effects of each hazard, and also to Table 3.3 for ways of minimising the effects of each hazard. Examples will be given of possible protective packaging materials, but it is not the intention to cover materials in detail in this chapter, as they are covered in other chapters in this text.

Shock

Shock is defined as an impact brought about by a sudden and substantial change in velocity, and is usually encountered when an item lands on a stationary surface such as a floor, or it can happen during horizontal impact such as when items knock against each other on a conveyor. Key points known about the shock hazard are:

- Not surprisingly, the more manual handling there is, for example in a mail order environment, the greater the possibility of shock damage occurring. Most of these drops will be from a height of around 1 metre, i.e. hand height.
- The heavier the pack the lower the likely drop height.
- As the weight of a pack increases, and personal injury becomes an important consideration, the human being will handle the pack carefully and will eventually resort to mechanical handling. Palletised loads, moved by forklift truck are much less likely to be damaged than primary or secondary packs.
- Handholds reduce the likely drop height.
- Cautionary labelling such as 'This way up' has minimal effect.
- Damage to the packaging around a product is most likely when the pack is dropped on a corner or edge, but damage to the contents is greatest (and unseen until the pack is opened) when the pack is dropped flat onto one of its faces.

The most effective way of minimising the effect of the shock hazard is to cushion the impact. Figure 3.1 shows the shock pulses for a cushioned and an uncushioned drop. In the cushioned drop, the cushioning attenuates (weakens) the initial shock at the pack surface so that the product's response takes place over a longer period of time. The areas under the curves represent energy.

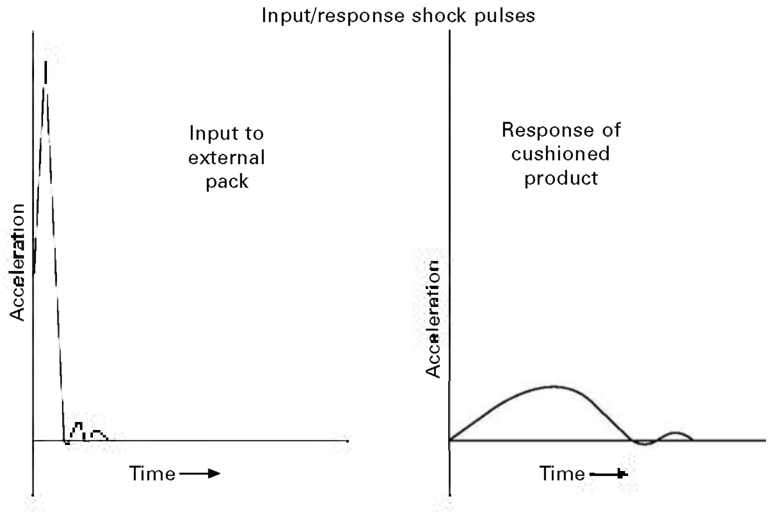
Some options for cushioning materials are listed in Table 3.3. The more resilient the material, the better its cushioning properties, so polymeric foams are more effective than corrugated board. The choice must always be made by going back to that fundamental point: what level of protection does the product need? Other factors to be considered are availability, possible contamination, surface abrasion, environmental impact and, of course, total cost.

Manufacturers of specialist cushioning materials produce dynamic cushioning curves which allow the user to calculate the thickness of material needed. This is

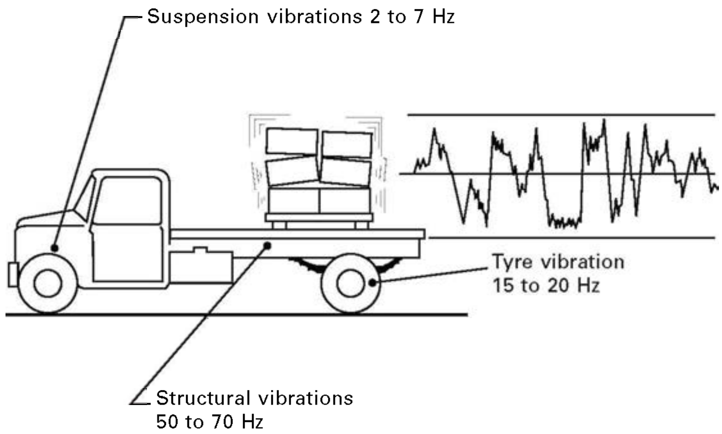
Table 3.3 Ways of minimising the effects of the common hazards

Hazard	Minimising the effects	
Shock	Reduce the amount of manual handling	
	Use cushioning materials, such as:	Polyethylene foam Expanded polystyrene Loose fill polystyrene chips Bubble wrap Compressed paper Moulded pulp Corrugated board
Vibration	Reduce product/pack movement:	Use tight shrink wraps Use accurate dimensions when sizing packaging Use pallet adhesives to prevent case movement
	Reduce contact points:	Good design of containers Label recess areas
	Protect surfaces:	Scuff resistant lacquers and film coatings
	Isolate the vibration	Use appropriate cushioning, or special 'air ride' vehicles, as used for susceptible products such as electronics
Compression	Good design of all levels of packaging	Design as a total pack, primary, secondary and tertiary
	Selection of pallet stacking pattern	Consider pallet stability and the likely stacking height
	Good storage conditions	Monitor temperature and humidity, especially when using paper/board
Puncture	Good pallet quality	Specify and monitor
	Good handling practices	Operator training
Changes in relative humidity	Operate good handling and storage practices throughout the supply chain Monitor relative humidity and introduce controls if necessary Use moisture-resistant materials/coatings	
Changes in temperature	Operate good handling and storage practices throughout the supply chain Monitor temperature and introduce controls if necessary Use temperature-resistant materials, e.g. expanded polymeric foams	
Exposure to light	Use opaque packaging	
Insects, rodents, birds, dust, dirt	Operate good standards of hygiene, including pest control, throughout the supply chain Carry out regular inspections to check on compliance	
Pilferage and tampering	Consider tamper evidence features in all levels of packaging Consider need for surveillance Consider anti-counterfeit measures	

important in the packaging of electronic goods and household appliances and further information can be found in the sources of information and advice at the end of this chapter.



3.1 Effect of cushioning on shock.



3.2 Typical sources of vibrations in road vehicles.

Vibration

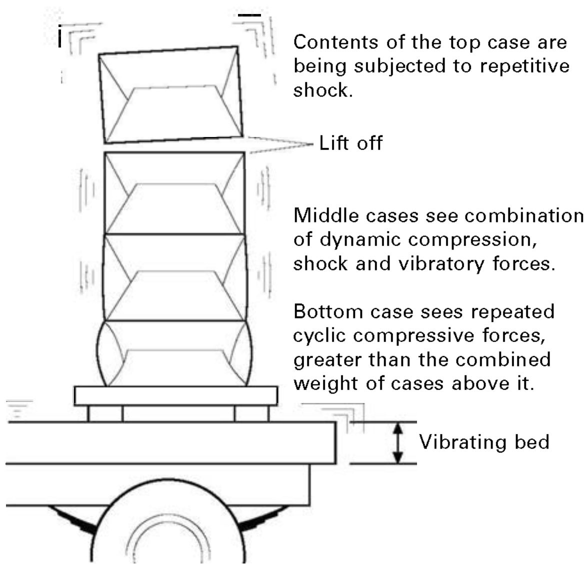
Vibration refers to oscillation or movement about a fixed point. The distance moved is the amplitude and the number of oscillations per second is the frequency, measured in hertz (Hz). It is impossible to avoid vibration, as it is associated with all modes of transport. Frequencies below 30 Hz are most commonly encountered in road transport, and are of most concern. The combined effects of different frequencies can be considerable, as shown in Fig. 3.2. The greatest effect is typically experienced over the rear wheels.

Vibration resonance describes a condition in which a vibrational input is amplified, such that the output is out of all proportion to the input, sometimes resulting in severe damage. Often the only way to avoid this is to redesign the product to eliminate critical resonance points. Occasionally, loads go into a stack resonance condition, where each container goes into resonance with the previous one until the entire stack is bouncing (see Fig. 3.3). This condition can result in destruction of the product and pack. The dynamic load on the bottom container can be several orders of magnitude greater than the actual weight resting on it, which means that a corrugated case specified to withstand a calculated top load will now be totally inadequate. Also, the top container is subjected to extremes of repetitive shock and vibrations of considerable amplitude. Since this top layer is essentially weightless for short periods of time, small side movements will cause it to move. In a stretch-wrapped load this movement can skew the entire pallet load to one side.

Vibrational effects should be designed-out at the development stage, by ensuring that packs are tightly wrapped and accurately dimensioned so that movement is limited, and by removing obvious contact points. As these are likely to be low-cost or even no-cost options, they should take precedence over adding features such as scuff-resistant coatings.

Compression

Like vibration, compression is an unavoidable hazard in the distribution environment, as all products are stacked in warehouses and on vehicles. The challenge for the packaging technologist is to understand the likely compressive forces and specify appropriate packaging to limit product damage. Typically, the warehouse condition is one of static loading over time (static compression) but dynamic compression, encountered when using clamp trucks, during rail shunting and in stack resonance must also be considered. Dynamic compression describes a condition where the compressive load is applied at a rapid rate. Compression testing in the laboratory



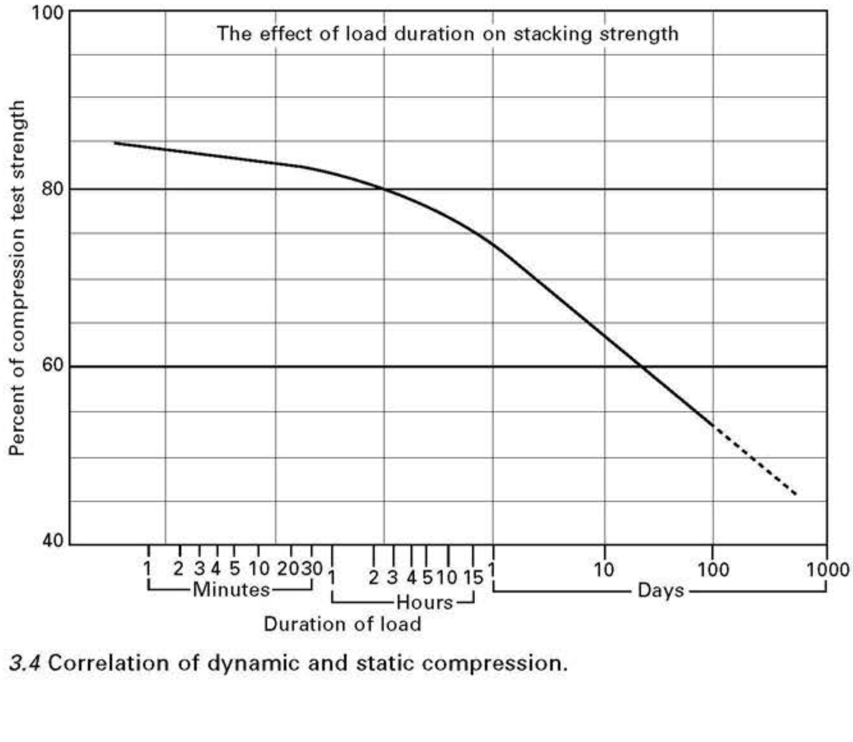
3.3 Stack resonance on a vehicle.

(e.g. test method ISO 12048:1994) is completed in a short period of time, i.e. it is a measure of dynamic compression values but the results can be correlated to indicate probable long-term warehouse stacking performance, which is likely to be of greater interest. This correlation for corrugated board is shown in Fig. 3.4. The initial part of the curve shows what the case will bear under dynamic or short-term load application. A container with a compression strength of 100 kg load clamped at an 85 kg load would be in danger of failing after about 10 minutes. The same container would fail in about 10 days if loaded to 60 kg. To last 100 days, the stack load should not exceed 55% of the dynamic compression value.

Not surprisingly, the humidity conditions encountered during warehousing and distribution can dramatically reduce the performance of corrugated board cases due to the hygroscopic nature of paper. For example, a change in relative humidity from 40% to 90% can result in a loss of about 50% of the case stacking strength. Thus corrugated cases destined for very humid conditions will have to be specified with sufficient stacking strength to allow for this inevitable loss.

As well as humidity, case stacking strength is also influenced by palletisation features such as pallet construction and pallet stacking:

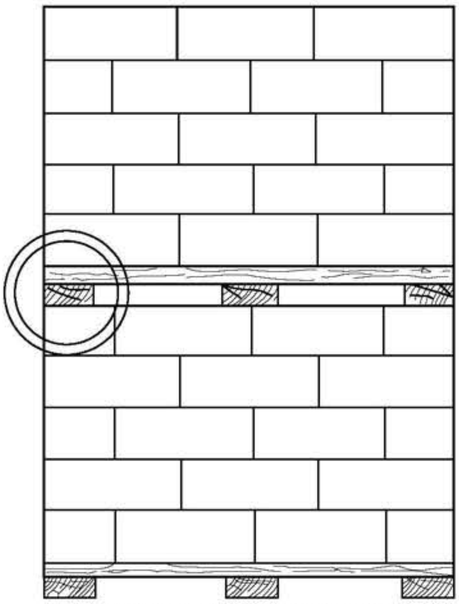
- *Pallet construction*. Pallets with close-boarded decks (i.e. no gaps between the boards) allow pack weight to be evenly spread across the deck. Open-boarded pallets use less timber, but small packs can be compressed against the edges of the boards, causing excessive damage. Where palletised loads are double-stacked, reversible pallets (i.e. top and bottom decks are identical) allow even spreading of the weight of the top pallet across the top area of the lower pallet,



3.4 Correlation of dynamic and static compression.

thus avoiding excessive compressive forces in this area. Single-sided pallets without load-spreading perimeter boards do not allow this load spreading and can result in high damage levels (see Fig. 3.5). The greatest load per unit area is not on the bottom case, but on the top case of the lower pallet.

- *Pallet stacking*. Allowing cases to overhang the edge of a pallet leaves the load-bearing walls of the case suspended in mid-air, with an associated loss of available compression strength, as indicated in Table 3.4. Probably more controversial is the choice of column or interlock stacking pattern. Figure 3.6 shows the distribution of load-bearing ability around the perimeter of a case, clearly indicating that this is greatest at the corners. Therefore, the best possible use of container load-bearing ability is when cases are stacked directly on top of each other in a vertical column. However, this is the least stable stacking pattern

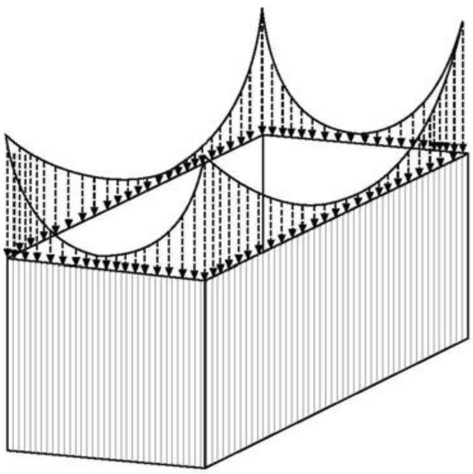


The greatest load per unit container area is not on the bottom container, but on the top container of the lower pallet.

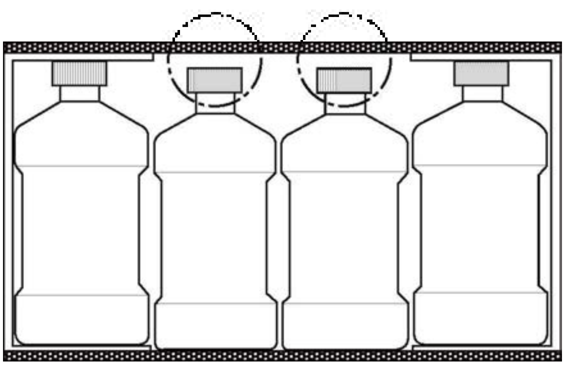
3.5 Compressive forces when using single-side pallets without load-spreading perimeter boards.

Table 3.4 Effect of overhang on compression stack strength

Degree of overhang	Percentage loss (range)
25mm on one side	14–34
50mm on one side	22–43
25mm on one end	4–28
50mm on one end	9–46
25mm on one side and one end	27–43
50mm on one side and one end	34–46



3.6 Distribution of load-bearing ability around the perimeter of a case.



3.7 The 0201 style corrugated case, showing that not all primary packs contribute to the case compression strength.

and therefore cases are commonly interlocked (brick-style as shown in Fig. 3.5), although this format has a lower stacking strength.

Finally, the case contents, i.e. the product in its primary pack, will also influence compression strength. Rigid bottles contribute to the overall strength of the secondary pack, although when using the 0201 style case (FEFCO), in which the short flaps do not meet, not all bottles contribute, as demonstrated in Fig. 3.7. A way to address this is to use an all-flaps meeting style, such as 0204. Flexible primary packs such as bags and stand-up pouches make little or no contribution to case strength and thus the case specification will need to be more robust than for rigid primary packs. The degree of rigidity of the primary packs is important, especially when using apparently rigid containers such as plastic bottles and the known 'creep' characteristics of the plastic must be taken into account. Bottles which are expected to contribute to load-bearing should be designed avoiding sharp corners and edges, since these features act as stress concentrators and promote cracking. Circular cross sections, large neck areas to spread the load and shallow angles are all preferable, although of course such features may not meet other functions, such as ease of use and brand image.

Typically, whatever the load-bearing packaging component chosen, it should be designed to have a compression test value three to seven times greater than the maximum stacking load expected during storage. This is frequently referred to as the stacking factor or the safety factor. The maximum stacking load must take account of whether or not pallets are double or triple stacked, i.e. block-stacked on top of each other, without using racking or any other means of supporting the weight. The shorter the distribution cycle and the less handling there will be, the lower the safety factor. Table 3.5 gives guidance for starting points, across a range of different conditions, but actual factors should be calculated for each application.

Puncture

Puncture refers to the piercing of a pack, which invariably results in product leakage and/or damage. It can be caused by external agents or by the product itself. External agents include piercing by the forks of a forklift truck, with the associated catastrophic effects or, less dramatic but nevertheless still unacceptable, piercing by nails or splinters in wooden pallets. In the former case the effects can be avoided by training; indeed, it is not possible to cost effectively protect goods against forklift truck damage by packaging specification, and training out bad forklift practice is the only feasible option. With regard to damage caused by unsuitable pallets, this emphasises the importance of treating pallets just like any other packaging component and applying appropriate specifications and inspection standards.

Temperature and humidity

This section will concentrate on the direct effects of changes of temperature and humidity on the *packaging* around the product, rather than on the *product* contained therein. Product spoilage will be discussed more fully in Section 3.3, the preservation function of packaging. The two hazards are discussed together here because of their interdependence; the higher the air temperature the more moisture it can hold without condensation occurring. The dew point is the temperature at which the air is saturated with water vapour; below this, water condenses out of the moist air in the form of droplets.

Table 3.5 Guidance for stacking factors

Condition	Stacking factor
Column stack, on overhang, minimum warehousing	3.5
Column stack, on overhang, normal warehousing	4.0
Interlock stack, on overhang, normal warehousing	5.5
Column stack, overhang, normal warehousing	5.5
Column stack, no overhang, freezer storage	5.5
Interlock stack, overhang, normal warehousing	6.0
Interlock stack, extended distribution and warehousing	7.0

Temperature and humidity changes will be encountered anywhere in the supply chain and are usually, but not always, due to climatic changes. The more varied the climatic conditions to which the pack is exposed, the more severe the hazard and its effects, so shipping goods between continents is obviously more hazardous than working solely in a domestic market. However, temperature and humidity changes can also occur due to poor control of storage conditions regardless of the climate, e.g. warehouse doors/windows left open, heating left on/off, or excessive use of gas-powered forklift trucks, and this can occur anywhere, even in a relatively short supply chain.

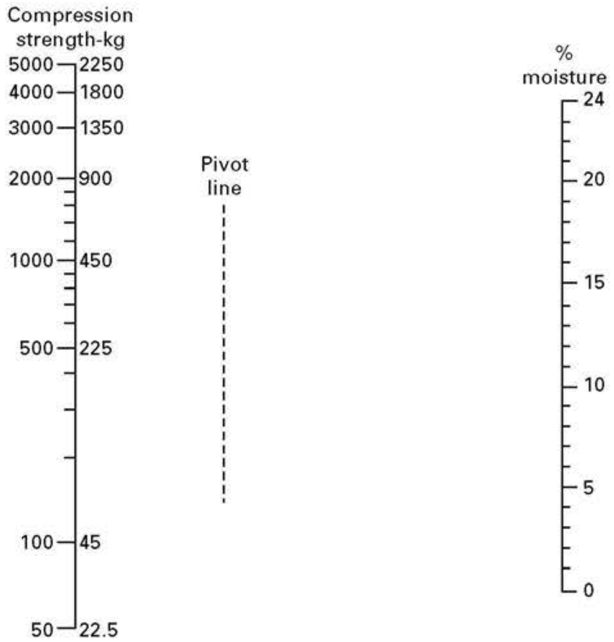
The effects of these changes are most apparent on cellulose-based packaging, i.e. paper and board. (Metals are also affected and unless suitably treated will corrode in high humidity – see Chapter 8 for more detail.) Cellulose fibres exposed to moist air will expand across their width as they absorb the moisture, hence sheets of board will vary in dimensions according to the humidity level, and such variations can affect carton cutting and creasing accuracy. Sheet flatness can also be affected by moisture, as the different layers absorb moisture differentially, resulting in curl (See Chapter 10). Paper and board packaging components should always be allowed to acclimatise in the conditions in which they are going to be used; bringing folding cartons from a cold warehouse into a warm packaging area and expecting good performance in terms of automatic make up, folding and gluing is unrealistic, and will result in high wastage and downtime.

Almost every property of paper and board is affected by temperature and humidity, but perhaps the most significant point to consider in the protection function of packaging is that as the moisture level increases, strength characteristics can decrease very rapidly. As already mentioned, a change in relative humidity from 40% to 90% can result in a loss of about 50% of the case stacking strength. Hence corrugated board cases specified to provide a level of resistance to compression during pallet stacking in one set of humidity conditions, will fail if the humidity increases significantly. Figure 3.8 gives a chart to estimate the compression strength of corrugated board at different moisture levels. To use the chart, draw a line from the compression strength to the board moisture content (see Chapter 10). Mark the position where the line crosses the pivot line. Now project a line from the new moisture content through the pivot line mark and read off the new compression strength.

As well as taking care over storage conditions, the main way of providing protection against the effects of moisture on paper and board is to use coatings to protect the cellulose base material. With regard to protection against extremes of temperature, other than the inclusion of insulating materials such as polymeric foams, this can only be done by careful management of the conditions throughout the supply chain.

Light

Light is most likely to present a hazard when packed products are on display and exposed to retail lighting, when typical effects will be change of colour, usually fading. To the consumer a faded carton may indicate an 'old' product and thus this is likely to be discarded in favour of an apparently newer option. Colourfastness of



3.8 Corrugated board compression strength vs moisture content.

substrates and printing inks should be checked during the development stages, and susceptible items should be packed in opaque primary and/or secondary packaging, or UV filters can be incorporated into packaging materials. Exposure of some products to light can result in chemical changes, and these will be covered in the section on the preservation function.

Dust, dirt, insects and pests

These hazards can be encountered at any stage and their effects vary from an aesthetically unpleasing dusty pack to a serious product infestation with potential damage to human health. Prevention is the only viable approach to these hazards, operating good standards of hygiene throughout the whole supply chain. This applies just as much to the manufacture, storage and delivery of packaging components to the packer/filler as it does to the product handling stages in the chain. See Chapter 21 on hazard and risk management for further information on this aspect.

Pilferage and tampering

Pilferage and tampering by humans, which is most likely to occur in the selling environment, also comes into the category of physical damage, and concern about this has created a requirement to consider the use of tamper evident and, in some cases, anti-counterfeit packaging. Tamper evidence is defined by the US Food and Drug Administration as: 'Having an indicator or barrier to entry which, if breached or missing, can reasonably be expected to provide visible evidence to consumers that tampering has occurred'. For a tamper evident pack to be effective, the consumer must recognise that tampering has taken place, i.e. the tamper-evident feature needs to be obvious. Typical tamper-evident devices currently in use include:

- metal and plastic caps with a breakaway band
- pop-up safety buttons used on metal caps (e.g. on jars of jam)
- shrink bands and sleeves with the sleeve covering the closure
- diaphragm seals, e.g. as used on jars of coffee and pots of vitamin tablets
- permanent adhesive labels which disintegrate and/or reveal a warning message, if an attempt at entry has been made.

None of these would present the determined, malicious tamperer with an insuperable task. The skilled tamperer will not confine his/her attempts at entry to the closure, and all other potential points of access should be considered when assessing the risk of tampering.

Counterfeiting is a serious problem in products such as pharmaceuticals, spirits, tobacco and perfume, and brand owners are constantly striving to stay ahead of the counterfeiter. Anti-counterfeit measures include building in a high level of complexity to the pack, such that it will be difficult to mimic, e.g. unique, custom-designed shapes for containers and closures, holograms on labels, printing inks which show up only in special conditions, e.g. UV light, and embedded micro-chips. The spirits sector also uses a range of special non-refillable fitments inserted in the neck of the glass bottle. The flow of product is maintained but the bottle cannot be refilled once empty.

3.3.4 Completing the process of evaluating the protection function

A useful exercise is to map the journey of the packed product from production to consumption. Note the number and type of product movements and storage conditions, and against each one, list the likely hazards (i.e. shock, vibration, etc., as studied in Section 3.3.3) and their causes and effects. This will identify where the hazards occur and what types of hazards are most prevalent. See Table 3.6 for a list of typical questions to consider, and refer to Chapter 21 on hazard and risk management.

Understanding and, wherever possible, quantifying these hazards is vital in ensuring the packed product can perform satisfactorily throughout its expected shelf life. This can be done by a combination of observation, use of known data (e.g. frequency levels for different modes of transport) and measurement. By quantifying the hazards in this way, the uncertainty surrounding events taking place in the environment can be removed and packaging specifications can be tailored to meet real, rather than imaginary hazards.

Shock, vibration and climatic hazards can be measured *in situ*, by including data loggers in specific loads. These can be purchased or hired and used to record and measure actual events and the time at which each event occurs. The data obtained can be analysed to show the extent of damage-causing hazards experienced during

Table 3.6 Mapping the journey; typical data which can be obtained

Hazard	Data
Shock	What level and skill of labour is available? To what extent is manual handling used? How many times is the pack handled as: • primary pack • secondary pack • tertiary pack What is the most likely drop height?
Vibration	What methods of transport are used? What are the most likely vibration frequencies experienced?
Compression	Are pallets always racked, or is block stacking likely? What is the maximum top load during storage? Are loads evenly distributed? What is the most likely maximum dynamic load?
Pressure	What are the likely altitude and pressure changes? This is important if air freight is to be used
Environment	Will the product be stored outside? What is the range of humidity and how rapidly does it change? What is the range of temperature and how rapidly does it change? What are the likely conditions of cleanliness? Are the goods likely to be stored in poorly managed conditions and is security a potential problem?

a journey. Due to the cost involved, this approach is usually only employed when high levels of damage have been experienced, or in the early packaging development stages for high value, fragile items.

Testing should be carried out as part of the development programme and time for this will need to be built in to the development schedule (see Chapter 18). Transit testing is commonly done using actual conditions, or it may be simulated by using calibrated laboratory equipment and the known conditions identified in the process of mapping the journey. The latter is the more expensive option, although it may be more reliable and thus avoid costly mistakes. When using actual conditions, sample packs are made up, sent out on a 'typical' journey and assessed at the end. This may be done at various stages, first of all trying out a small number of packs and then building up to full pallet loads, or full vehicle loads. Provided the process is managed well, this testing can provide valuable 'real-life' information. Points to consider include:

- Trial packs should be representative of final packs and use the same materials.
- Vehicles should follow a prescribed route, over an agreed distance and class of roads.
- If the packs are palletised, the trial should continue to the end point, with secondary packs being transferred to mixed pallets if this is what will happen in reality. Primary packs should then be treated as they are during display, selection and use by the final consumer, e.g. taken home in a shopping carrier bag.
- Wherever possible, use a packed product of proven performance as a control.
- Standards must be set for what levels of damage are acceptable.

3.4 Preservation

Preservation means the prevention/reduction of changes due to biological and chemical hazards, which would lead to product spoilage. The objective of preservation is to extend the shelf life of a product. This section applies mainly, but not exclusively, to the food, drink, pharmaceutical and cosmetic industries.

3.4.1 Shelf life

According to the Institute of Food Science and Technology, 'shelf life' is defined as the time during which the product, when stored at the recommended conditions, will:

- remain safe;
- be certain to retain desired sensory, chemical, physical and microbiological characteristics;
- comply with any label declaration.

When considering the preservation function of packaging, it is important to recognise that whilst packaging can and does contribute to shelf life, it cannot overcome inherent product problems; if the product is unsafe at the point of packing, it is likely to remain unsafe inside the pack. Also, if temperature is a key factor in maintaining preservation, e.g. chilling or freezing, the packaging has only a 'supporting' role to play; if the temperature of the packed product is allowed to rise to the point where deterioration occurs, the pack will not compensate for this failure to manage storage conditions.

Within the limitations mentioned above, to determine the optimum packaging required to extend shelf life, we need to define the product in terms of what will cause it to deteriorate, i.e. what is the spoilage mechanism. We then need to understand what process (if any) will be used to prevent/delay spoilage and the extent to which this will affect the packaging used, and therefore determine its key properties. Only when we have a packaging specification which defines the required properties can we begin to investigate possible solutions.

3.4.2 Define the product-spoilage mechanisms

Defining the spoilage mechanism of a product is part of the research and development stage of the *product*, and this is an example of how product and pack development personnel must work closely together. Product development specialists should be able to provide the information needed to define the product in terms which allow the packaging technologist to specify key packaging attributes. This section provides only a broad introduction to spoilage mechanisms, which is no substitute for the detailed knowledge expected of the food, cosmetic or other product scientist.

Product spoilage, and therefore shelf life is determined by microbiological, physical or chemical factors, depending on the product, the process, the packaging and the storage conditions (Blackburn, 2000). Broadly, spoilage due to microbiological spoilage is referred to as biotic spoilage, and that due to physical and/or chemical factors is known as abiotic spoilage.

Biotic spoilage is caused by microorganisms (bacteria, moulds, yeasts) which may render a product unacceptable in appearance, taste, smell and effectiveness, or be toxic and cause sickness. Different organisms have preferred conditions for growth and adverse conditions in which they will not propagate, and this is the basis of product preservation systems. The conditions to be considered are as follows:

- *Temperature*. Microorganisms may be classified by their preferred reproduction temperature:
  - psychrophiles grow best in fairly cool conditions (10–20°C);
  - mesophiles grow best at 20–40°C;
  - thermophiles prefer temperatures in the range 40–60°C.

  Note, however, that there is considerable variation within each classification and these temperature ranges are not exact.
- *Humidity*. Microorganisms need water in which to grow and as a general rule, the lower the level of available water in a product, the less likely it is that microorganisms will propagate.
- *Acidity*. Microorganisms have an optimum pH level at which they will grow. In general, moulds and yeasts grow best in acidic environments and bacteria grow best in neutral to slightly alkaline conditions, although there are exceptions to this.
- *Presence of oxygen*. Some microorganisms need oxygen to propagate and are known as aerobes, while others cannot propagate in the presence of oxygen and are known as anaerobes. Some can propagate in either oxygen or oxygenless environments. In general, moulds and yeasts need oxygen to propagate, although some yeasts grow in anaerobic conditions.
- *Nutrient source*. All microorganisms need a nutrient source, although their needs vary greatly. Nitrates, lactates and amino acids are typical nutrient sources found in foodstuffs.

Abiotic spoilage refers to the chemical or physical changes brought about by external factors such as oxygen, moisture, light, temperature, loss/gain of volatiles, e.g.:

- oxygen, causing rancidity in fats, creams and oils
- loss of moisture causing drying out and hardening of bread, lipstick, pastes, etc.
- gain of moisture causing lumping of powders and loss of crispness of cereals and biscuits; corrosion of metal products and packs also comes into this category
- light causing colour fading or oxidation
- excessive heat causing drying out
- excessive cold causing undesirable freezing e.g. emulsions
- loss of volatiles such as some of the oils in tea, which affects its taste
- gain of volatiles which make a product taste odd, e.g. chocolate stored next to highly fragranced soaps, without an adequate barrier in the packaging will quickly pick up the volatiles in the soap and taste soapy. Unacceptable volatiles

can also be picked up from printing inks and adhesives, due to high levels of retained solvent.

3.4.3 Preservation processes

The basic principle of product preservation processes is to address the cause(s) of spoilage, and then to use appropriate packaging and storage conditions to maintain the product in its desired state. Referring back to the causes of biotic spoilage listed in the previous section, it can be seen that these can be addressed by:

- changing the temperature to destroy microorganisms, or impede their growth, using heat (pasteurisation, sterilisation) or cold (chilling, freezing).
- reducing the water activity (A_w) in a product. A_w is a measure of the amount of available water in the product and lowering this limits microorganism growth. Methods of reducing A_w include drying (which removes water) and the addition of salt or sugar (which 'ties up' the free water).
- changing the acidity level, e.g. pickling using vinegar.
- varying the oxygen level, which can be done by vacuum packaging (where the product is packed and then the air is evacuated from the pack before sealing) or by changing the gaseous mixture around the product (modified atmosphere packaging – MAP; discussed further in Chapter 20). The use of oxygen scavengers to reduce the free oxygen available may also be considered under this heading.

See Table 3.7 for a summary of these preservation methods, along with considerations for packaging requirements.

Using the same approach to reduce/prevent abiotic spoilage, it can be seen that the key property required of the packaging is an appropriate barrier to the ingress/loss of the damage-causing factor, e.g. moisture, air and light (see Table 3.8). To specify the correct level of barrier, it is necessary to know the extent to which the factor can be tolerated before spoilage takes place, e.g. knowing the extent to which a biscuit can absorb moisture before it becomes unpalatable allows the packaging technologist to design the optimum pack, which will give the required shelf life, but not be overspecified such that resources are wasted.

3.4.4 Predicting packaging characteristics for particular foodstuffs

Provided the critical values of a food product are known, i.e. at what level the environmental spoilage-causing factor of gain or loss of moisture vapour, gas (or light) becomes unacceptable, it is possible to calculate shelf life based on the relevant barrier properties of the packaging material. Conversely, knowing the desired shelf life can dictate the barrier specification of the packaging material. Assuming correct storage conditions are maintained, especially for chilled and MAP products, it is the pack's barrier to gain or loss with respect to these environmental factors which will determine shelf life. Knowing the spoilage mechanism of the product is thus the first step in predicting packaging requirements. A useful list of deterioration indices for

Table 3.7 Summary of the common preservation methods and associated packaging requirements

Preservation	Method	Packaging properties
Cooling	Chilling	Able to withstand storage temperature without deterioration such as cracking or loss of print Odour barrier May also require light barrier Toughness, puncture resistance to withstand handling on display Pack should fit standard domestic refrigerator
	Freezing	Able to withstand blast freezing and storage temperatures without deterioration, as above Appropriate moisture barrier, to prevent freezer burn Odour barrier May also require light barrier Toughness, puncture resistance to withstand handling on display
Heating	Pasteurisation, hot filling Sterilisation (canning and retorting)	Able to withstand temperature and pressure changes during heating process Water resistance Toughness, puncture resistance to withstand physical handling during process
Drying	Air drying, heat drying, salting	Appropriate moisture barrier Resistance to chemicals used
Chemical Preservation	Pickling/other chemicals Oxygen scavengers	Resistance to chemicals used
Varying oxygen levels	Vacuum packaging MAP Oxygen scavengers	Gas barrier Puncture resistance
Irradiation		Resistance to ionising radiation

Note also the requirement for correctly sealed packs.

different classes of foods is given in Table 3.9. Note that many foods are sensitive to more than one spoilage factor.

The following is a very simple approach to calculating packaging barrier requirements, which can be used as an indicator. It is demonstrated in relation to determining the required moisture barrier, although it can be applied to gas barriers.

First of all the maximum amount of moisture allowable in the product contained in the pack, before spoilage starts to occur must be known. Assume this to be W grams. Next we need to measure the surface area of the pack as carefully as possible, allowing for changes due to handling, especially for flexible packs. Assume this to be A square metres. If the desired shelf life is T days, then we must look for a pack with a moisture vapour transmission rate (MVTR) of less than:

$$\frac{W}{T \times A} \text{ grams per square metre per 24 hours}$$

When considering barrier properties such as MVTR, packaging materials can be divided

Table 3.8 Summary of packaging requirements to reduce/prevent abiotic spoilage

Spoilage mechanism	Packaging properties
Oxygen	Appropriate gas barrier
Loss of moisture	Appropriate moisture barrier, related to the equilibrium relative humidity of the product
Gain of moisture	Appropriate moisture barrier, related to the equilibrium relative humidity of the product May require moisture permeable pack
Light	Appropriate light barrier
Heat/cold	Insulation Importance of control of storage and handling conditions
Loss of volatiles	Appropriate gas barrier Appropriate chemical resistance
Gain of volatiles	Free from taint and odour

Note also the requirement for correctly sealed packs.

Table 3.9 Approximate order of importance of specific deterioration indices for certain foods

Foods	Microbial changes	Inherent changes	Moisture changes	Oxidation changes	Taint, etc.	Light	Physical damage
Baked goods	4	4	1	2	4	4	2
Raw and cooked meats	1	2	4	2	6	4	6
Fish	1	3	4	2	–	–	–
Shellfish	1	4	1	1	–	–	–
Potatoes	2	–	1	–	–	3	4
Green vegetables	–	–	1	2	–	–	3
Soft fruits	1	–	–	–	2	–	3
Salads	2	–	1	–	–	–	–
Breakfast cereals	–	–	1	4	3	–	2
Chocolate	5	–	1	2	3	–	4

1 = most important, 7 = least important.
Source: Paine (1992).

into two categories: those such as glass and metal, which have an absolute barrier, i.e. they are impermeable, and the permeable materials such as paper and plastics. MVTR is a measure of how quickly moisture permeates through the packaging material and is not the only consideration; if a pack is not correctly sealed, even an impermeable glass bottle will result in a permeable pack, hence the need for careful control of sealing parameters during filling, and in-process checks on the packaging line.

MVTR data for some of the common packaging plastics are given in Chapter 13 and these can be used as an initial guide to packaging material selection and to inform storage trials, thus providing a basis on which to start comparing potential alternatives and gain a preliminary idea of packaging material costs. Note that permeation is inversely proportional to thickness of the barrier and hence a 50 μ layer will be twice as good a barrier as a 25 μ layer, and that the temperature and humidity conditions to which the product is likely to be exposed in the supply chain are a vital factor in calculating the required barrier. It is essential to specify these and check that the data being quoted are applicable to the conditions expected.

The data given in Chapter 13 are generic and transmission rates for specific grades within each type of plastic are quoted by individual manufacturers and can usually be obtained from data sheets. Actual measurements of moisture, oxygen and light barriers can be carried out using laboratory testing, and references to independent laboratories carrying out such work are given at the end of this chapter. It should also be noted that the quoted data are for sheet materials in pristine condition and any creases or folds introduced during the packaging and handling processes will reduce the barrier performance. This is why the calculated barrier levels should be regarded as minimum values.

Important factors which have an effect on shelf life and barrier requirements are the size and geometry of the pack. Because moisture vapour and gas transmission rates are related to pack surface area, the smaller the pack (i.e. the higher the pack surface area to product ratio), the greater the permeation through the pack and the higher the barrier required per gram of product. This is important when developing different pack sizes and shapes and it cannot be assumed that a material which provides an acceptable barrier for one size already on the market will be suitable for another size or shape variant.

3.5 Using packaging to provide convenience

The way in which a pack is handled (and the product used) is determined by the design of the pack itself. Packaging designers have the opportunity to build in features to make handling easy, convenient and safe. If it is both intuitive and ergonomically sound how the pack should be picked up, opened and unpacked, potential damage to the contents and personnel will be minimised. This applies just as much to secondary packaging as it does to the consumer-facing primary pack.

Good pack design will determine how easy/difficult it is to dispense the desired amount of product and this is especially important for potentially 'difficult' products such as nail enamel, shoe polish, syrups, motor oil, viscous adhesives, paint, etc. If the pack offers clean and safe delivery, with no mess or loss of product, it can provide the all-important competitive edge in a crowded market. Just some examples of consumer convenience are:

- the ability to dispense and direct the required amount of product using aerosols, natural pump sprays, special nozzles on tubes, brush applicators, etc.;
- easy product access from tubes and squeezable bottles;
- easy-open features such as tear-tapes in film wraps or 'tear here' cuts in sachets;
- easy-open and reclose features such as flip-top closures on sauces and shampoos;
- packs which collate, for example, five individually-wrapped snacks into one pack which is easier to handle and store in the cupboard than single packs;
- boil-in-bag and heat-in-tray foods, which mean no dirty saucepans;

- ring-pull cans, requiring no special opening tools.

Convenience on the filling and packaging line and in distribution is also important in the quest for cost and resource-efficient solutions, e.g.

- the stability (affected by material and shape) of a container is critical in determining the running speed – lightweight plastic bottles are less stable than glass and tall/narrow shapes are less stable than short/squat shapes;
- containers which do not stand vertically for filling usually require pucks (specially made holders in which each container is supported while on the filling line), which in turn add to cost and development time;
- designing a 'punt' into a container (usually on the base) which locates it in the correct orientation for labelling;
- the use of pallets, roll cages and special trays, for ease of movement, loading and unloading;
- the use of cut-out holes in large corrugated cases for easy lifting by hand;
- the collation of products into shelf-ready packs makes them convenient to handle in the store when the shelves are being filled;
- the use of custom-made display systems for ease of recognition at the point of consumer selection;
- the use of marking and coding systems for manual or automatic recognition of the product as it is moved into and out of storage;
- assembling the components required for a production operation (e.g. car assembly) in one 'kit' which speeds up delivery to line, and quickly identifies if anything is missing.

3.6 Packaging as the source of product information

Packaging provides the ideal (and often the only) means of delivering valuable information to anyone engaged in handling the product, as well as the final consumer. There is a need for information on the identity of the product, its weight/volume, destination and handling and possibly unpacking/repacking instructions, and such information must be easy to locate and understand. For important instructions, consideration should be given to the use of pictograms, to overcome any language barriers. Information on secondary and tertiary packaging must also show information such as product, number in pack, product codes and bar codes, for ease of recording stock.

3.6.1 Types of information

For the consumer there is an increasing need to provide legal, promotional and usage data for a product, whether it is a bar of chocolate, a tube of toothpaste or an expensive perfume or skincare product. The information required is further increased when products are sold into several different geographical markets, where multi-lingual copy is needed. Legal information required includes product name, use of the product (if not obvious), weight/volume, manufacturer's or seller's (e.g. Tesco) name and address, expiry date, ingredients list, batch code (for traceability) and any relevant warning statements.

With regard to promotional and usage information, along with advertising, packaging provides the seller with a means of informing the consumer about the uses and benefits of the product, designed to encourage purchase. Once that purchase is made, it is the packaging alone which is expected to convey the definitive information on the product. This may necessitate the use of a leaflet, which must be signalled to the user (e.g. by a statement on the carton, such as 'See leaflet for instructions').

3.6.2 Information formats

Information is required in the form of printed copy, perhaps supported by illustrations, and in electronically readable form, such as bar codes and matrix codes. Whatever the form, 100% legibility every time is the goal, which means using an appropriate size of type and colour contrast, and ensuring that the printing process used is adequate for the accuracy demanded. Increasingly, the provision of information for the visually-impaired is required, using raised characters as in Braille.

3.7 Packaging to sell the product

Today, most shopping is done in large supermarkets and this applies not only to food and drink, but also to cosmetics, garden chemicals, hardware, textiles, electrical equipment, etc. The role of the specialised, trained sales assistant to help one make a choice has declined and in the generally impersonal world of the retail store, it is packaging which carries out the selling role – the 'silent salesman'. The manufacturer/seller must use the packaging, usually seen before the product, as the means of attracting the would-be purchaser. This is done by a combination of the colour, graphics, shape and size of the pack, which must combine to provide novelty, or a familiar chord of recognition, usually backed up by advertising depicting the pack and portraying the desired product image. Think about brands with which you are familiar, and the features used by the brand owner to ensure that you instantly recognise their product. For more information, see Chapter 6 on packaging and marketing and Chapter 18 on pack design and development.

3.8 Conclusion

As pointed out in Chapter 1, packaging has the potential to deliver cost effective solutions by reducing wastage and costly (and perhaps irreparable) damage to the product. The development and use of correctly specified packaging materials and formats, related directly to the demands of the goods, will ensure that excessive costs are not incurred unnecessarily. Good packaging solutions also have the potential to reduce the total cost of moving goods, by providing safe and convenient handling systems.

The cost of packaging must be related to the product's value, image and end use. For most manufacturers this means the minimum spend commensurate with meeting all the required functions of packaging. This is not the same as the lowest cost option. If a product fails to attract the attention of the consumer, due to poor packaging presentation, the packaging is not meeting its required functions.

Finally, the relative importance of each of the functions of packaging varies with the product. For example, protection against physical damage will be very important for a television set, but the selling function of the packaging will be less important, as most people buy a TV after having seen a display model in the store. To the consumer, the packaging is simply a convenient means of getting the item home safely. On the other hand, the packaging of a breakfast cereal or pet food on the supermarket shelf, amongst 25 other varieties of similar products, has a very important selling function to fulfil.

3.9 Sources of further information and advice

There are several general texts available on packaging technology, recommended for reference, such as:

- Yam, K. L. (2009) *The Wiley Encyclopaedia of Packaging Technology*, 3rd edn. Wiley, Chichester.
- Soroka, W. (2010) *Fundamentals of Packaging Technology*. Institute of Packaging Professionals, Naperville, IL (www.iopp.org).

References for pack testing:

- Instrumented Sensor Technology: www.isthq.com
- Dallas Instruments: www.dallasinstruments.com
- Pira International: www.pira.co.uk

Note: Sources used in the preparation of this chapter also include teaching and learning materials written and used by the author in the delivery of courses to a number of organisations, such as the Packaging Society, Loughborough University, University of Warwick, University of Bath and London College of Fashion (University of the Arts London).

3.10 References

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4
Packaging legislation

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Abstract: This chapter provides an introductory summary of the main legal requirements relating specifically to packaging. These include aspects of law relating to the design of packaging and the performance of its functions, together with the legislation introduced to reduce its environmental impact. Although they have no direct statutory authority, the guides provided by the enforcing authorities, and the normal commercial requirements with the related standards are also described.

Key words: UK packaging law, food safety and labelling regulations, filling regulations, environmental regulations, including essential requirements, producer responsibility obligations.

4.1 Introduction

4.1.1 The role of law within civilised society

Whatever we are doing, our activities, and the materials used to undertake those actions, are governed by some form of legislation. Although at times this may seem inconvenient, it could be argued that it is impossible to have an effective society without some form of agreement as to what is to be acceptable and what is not. From the simple group decisions of prehistoric times, the concept of law has developed into national, regional, and international regulations. As the situations which society would wish to address have become more complex, so have the laws regulating them. Within the trading activities of society, law has functions of establishing normal expectations, and thereby making communications within business easier. The area of trade and regulation may be within the same country, in which case the applicable laws would be those of that country. However, the country may be within a legal region, such as the European Union (EU) in which compliance would be required with the legislation of the region, in addition to those of the countries involved. In international dealings there may also be legislation and standards established by recognised international authorities, such as the World Health Organisation (WHO) or the United Nations (UN).

4.1.2 How laws are made and enforced

The motive behind making new laws, or revising existing ones, is normally the recognition of a situation in which the current legislation is considered to be no longer appropriate. Within the European Union, the issue is the subject of representation by those concerned to the national government, and thence into the European Commission, which works through consultation processes to establish an appropriate piece of legislation to be submitted to the European Parliament for approval. The resulting laws may be in one of two forms. EU Regulations are directly applicable to all member states and must be implemented and followed exactly as laid down, whereas EU Directives are less prescriptive and require the enactment into national legislation before they become applicable. The development of this national legislation may lead to national variations of interpretations and applications of the Directive. Also, some Directives are optional harmonising directives and so their inclusion within national legislation is at the discretion of the national governments. An example of an optional harmonising directive is the Aerosol Dispensers Directive, which has mandatory force elsewhere in Europe, but not within the UK. As part of this process of bringing both Regulations and Directives into national legislation, each national government is required to establish the appropriate enabling legislation, including the selection of the appropriate enforcement authority. Once the enabling legislation is in force, the details are issued and in the UK this is done via Statutory Instruments (SI).

These processes are normally undertaken in consultation with advisory groups drawn from representative trade organisations. It is usual for the enforcement authority to provide guidance to those affected by the new legislation as to their interpretation, usually in cooperation with the same advisory groups they would have been consulting during the preparatory stages. Such guides clearly state that they have no force in law, but keeping records which show the appropriate guide has been followed is an important way of building a 'due diligence' defence in the UK. The basis of such a defence is to be able to present documentary evidence to show that there was the intention to comply, as all reasonable steps had been taken to seek to comply with the legislation. Eventually the first case will come to court, and begin to establish precedents. This is termed a 'test case' as it is the opportunity for the authorities' interpretation of the law to be examined and established as 'case law'. The details continue to be clarified as further cases are brought to the courts.

4.1.3 Law and trading conventions

Alongside the law, there is a series of trading conventions, which have been established by specific trade associations, or wider representative bodies. Whilst these have no direct authority in law, their influence should not be underestimated, for example in the control of bar-code systems. These conventions will be discussed later.

4.2 Legislation relevant to packaging

Before considering the legislation directly related to packaging, it is necessary to remember that there is a wide range of legislation with which companies also have to ensure compliance. Examples include: the ownership and use of premises; employment of staff; health and safety; financial transactions; taxation; contracts with suppliers and customers; control of the environmental impact of processes; and the appropriate licensing of operations and facilities. Also, there is legislation which is concerned with the product which is being packed, and so becomes applicable to the packaging being used. Examples include the supply of foods, and the control of hazardous substances.

4.3 Legislation relating to product quality and safety during manufacture, distribution, storage and use

The general legislation under this heading includes the provisions of consumer protection and the safe handling and use of products.

4.3.1 Legislation concerning safety of packaging for foods

As most packaging is used to supply food, the legislation relating to packaging for foods will be described more fully. Directive 89/397 on the Official Control of Foodstuffs was enabled in the UK by the Food Safety Act of 1990. As the requirements of the Directive have been updated, these have been incorporated into UK legislation by several statutory instruments, and advised by codes of guidance. Most of the requirements are concerned with the quality of the food itself, but amongst them are some which apply to packaging and others which apply to labelling. Earlier legislation concerning materials in contact with food is derived from Directive 89/109/EEC, enacted in the UK as the Materials and Articles in Contact with Food Regulations 1987, and applied as Statutory Instrument SI1523 1987. The main area of concern is the possibility that components of the materials in contact with the food could leach into the food and endanger a person's health, or adversely affect the quality and taste of the food. There is also the design of a symbol which may be included as the moulding of a plastic, or into the labelling of the product to indicate that the materials which have been used for the food contact have been tested in accordance with the various regulations and are suitable for contact with foods (see Fig. 4.1).

As the use of plastics in packaging is so widespread, it is not surprising that there is emphasis on legislation specifically directed towards the control of substances in plastics. Some materials are restricted in their use (such as vinyl chloride monomer and regenerated cellulose) and there is a series of leaching tests to establish whether a plastic will release materials into the food, simulating aqueous, acidic and fatty foodstuffs. At the time of writing, this legislation is being revised and several pieces of legislation are being compiled into an updated Directive. The latest guidance is available for reference on the Food Standards Agency website: http://www.food.gov.uk/.

The enforcing authority for food standards in the UK is the Local Authority Trading Standards Officer, who is mainly concerned about the quality and fairness of trade of the product. The enforcing authority for the hygiene of the materials, preparation premises and processes is the Local Authority Environmental Health Officer.

Other packaging materials used in contact with foods include paper and board. The general requirement for all materials in contact with foods is given by the Regulation (EC) No. 1935/2004, which states:

> Materials and articles ... shall be manufactured in compliance with good manufacturing practice so that, under normal or foreseeable conditions of use, they

4.1 The only EC-approved symbol that may be used to denote food contact materials and articles when they are not already in contact with food when sold (FSA guide, 2009).

do not transfer their constituents to food in quantities which could: endanger human health; or bring about an unacceptable change in the composition of the food; or bring about a deterioration in the organoleptic characteristics of the food.

However, with respect to paper and board the legislation has not been developed to specify the methodology by which these objectives are to be met, and because of the absorbent nature of the material, the procedures used for plastics are not suitable. Consequently the Confederation of European Paper Industries has developed an industry guideline document, based mainly upon the recommendations of the German industry, covering the permitted components of the papers and boards, and their coatings.

Although glazed pottery has been used as containers and serving crockery for many centuries, there is ongoing concern about the content of the materials used to colour the glazes, and particularly to restrict the amounts of lead and cadmium which are able to leach from them into the food. The most recent legislation introduced concerning these materials implements the amending provisions of European Directive 2005/31/EC and was introduced in the UK under the Ceramic Articles in Contact with Food (England) Regulations 2006. Further information may be found on the Food Standards Agency website.

Glass containers for foods are required to comply with the general requirements for materials in contact with foods, but there is no specific EU legislation relating to glass. The high temperatures used in its manufacture clean any organic contamination, and glass is regarded as almost inert, with a low risk of unacceptable leachate unless it has been decorated with unsuitable enamel. Any cold-end treatment should be of food contact grade. There are concerns for the potential effects of traces of alkali leaching from glass and affecting sensitive pharmaceutical ingredients, which are covered by a specification for 'Pharmaceutical grade' glass (as described in Section 4.3.2).

Metal containers for foods are also required to comply with the general requirements for materials in contact with foods. Petroleum-based lubricants used in the formation of containers have to be effectively removed. Other materials which are used in association with metals for the construction of packaging containers and closures include a range of coatings and sealing compounds. These are subject to the same general requirements concerning contact with foods, and some potentially harmful ingredients are restricted. For example, a specific limit of migration into food has been established for the use of PVC gaskets to seal the lids of glass jars.

A current example of a recent EU Regulation which has an indirect effect upon packaging is REACH, i.e. Regulation (EC) No. 1907/2006 concerning Registration, Evaluation, Authorisation and Restriction of Chemicals. The purpose of REACH is to extend the current legislation covering all chemical substances manufactured within, or imported into the EU at quantities of 1 tonne or more. The requirements of REACH are

> **R**egistration of basic information of substances to be submitted by companies, in a central database. **E**valuation of the registered information to determine hazards and risks. **A**uthorisation requirements imposed on the use of high-concern substances. This process will be used for both new and old **CH**emicals. The new regime also creates a European Chemicals Agency (ECHA) and amends current legislation.

The Food Labelling Regulations 1996 (SI 1996/1499) consolidate and replace the Food Labelling Regulations 1984 in England, and corresponding legislation elsewhere within the UK. They principally implement Council Directive 79/112/EEC on the labelling, presentation and advertising of foodstuffs (apart from the provisions of that Directive relating to net quantity: see Section 4.4.1).

The name of the food must be an accurate description, supported by the ingredients list, which is to indicate the ingredients in descending order of the amount present. Some ingredients, such as vitamins, have to be blended with other materials in order to handle them, and so are known as compound ingredients. The make-up of compound ingredients is also to be declared, as are the functions of specific groups of ingredients (such as acidity regulators). The amount of the product within the pack is required to appear in a prescribed print format (type height and location). The metric system is normally used, but derogation has recently been agreed for dual labelling with imperial units to continue to be used on some groups of products within the UK. The information on the pack is also required to advise of potential allergic reactions to the listed ingredients of food products.

The information on a pack is also required to include instructions for use and the country of origin of the product. The shelf life of the product must also be indicated adjacent to the batch number and storage conditions, as the shelf life is dependent upon the storage conditions being maintained. The form in which the shelf life is communicated depends upon the duration of the shelf life. Finally, the pack is also required to provide the name and address of the importer, manufacturer, packer or seller, to whom the customer may complain, or obtain further information should the need arise.

4.3.2 Legislation concerning safety of packaging for medicines

There are widespread requirements that medicines are to be contained within child-resistant packs. Exhaustive panel tests are required to validate that the packs cannot usually be opened by young children and that they can usually be opened by an elderly person. The details of the tests vary widely from country to country. This legislation applies not only to re-closable containers, but also to the single use blister-packs used for some tablets and capsules. Child-resistant closures are also required to be used on hazardous substances such as household bleach and garden chemicals. The design and layout of the text of the pack is controlled as part of the product licence. Amongst these is a requirement that the product name and strength appears in Braille. This may be achieved by embossing a carton, or printing a thermally raised varnish onto a label.

Pharmaceutical measuring devices such as spoons are required to be 'CE' marked, which indicates that the device has been validated and subject to ongoing process controls to ensure that it accurately delivers the required quantity of the medicine. As expected, the requirements for materials in contact with pharmaceuticals are more demanding than those for foods. For instance, it is commonly thought that glass is inert, but it does tend to leach a small amount of alkaline material. There are some pharmaceutically active compounds which are sensitive to such small traces of alkali, and so pharmaceutical grade glass has limits on the amount of alkali released under test conditions. Similarly, any plastics which may be in contact with medicines which are to be injected directly into the patient's blood stream have more stringent requirements concerning possible leachates from the plastics, in addition to those controlling the sterility of the materials.

4.3.3 Legislation concerning safety of aerosols

Aerosols are commonly used but are potentially hazardous because they are pressurised containers, often containing flammable or corrosive substances. The Aerosol Dispensers Directive has been subjected to several updates, and covers areas such as: the size of the container by material; the testing of empty cans; the testing of finished aerosol product; and the requirements for clear labelling for instructions for safe use and disposal, together with appropriate warnings. The legislation includes the provision of the 'reversed epsilon' mark ϶ to indicate compliance with the requirements of the Directive and enable smooth transport across the borders between EU countries. Aerosols are required to carry specific UN warning markings on the cases and shipping containers.

4.3.4 Legislation concerning protection of the workforce

Legislation on the control of substances hazardous to health (COSHH) requires that the operators are fully trained in the safe handling of the materials they are using. Also the risks involved in their procedures are required to be fully assessed and eliminated, or reduced to a safe minimum. The packaging of bulk ingredients, and the storage of intermediate products, should be designed to minimise risks in handling and use. Similarly, all equipment being used is required to be constructed and guarded to prevent accidental injury. There are strict limits on the amount of noise that may be emitted in the working environment, and under normal circumstances the standard minimum temperature for the workplace is 13°C.

4.4 Legislation concerning honesty in trade

There is nothing new about problems of dishonest trade. Ancient laws called for fair measures, and the prophets preached against unjust trading practices, including balances, weights and measures. Within recent decades, a range of legislation has been introduced to cover the amount of product provided and the perception of quantity and quality conveyed by the packaging, in its size, text and illustration. Although the Consumer Protection from Unfair Trading Regulations 2008 are concerned mainly with accurate commercial representation, they have implications for the marks which might be included in the print, and aspects of the packaging. These may include packaging which is significantly over-size for its contents, or containing compartments which appear to provide product but are actually empty.

4.4.1 Legislation relating to the filling of products

The Weights and Measures Act of 1963 continues to be in force within the UK, in some areas such as those concerning the calibration of weighing equipment and the amount declared by count, which is required to be precisely accurate, unless clearly stated otherwise. However, most of its requirements were replaced by the Weights and Measures Act of 1979, subsequently updated in 1985, which implements Directive 75/106/EEC and Directive 76/211/EEC. These were amongst the first pieces of EU legislation to impact upon the packaging industry in the UK. The main change was from the concept of 'minimum net weight' to 'average fill'. It is also necessary to control the variation in the amount being filled. This is achieved by introducing a 'tolerable negative error' with statistical conditions to limit the quantities of packs at the lower end of the range. These requirements are summarised in three rules:

- The average of the contents of the packs shall not be less than the nominal quantity (the label claim).
- Less than 2.5% of the packs may contain less than the nominal quantity minus the permitted tolerable negative error.
- No packs may contain less than the nominal quantity minus twice the permitted tolerable negative error.

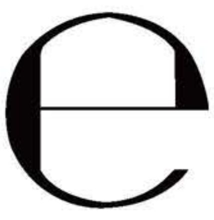
The filling operation is required to become more accurate, as a percentage of the label claim, as the value of the permitted tolerable negative error changes as the nominal quantity increases (see Table 4.1).

Also, the place of enforcement of this legislation moved from the retailer to the factory where the product was packed. Statistically-based investigations of the operation of the filling processes were required in the setting-up of appropriate sampling systems for routine production checks, to show that the filling process was under adequate control and this became the basis for a 'due diligence' defence. The UK legislation also introduced the concept of the 'Home Authority Trading Standards Officer' so that the Officer with whom the company dealt with routinely would be involved with any complaints or legal proceedings. The Home Authority Trading Standards Officer is the authority to whom application is made to approve the use of a specific 'e' mark on the pack, to enable smooth transportation across borders within the EU. The mark must be as specified in Fig. 4.2 (not a font similar to it) at least 3 mm high and appear in the same field of vision as the statement of quantity. The height of type required to be used to declare the statement of quantity relates to the size of the pack.

This legislation also introduced the concept of 'measuring container bottles', which have a target filling mark included within the moulding and a guarantee that if filled to that mark the product will comply with the legislation. Although they give an additional assurance to the final customer, and move the responsibility for the statistical control to the bottle manufacturer, the responsibility for overall compliance remains

Table 4.1 The permitted tolerable negative error changes with the quantity of product within the pack

Nominal quantity (Qn) g or ml	Tolerable negative error	
	as % of Qn	g or ml
5–50	9	
50–100	–	4.5
100–200	4.5	–
200–300	–	9
300–500	3	–
500–1000	–	15
1,000–10,000	1.5	
10,000–15,000	–	150
above 15,000	1	–



4.2 The use of the 'e' mark is authorised by the Home Authority Trading Standards Officer.

with the filler. Such bottles are more expensive because of the additional controls, and the associated waste arising from their production to a tighter specification than would normally be required by the trade association conventions. However, in the case of glass containers, they provide a useful example of where trade association conventions have been upgraded into legislative regulations.

The EU Regulation No. 1169/2011 is now implemented. This affects the provision of nutritional information, and the highlighting of potential allergens. It also affects the declaration of the country of origin, and minimum type-size of the relevant text.

4.4.2 Legislation concerning deceptive packaging and label claims

The Trades Descriptions Act 1968 has been updated by the the Consumer Protection Act 1987. Part of this Act implemented European Community (EC) Directive 85/374/EEC, the product liability Directive, by introducing a regime of strict liability for damage arising from defective products. It also created government powers to regulate the safety of consumer products through statutory instruments, and identified the criminal offence of giving a misleading price indication. Similarly the Labelling Regulations are required to accurately describe the product. For instance, the Food Labelling Regulations 1996 SI 1499 requires that it is only permitted to claim that the product is a rich source of that vitamin if the amount expected to be taken during the day provides at least half of the recommended daily intake.

Another area of close legal scrutiny is whether the claims made for the product imply medicinal properties. Within the EU only licensed medicines are allowed to make or imply curative or preventative properties for the product. If so, the product falls under the exacting demands of the Medicines Act in the UK and is required to be licensed with clinical support for the claims made, and evidence of the safety of the product. This legislation brings an additional level of enforcement through the requirement for the quality control systems to be under the supervision of a 'qualified person', who is personally responsible to the medicines inspectorate for the suitability of the production facilities, and the quality of each batch released onto the market.

4.4.3 Legislation concerning design rights, patents and copyright

In the fiercely international competitive market, it is necessary to protect against competitors introducing similar products which are 'passed off' as the original product. This may be in the physical design, or in the text or graphics of the labelling. The main aspects of legislation in this area are the Trade Marks Act, and the Copyright, Designs and Patents Act. As for all aspect of legislation, professional advice must be sought by the newcomer to a market, in order to ensure that the new product is distinctly different from competitors' products.

4.5 Legislation concerning protection of the environment

4.5.1 The EU Directive on Packaging and Packaging Waste 94/62/EC

The Directive on Packaging and Packaging Waste 94/62/EC was incorporated into UK law as the Producer Responsibility Obligations (Packaging Waste) Regulations, and the Packaging (Essential Requirements) Regulations, both having been amended several times. These Regulations are examples of variation in implementation of a Directive across the differing countries of the EU (as indicated in Section 4.1.2). The system adopted in the UK is completely different from that in other member states. There are also differences between the implementation of each of the Regulations. The Producer Responsibility Obligations (Packaging Waste) Regulations impose a threshold of £2 million turnover and handling of 50 tonnes of packaging, below which no action is required. The definition of packaging is by a decision tree (basically 'Does it contain the product?', 'Is it intended to be discarded prior to use of the product?') and the Regulations are enforced by the Environment Agency. The Packaging (Essential Requirements) Regulations apply at the point at which the product was first placed onto the market, regardless of turnover or tonnage. The Regulations endorse a series of CEN standards (published by the Comité Europeén de Normalisation therefore having authority across Europe) including the definition of packaging by a definitive list, and are enforced by the Local Authority Trading Standards Department.

The basic requirement of Producer Responsibility Obligations (Packaging Waste) Regulations is the 'polluter pays' principle. In the UK this obligation is shared across the packaging supply chain, increasing as value is added to the item, from material supplier, converter, packer-filler and retailer. It is usual for a company to perform more than one activity in the packaging supply chain. For instance, a food manufacturer would be responsible for the pack/fill obligation of the primary pack and both the pack/filling and selling obligations of a transit case used to ship the product to the retailer, as the retailer is the end user of the transit case and thus the food manufacturer is the seller as well as the pack/filler. The materials are divided across seven categories, paper/board, plastics, steel, aluminium, glass, wood and other (hessian, cork, etc.) with rules for allocating composite materials. There are additional obligations for imported materials and finished products, and exemptions for materials exported, as they do not end up in the UK waste stream. Consequently suppliers have an interest in where their materials, or packaging components, have been supplied. There are also requirements to provide information to the public to encourage recovery and recycling activities. Most companies use the services of a Packaging Compliance Scheme to handle their registration with the Environment Agency, and to assist them in updating and maintaining their data collection and reporting systems, as they may be audited to ensure they meet the requirements.

The Packaging (Essential Requirements) Regulations include limits on the content of heavy metals, and a requirement for design to enable recovery and recycling. There is also a requirement to minimise the amount of material used in the packaging. This is applied via a procedure in which it is required to be shown that the amount of material being used has been reduced until something prevented further reductions. There is a list of technical, legal, commercial and marketing considerations which might become the limiting factor.

4.5.2 Green claims and recycling information

The international standard on environmental claims ISO 14021 has been established to clarify the quality of information which the consumer may expect. It is applied in the UK through the green claims code, which is being updated. Trading Standards Officers are empowered under the Trade Descriptions Act, and the Department of Fair Trading through the control of Misleading Advertising Regulations 1998. The attributes of green claims (made in text or by the use of symbols) are that they should be: truthful; accurate; able to be substantiated; clear and relevant; in plain language; specific and unambiguous. The use of symbols is widespread but many do not have clearly understood meanings. A useful summary of these symbols and their significance is provided on the recycle-more website (www.recycle-more.co.uk). There is also a series of symbols indicating the expected availability of facilities for recycling, which is being promoted by the major retailers and recycling schemes in the UK as a means of discharging their responsibilities for providing information promoting recovery and recycling.

4.5.3 Environmental factory operations

The wider subject of the environmental impact of factory operation includes controls on effluents, emissions, categories of factory waste, resource utilisation, etc. These are also connected with the international standards ISO 14000/14001. However, this legislation is outside the scope of this chapter.

4.6 Legal considerations in international trading

With regard to trade across international borders, there are legal requirements in the country in which the product is made, the shipping of the product, and its distribution and sale in each destination country. There is also the possibility that the product may not end up in the intended market. There are shared regulations, such as the various United Nations transport regulations, affecting the specification and testing of containers and the use of international standards and symbols for the shipping of potentially hazardous substances. These are very detailed and the requirements vary with the material, the quantity, the method of shipment, and the location to which they are being sent. Alongside these may be requirements of the operating policies of insurance and shipping companies. It is not unusual to find shared objectives but differences in the details of the regulatory approach taken. Examples are given in Table 4.2. In light of these issues, it is recommended that the services of

Table 4.2 Comparison of example regulations or trade conventions between Britain/Europe, the United States and Japan

Area of application	Britain/Europe	United States	Japan
Food contact materials and food labelling	As Section 4.3.1 Food Standards Agency	Similar intentions but differ in detail and format, e.g. presentation of nutrition information. US Food and Drugs Authority (USFDA)	Similar intentions but differ in detail and format, e.g. use of both 'Best before' and 'Use by' dates. Japan Ministry of Health and Welfare
Filling control	Imperial and metric; average with limits on low variations, as Section 4.3.1	Traditional, or metric; average with limits on low variations; revised as the accuracy of filling techniques improves, by the National Institute of Standards and Technology	Metric; average with limits on low variations. Some pack sizes are retained to reflect the previous non-metric system
Child-resistant closures	As Section 4.3.1 and Chapter 15	The panel test criteria are different	The panel test criteria are different
Main bar code symbology	13 digit, begins with 5 GS 1 UK	Developed the original 12 digit, now extending to include 13 digit	13 digit, begins with 4
RFID frequencies – UHF 'tags' for international operation have to respond to frequencies from 860 to 960 MHz	865–868 MHz EPC Global	Developed VHF 13.56 MHz and then UHF at 915 MHz. RFID Journal	950–956 MHz RFID Journal

appropriately qualified and experienced agents are secured to help to navigate safely through the applicable legislation at each stage of the product's journey to the final customer.

4.7 Sources of further information

Hard copies of the various Directives and Regulations and their national implementation may be obtained from the appropriate publishers or suppliers. As indicated in the introduction, the various government agencies have taken the opportunity to provide guidance as to how they expect the legislation to be interpreted, and how a company may ensure compliance.

The advice of the appropriate enforcing authorities should be sought at the development stages of a new product or pack change. In the UK the Trading Standards Officers should operate on the 'Home Authority Principle', which makes it advisable to build an effective working relationship with the local officer. Information and advice may also be sought from the trade association or from common interest groups such as the Industry Council for Packaging and the Environment (INCPEN).

Appropriately qualified and experienced consultants are available to provide advice and assistance.

4.8 The role of trade associations

Trade associations are paid for by their members and are operated for their benefit. This includes the provision of advice to their members on regulatory requirements related to their industry. They also provide advice to legislators through the consultative procedures in the preparation and implementation of regulations, as indicated in Section 4.1.2. They also provide information to the public, and make collective arrangements for the discharge of legal responsibilities, as the compliance schemes do for the Producer Responsibility Obligations.

4.9 What is legally required and what is good practice?

Whilst it is imperative to comply with legal regulations to avoid the risk of prosecution and the subsequent penalties, it is also necessary to understand and fulfil the appropriate trading requirements in order to provide the product as the customer would expect it.

4.9.1 Industry guides

Each industry has its trade association and their appropriate guides which serve to provide information on both the legal and operational requirements. An example is the British Aerosol Manufacturer's Association (BAMA), which provides information to enable manufacturers in the UK to produce products suitable for shipment across Europe, as the appropriate Directive has not been adopted into UK law. There are other industry guides which are used as the enforcement instrument by the regulatory authorities. For example, the 'guide to good manufacturing practice' is used in enforcement by the medicines and healthcare regulatory authority.

4.9.2 Trade conventions

It is important to be aware of the appropriate trade conventions, as whilst trade conventions are unenforced unless invoked in commercial contracts, they may be taken as the default understanding if not otherwise stated. For example, within the print industry an order may be considered to be complete if the quantity of items provided is within 10% of the quantity requested. This could cause difficulties in scheduling and collecting materials together for a required production run, especially if it is for a specific order requiring a minimum quantity.

There is also a range of informal systems which may change rapidly, such as the major UK retailers' different symbols for the labelling of food contents and the provision of advice for the disposal or recycling of waste packaging. Other examples include: statistical conditions on glass container tolerances; the normal tolerances on thickness of paper and carton board; the management of bar code numbering registers and symbology, including radio frequency identification, and electronic data interchange software conventions. There is also a range of informal systems which may change rapidly, such as the major retailers' different symbols to indicate the analytical values relating to the content of foods and the provision of advice for the disposal or recycling of waste packaging.

4.10 Methods of enabling consistency of compliance

It is important to ensure that company policies and procedures are set up in such a way as to manage compliance throughout the supply chain, using the appropriate standards to demonstrate compliance. The most widely used standard is ISO 9001, which comes from a quality control background and has developed towards encouraging an ethos of continual improvement across all aspects of the business. There is a special version of ISO 9001 for suppliers to the pharmaceutical industry, including reprographics and printed materials.

As its name suggests, the 'BRC/IoP Global Standard for Packaging and Packaging Materials' focuses upon the requirements of those particular sectors of business activity. Its requirements cover areas which are particularly relevant to packaging under the headings of: senior management commitment to continual improvement; hazard and risk management; technical management; site standards; product and progress control; and personnel. As indicated in Section 4.9.2, it is necessary to also be aware of the trade conventions relating to the area of operation.

4.11 The consequences of failure to comply with legislation

The failure to comply with legislation will lead to the occurrence of circumstances which the regulations are in place to prevent, such as: failing to provide the appropriate level of preservation; failing to provide the required information; or delivering poor quality or unsafe packs into the market. These may be handled as customer complaints, but may also lead to legal proceedings. The penalties for non-compliance may be brought against different bodies. Commercial cases may be brought against the company and in some cases the directors. Some cases, such as medicines and some environmental issues, may be against the responsible individual within the company. Alongside the legal penalties are the issues of damage to consumers' confidence in the product, or in that sector of the market. If the situation led to failure to supply saleable product, commercial proceedings could be very severe, such as the sanction of the penalty clauses within a commercial contract to recover loss of profit. The trading relationship with the customer would be adversely affected. This may include the de-listing of the product by the major retailers, with negative consequences for the financial health of the supplying company.

4.12 Sources of further information and advice

Guide to Packaging and Labelling Law by Charles James, 2nd edition, 2012.
Online access to UK legal publications: Office of Public Sector Information (http://www.legislation.gov.uk/).

Online access to guidance notes – the references to the current UK regulations are within the guidance notes:

- Food Standards Agency (http://www.food.gov.uk/).
- Paper and Board Food Contact Guidelines (www.paper.org.uk/members/current_issues/food_contact/Pre_Pub1_rev_bp-20090423-00012-01-E.pdf).
- Environment Agency – Packaging Waste Regulations (http://www.environment-agency.gov.uk/netregs/legislation/current/107198.aspx).
- Department for Business Innovation and Skills (BIS) Essential Requirements Guidance update (http://www.bis.gov.uk/assets/biscore/business-sectors/docs/p/11-524-packaging-regulations-government-guidance).
- Office of Fair Trading Guidance (http://www.oft.gov.uk/OFTwork/publications/publication-categories/guidance/cprregs/).
- Department for the Environment. Food and Rural Affairs (DEFRA) Producer Responsibility Pages (http://www.defra.gov.uk/environment/waste/business/packaging-producer/).

4.13 Disclaimer

The views expressed in this chapter are intended to provide a basic introduction to the wide range of legal requirements related to packaging. Any interpretations are expressions of the personal opinion of the author and should not be taken as definitive. Reference to the guidance provided by the appropriate regulatory authority is recommended in the first instance, followed, if necessary, by specialist legal advice.

5
Packaging and environmental sustainability

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Abstract: This chapter introduces the link between packaging and the environment. It explores the need to reduce consumption for the benefit of future generations. Various definitions and terms are explained including sustainable development and carbon footprinting. Compliance with European legislation concerning packaging waste and the environment is covered from waste reduction such as packaging minimisation, re-use, recycling through to disposal methods such as composting, energy recovery and landfill.

Key words: sustainable, sustainability, environment, environmental, aspect, impact, waste, recycling, packaging.

5.1 Introduction: why bother?

There are many reasons for considering the environment in the design, manufacture, use and disposal of packaging and packaging materials. The first and arguably the most important is the use of potentially scarce materials. Profligate and wasteful use of these resources will result in a shortage for the future. However, taken into consideration at the same time should be the following:

- Increasing cost with increasing scarcity
- Effect on future generations
- Waste produced
- Compliance with the law and voluntary agreements
- Climate change and disruption.

Increase or reduction in cost is core to any profitable enterprise and will not be covered in detail here.

In terms of the effect on future generations, the products that are best known to most members of the public are fossil fuels such as petrol, oil and gas and materials such as plastics derived from oil. There is some debate as to when the world will run out of oil as extraction of oil from certain locations such as the Falkland Islands or Alaskan shale becomes a likelihood when market prices rise and what was previously an expensive production cost is supported by a higher selling price. Increases in cost or shortage of these materials could have a catastrophic effect on the lives of our children and grandchildren.

Please note that it is not practical within this chapter to refer to how every country has approached its legislation, guidance and modes of operation with respect to packaging and environmental sustainability. Therefore the examples given are specific to the United Kingdom.

5.2 Key definitions

To assist in the understanding of the concepts of packaging and the environment, there are some definitions that must be explained.

5.2.1 What is 'packaging'?

'Packaging' shall mean all products made of any materials of any nature to be used for the containment, protection, handling, delivery and presentation of goods, from raw materials to processed goods, from the producer to the user or the consumer (EC Directive 94/62).

5.2.2 What is the 'environment'?

The surroundings in which an organisation operates, including air, water, land, natural resources, flora, fauna, humans and their interrelation (ISO 14001 clause 3.5).

5.2.3 What is an 'environmental aspect'?

An aspect of an organisation's activities, products or services that can interact with the environment (ISO 14001 clause 3.6).

5.2.4 What is an 'environmental impact'?

Any change in the environment, whether adverse or beneficial, wholly or partly resulting from an organisation's environmental aspects (ISO 14001 clause 3.7).

5.2.5 What is meant by 'sustainable development'?

There is no universally agreed definition of sustainability or sustainable development. The following are possible:

- The impact of our personal values, choices and behaviours on the wider world.
- Sustainable development must be considered in the context of scarce resources and the needs of future generations.
- There is a Native American saying: 'We don't own nature. We borrow and manage it in our lives, thinking about our descendants'.
- 'No generation has a freehold on this earth. All we have is a life tenancy with a full repairing lease' (Margaret Thatcher, 1988).
- Sustainable development is: 'development that meets the needs of the present without compromising the ability of future generations to meet their own needs' (*Our Common Future*, Oxford University Press, 1987; also known as the Brundtland Report, after the former Norwegian Prime Minister Gro Harlem Brundtland).

However, this raises a variety of questions about the extent of our own needs and those of future generations. In summary, 'sustainable development' can be thought of as a three-legged stool, one leg representing each of the social, environmental and economic aspects of a community. If any of the aspects is neglected and either withers or does not grow at the same rate, then the stool becomes unstable. Sustainability is no longer just 'nice to have' or exclusively part of corporate social responsibility but is seen as a business necessity to attract consumers and protect market share.

5.2.6 What is 'waste'?

'Any substance or object … which the holder discards or intends or is required to discard' (EU Directive: 75/442/EEC).

5.2.7 What are 'recycling', 'recovery' and 'energy recovery'?

Recovery has a broad definition laid down in EU Directive 75/442 and includes recycling, organic recovery of waste by means of recycling, re-use or reclamation or any other process with a view to extracting secondary raw materials, or the use of waste as a source of energy.

'Recycling shall mean the reprocessing in a production process of the waste materials for the original purpose or for other purposes including organic recycling but excluding energy recovery' (EU Directive 94/62). In reality, this means the processing of waste material (such as glass containers or corrugated cardboard) through a process (such as melting for glass or re-pulping into fibres for board) and making into another item (such as a glass object, not necessarily packaging; or into a sheet of paper, again not necessarily packaging).

'Energy recovery shall mean the use of combustible packaging waste as a means to generate energy through direct incineration with or without other waste but with recovery of the heat' (EU Directive 94/62).

'Organic recycling shall mean the aerobic (composting) or anaerobic (biomethanisation) treatment, under controlled conditions and using micro-organisms, of the biodegradable parts of packaging waste, which produces stabilised organic residues or methane. Landfill shall not be considered a form of organic recycling' (EU Directive 94/62).

5.3 Waste

'An empty Coke bottle is no different in value or substances to a full one except you've removed the contents. The only thing that has changed is your attitude to it' (Gerry Gillespie, Advisor to the New South Wales Government, Australia).

In the UK we have buried our domestic, industrial and commercial waste in the ground for many years. This has been the cheapest and easiest method of waste disposal. Other European countries do not do this for a number of reasons, including:

- The water table in some parts of Europe is much nearer the surface than in the UK and any waste that is buried can easily contaminate water systems;

- There are fewer naturally occurring or man-made holes in the ground than in the UK (caused for example by gravel extraction);
- The geology is such that digging holes to bury waste is difficult.

Consequently, incineration of waste (with energy recovery) has developed much faster than in the UK and is the main disposal method in other EU member states.

Production, consumption and waste disposal patterns in the UK are currently incompatible with sustainable living. They account for a significant proportion of greenhouse gas emissions and are dependent on inputs of non-renewable resources, energy and water. Products and materials are currently disposed to landfill that could be reused, recycled or have energy recovered from them (Defra Waste Strategy Annual Progress Report 2008/09).

5.4 Compliance with the law

The first environmental legislation was introduced in England around 1388 and made the offence of dumping of animal remains, dung and garbage into rivers, ditches and streams, punishable by death. Today there are many environmental laws, many of which emanate from the EU. Examples that can affect packaging are described in Sections 5.4.1–5.4.4.

5.4.1 Landfill Directive 1999/31/EC

In England and Wales the Directive is applied under the Landfill (England and Wales) Regulations 2002 (as amended). This has set targets that are binding on EU member states for the diversion of biodegradable waste from landfill in favour of more environmentally acceptable alternatives:

- By 2010 reduce to 75% of 1995 figure
- By 2013 reduce to 50% of 1995 figure
- By 2015 reduce to 35% of 1995 figure.

For many generations the UK has dumped all its rubbish into a hole in the ground. The main reasons for this are:

- Mineral extractions such as gravel had left many holes
- Landfill was convenient and easy
- The cost of sending to landfill was low.

However, a combination of factors has led to a lower reliance on landfill:

- Realisation that decomposing waste has an impact on human health
- Release of methane gas
- Odour
- Pests
- Noise
- Contamination of groundwater
- Escalating costs (Landfill Tax)
- Lower availability of sites.

In 2010, the government conducted a Review of Waste Policy with an aspiration of working towards a zero waste economy. The Review and Action Plan were published in June 2011 with many targets stretching into 2014.

In addition, the Government's Waste Strategy 2000 set the following timetable, focusing specifically on recycling and composting:

- Increase recycling/composting of household waste to 25% by 2005
- Increase recycling/composting of household waste to 30% by 2010
- Increase recycling/composting of household waste to 33% by 2015.

These were subsequently increased by the Waste Strategy for England 2007 to:

- Increase recycling/composting of household waste to at least 40% by 2010
- Increase recycling/composting of household waste to 45% by 2015
- Increase recycling/composting of household waste to 50% by 2020.

5.4.2 Packaging and Packaging Waste Directive 94/62/EC (as amended by Directive 2004/12/EC)

There are two types of Directive that can be enacted by the EU. The first is enacted under Article 100 of the Treaty of Rome and takes effect immediately and requires no transposition into member state laws. The second is enacted under Article 95 and, when published, sets dates for transposition into Member State laws. In addition, any targets are minimum requirements and can be increased by Member States. The Packaging and Packaging Waste Directive is of the second type and has been enacted in different ways in Member States of the EU. Packaging and Packaging Waste Directive 94/62/EC is transposed into UK legislation as the Producer Responsibility Obligations (Packaging Waste) Regulations and the Packaging (Essential Requirements) Regulations.

5.4.3 The UK Producer Responsibility Obligations (Packaging Waste) Regulations

These Regulations implement most of the Packaging Waste Directive 94/62/EC (as amended) and set targets for recovery and recycling of packaging placed on the market by materials – paper/board, plastics, glass, aluminium, steel, wood and other (hessian, cork etc.). The fundamental requirements of the EU Directive are:

(i) At least 60% by weight of packaging waste must be recovered or incinerated at waste incineration plants with energy recovery;
(ii) At least 55% and no more than 80% by weight of packaging waste must be recycled;
(iii) The following minimum recycling targets for materials contained in packaging waste must be attained:
   - 60% by weight for glass;
   - 60% by weight for paper and board;

- 50% by weight for metals;
- 22.5% by weight for plastics;
- 15% by weight for wood.

These targets apply to all packaging placed on the market within a Member State.

As stated, the Packaging and Packaging Waste Directive has been enacted differently in various EU Member States. Detailed information on implementation of the Packaging and Packaging Waste Directive in EU Member States can be obtained from *Understanding European and National Legislation on Packaging and the Environment*, published by Europen (The European Organisation for Packaging and the Environment).

The UK Government has taken a view that the targets shall not be imposed on small businesses and thus, in the UK, a company need take no action until its turnover exceeds £2m per year and more than 50 tonnes of packaging have been handled. To ensure the overall targets are met, the targets for companies above these thresholds are higher than those in the Directive. These have been steadily increasing year on year. Table 5.1 lists the minimum recycling targets for materials contained in packaging waste that must be attained. Of the material required to be recovered, a minimum of 92% of the recovery must be by recycling.

To comply with the Producer Responsibility Obligations (Packaging Waste) Regulations in the UK, a company exceeding both turnover and tonnage thresholds must in a calendar year:

(a) Register as a Packaging Producer with one of the Environment Agencies by 7 April and submit details of the packaging handled in the previous calendar year;
(b) Recover and recycle (or have recycling and recovery performed on its behalf) amounts of packaging equivalent to their obligation calculated from the targets above based on the packaging handled in the previous calendar year (the relevant Agency will perform this calculation) and keep evidence of this recycling and recovery;
(c) Provide a certificate of compliance to the relevant Agency by 31 January in the next calendar year.

The relevant Agencies will charge a fee for Registration. Evidence of recycling is in the form of Packaging Recovery Notes (PRNs) which can only be issued by a reprocessor of packaging waste registered with the relevant Agencies and these will also be charged for by the reprocessor(s).

Table 5.1 Minimum recycling targets in percent

	2012	2013	2014	2015	2016	2017
Paper/board	69.5	69.5	69.5	69.5	69.5	69.5
Glass	81	81	81	81	81	81
Aluminium	40	43	46	49	52	55
Steel	71	72	73	74	75	76
Plastic	32	37	42	47	52	57
Wood	22	22	22	22	22	22
Total recovery	74	75	76	77	78	79

Alternatively, an Obligated Producer can register with a Packaging Compliance Scheme approved by the relevant Environment Agencies, submit details of the packaging handled and pay fees to the Compliance Scheme. The Compliance Scheme will then arrange the recovery and recycling and certificate of compliance on behalf of its members. The relevant Agencies responsible for regulating the Producer Responsibility Obligations (Packaging Waste) Regulations in the UK are: The Environment Agency (EA) in England and Wales, The Scottish Environmental Protection Agency (SEPA) in Scotland and the Northern Ireland Environment Agency (NIEA) in Northern Ireland.

What does this really mean?

Packaging should not be sent to landfill as much of it can be recycled. In the UK the recycling loop has been active for many years for glass containers, newspaper and certain forms of aluminium and steel. The recycled content is significant and the public are accustomed to taking these materials to recycling centres. Since the Packaging Waste Regulations have come into force, many local authorities now have kerbside collections for all paper and board packaging, steel and aluminium cans and plastic bottles. Glass is also collected at the kerbside by some authorities and bottle banks are available in some areas.

There is currently a disagreement concerning the inclusion of glass in co-mingled kerbside collections. On the one hand, Local Authorities are targeted to reduce overall weights to landfill and glass, being relatively heavy compared with other packaging materials, is an attractive addition and is claimed to drive up total weights diverted from landfill. However, the process of collection and sortation of mixed materials including glass leads to contamination of these other materials with broken glass. The paper recycling industry does not like to receive paper/board contaminated with glass fragments and will pay less for such contaminated materials. Similarly, glass that is collected by the co-mingled route is of course mixed in colour and often contaminated with other waste, which again leads to a lower value of potential recyclate. Much glass collected by the co-mingled route is used for aggregate and not for recycling into glass containers.

There is also much debate about the export of packaging waste for recycling outside of the UK and outside of the EU. If packaging waste is exported to an accredited reprocessor overseas, the exporter can legitimately issue Packaging Export Recovery Notes (PERNs) that can be used as evidence of the Recovery/Recycling Obligations for Producers in the UK in stead of PRNs (see above). It is claimed that the UK would not meet the EU targets for some materials if exporting for recycling was not available. Conversely, as exporting is possible, the revenue from PERNs is benefiting recycling companies abroad and not in the UK.

However, since the Producer Responsibility Obligations (Packaging Waste) Regulations came into force in 1997, overall recycling of packaging in the UK has increased from 28% to 61% in 2008 (*Making the most of packaging – A strategy for a low-carbon economy*, Defra, 2009).

5.4.4 The UK Packaging (Essential Requirements) Regulations

These Regulations implement Articles 9 and 11 of the Packaging Waste Directive 94/62/EC as amended.

Article 9

Packaging shall be so manufactured that the packaging volume and weight be limited to the minimum adequate amount to maintain the necessary level of safety, hygiene and acceptance for the packed product and for the consumer. This is not considered to indicate a preference between material types (e.g. glass versus plastics) or packaging systems (e.g. single trip versus reusable), although consideration of the overall environmental impact of the packaging system used would be encouraged (Packaging (Essential Requirements) Regulations, Government Guidance Notes, May 2010).

This means that whilst there is a requirement to minimise the weight and volume of packaging, it does not mean that a glass bottle should be so light that it shatters in transit or on the filling line. It does not mean that the barrier properties of a plastic film are insufficient to prevent the transmission of oxygen that shortens shelf life of the contents. It does not mean that the pack has to be so small that the ingredients list is in type too small to be easily read. It does not mean that there would be a high level of rejects in production of the packaging component or that the pack is not accepted by consumers nor is so difficult to use that the consumer will not purchase the product again.

A series of seven standards in relation to packaging were published by the European Committee for Standardisation (CEN). These provide framework methodologies for considering reduction, reuse, recyclability and recovery. The CEN Packaging Standards can be used for demonstrating compliance with the essential requirements above. Compliant packaging enjoys freedom of movement across the European Community. The Standards can also help inform decisions on packaging design, for example around material specification, maximising recyclability and recovery, minimising component parts, reducing wasted space and optimising pack size.

The use of the CEN standards will carry with it the presumption of conformity of the packaging with the essential requirements in all Member States. In other words, if the standards are used, the product will be considered to meet the essential requirements unless there are grounds for suspecting otherwise. These standards are available from British Standards Institute (BSI). It should be noted that the standards represent only one means of establishing conformity with the essential requirements, and that other means may be acceptable (Packaging (Essential Requirements) Regulations, Government Guidance Notes, May 2010). In the UK, Local Authority Trading Standards Departments are responsible for regulating the Packaging (Essential Requirements) Regulations.

Options for packaging minimisation

Before considering where packaging can or should be reduced, it is important to revisit the functions of packaging, layers or 'levels' of packaging used and cost effectiveness. As already discussed in Chapter 2, the functions of packaging are to:

- Contain, protect and preserve the product
- Provide a convenient and safe way of handling and using the product
- Give information about the product
- Present and help to sell the product.

What do we expect from packaging? Packaging must:

- Match product needs, whether physical, chemical or aesthetic (if the product is sub-standard, the pack is unlikely to make up for this)
- Meet market needs, by satisfying both consumer expectations and the demands of retailer/wholesaler (if the consumer is disappointed with the pack, it influences how they feel about the product and the brand)
- Be technically and economically feasible to produce, fill, move, display, sell, use and dispose of.

Levels of packaging

Most products placed on the market that are packed have more than one 'level' of packaging around them.

Primary packaging is packaging around the product when the consumer takes it home, i.e. that which ends up in domestic waste. Examples of primary packaging could be a bottle for wine, beer or spirits, along with the closure and label(s) used; a jar, closure and label for jam or sauces; a carton for a dozen ball point pens; a metal can and label for fruit or vegetables; a label applied directly to a product, e.g. an apple, to provide product information. It must be noted that there is often more than one item of primary packaging, such as a plastic film bag containing breakfast cereals which is then contained within a cardboard carton.

Secondary packaging is packaging that is used to group or collate primary packs together. This packaging does not usually end up in the domestic waste stream. Examples of secondary packaging would be a corrugated board outer to hold a dozen bottles of wine or two dozen cans of peaches; or a tray with film overwrap (the tray may be used for shelf display). As can be seen from the tray/film example, there may be more than one item of secondary packaging.

Tertiary packaging is packaging used to hold secondary packs together and allow transport through the distribution chain. Examples of tertiary packaging could be pallets or roll cages, or stretch or shrink wrap film holding goods securely on a pallet and the pallet label.

One of the tasks of a packaging technologist is to ensure that the goods arrive at the retail outlet in the correct condition and that the goods can be taken by the customer to their home and arrive in that same condition. Where there is more than one level of packaging, any reduction in packaging weight or volume will have an effect on the amount of protection afforded to the goods by that packaging. It is wasteful to adopt the 'belt and braces' approach. If the change in amount of protection caused by a reduction in a level can be taken up by one of the other levels without overall reduction in protection, then that reduction is meaningful and genuine. However, where a reduction in the amount of protection cannot be taken up by one of the other levels, and indeed one of the other levels has to be increased to maintain the overall amount of protection, there is not a meaningful or genuine reduction.

For example, household cleaner is packed in an HDPE bottle and 12 bottles collated in a corrugated tray with an LDPE film overwrap. The secondary packs are able to be stacked up to 10 high without damage and transported through the distribution system. If the weight of the bottle could be reduced by 20% and the bottle can still deliver the household cleaner from the supermarket shelf to the home, this could be considered a packaging reduction. However, this may mean that the method of collation and transit results in bottles collapsing under the weight of a 10 high stack. This of course could be addressed by using a full corrugated case with divider to ensure the bottle reaches the supermarket in satisfactory condition, but this would mean (a) more labour involved at the supermarket to put the bottles on the shelf as they would need to be taken out of the case individually and placed on the shelf rather than previously 12 being put on the shelf together; and (b) the weight of the case will be significantly more than the tray and shrink-wrap. In this situation it is questionable if a genuine packaging reduction has been made, but on the supermarket shelf it can certainly be claimed a reduction has been made.

Article 11

(i) Hazardous Content

The sum of concentration levels of the heavy metals (cadmium, mercury, lead and hexavalent chromium) in packaging or any of its components must not exceed 100 ppm. There are some derogations such as recycled glass and recycled plastic crates and pallets.

(ii) Noxious Substances Minimisation

Packaging shall be so manufactured that the presence of noxious and other hazardous substances and materials as constituents of the packaging material or of any of the packaging components is minimised with regard to their presence in emissions, ash or leachate when packaging or residues from management operations or packaging waste are incinerated or landfilled.

Cost effective packaging

This is packaging that meets all the necessary functions of packaging at minimum overall cost. As with packaging minimisation, it is necessary to consider the combined performance of all three levels of packaging when looking for cost effectiveness. In the example given above, the overall cost may have increased.

Cost effective packaging is not just the cheapest option, but must provide the specified amount of protection and preservation and be suitable for the filling line and distribution system. This will avoid raw material, product and labour waste during production and avoid product deterioration that could lead to customer complaints, product recall or protection. So, in summary, cost effective packaging must:

- Be easy and safe to fill/handle/use
- Be compatible with product and packing line machinery
- Maximise packing line efficiency and minimise waste and its disposal cost
- Save money and valuable resources

This will then demonstrate good environmental management.

5.5 Packaging re-use and recovery

Packaging must be manufactured so as to permit reuse or recovery in accordance with specific requirements:

- Re-use
- Recovery as recycling
- Recovery as energy
- Recovery as composting or biodegradation.

We now examine each of these requirements in turn.

5.5.1 Re-use

The physical properties and characteristics of the packaging should enable a number of trips or rotations in normally predictable conditions of use:

- It must be possible to process the used packaging without contravening existing health and safety requirements for the workforce
- The requirements specific to recoverable packaging when the packaging is no longer re-used and thus becomes waste must be met.

Examples of re-use would be plastic crates/tote boxes used for distribution of goods (often but not exclusively foods) by certain high street retailers or wooden pallets used by a company or hired out by a pallet management company for use within the distribution cycle. In both of these examples, the crates or pallets are returned through the distribution system for re-use. It would be necessary for such packaging materials, especially for those used for food, to be subjected to inspection and/or cleaning before re-use. Another example would be returnable beer or mixer bottles. In these circumstances, as these are for direct food contact, the bottles would, as a matter of course undergo a rigorous inspection and cleaning process.

Certain bespoke toiletries retailers offer a refill service for liquid products, where the consumer takes the bottle back to the shop and it is refilled at the high street premises by the shop staff. Some laundry products are available as a refill pack where the consumer purchases a container which may include a dispensing device such as a trigger spray on the first occasion but subsequently may purchase a lightweight refill pouch of the liquid and refill the bottle in the home.

There are a number of aspects of re-use to take into consideration. On a commercial scale (e.g. crates/tote boxes, pallets or bottles for beer), re-use considerations include:

- Losses
- Economics of collection and washing
- Environmental impact of washing process – energy, water, cleaning agent
- Effluent produced
- Hygiene and safety
- Specification sufficient for the product to withstand multiple trips.

In the home, re-usable packaging:

- Must be cheaper for the consumer
- Must be easy to refill, without spilling
- Must be durable to withstand multiple use.

The item must also be capable of being recovered or recycled at the final end of life.

5.5.2 Recovery by recycling

A percentage by weight must be capable of recovery by recycling, i.e. must make a positive contribution to the output of the material recycling process for which it is considered suitable. Considerations here include:

- Environmental impact of recycling process – the use of recycled material does not always have a lower environmental impact than the use of virgin material.
- Economics and sortation of waste material – it may be difficult or costly to separate waste materials, resulting in a higher cost for recycled product; mixed plastics are very difficult to sort and are often contaminated with food residues.
- Market for recyclate – there may be little demand for recycled material; due to an increase in wine consumption, recycled green glass is available in quantity but there is little demand in the UK.
- Performance of recycled materials – whilst glass, steel and aluminium can be recycled almost indefinitely, both paper/board and plastics suffer some degradation with every recycling process.

5.5.3 Recovery as energy

Packaging waste processed for the purpose of energy recovery should have a minimum inferior calorific value (also known as 'minimum net calorific value') to allow optimisation of energy recovery. In the absence of harmonised standards, this is taken to mean that the packaging will make a positive contribution to the energy recovered in a waste incinerator (Packaging (Essential Requirements) Regulations, Government Guidance Notes, January 2011).

This means that once ignited, it must not be necessary to apply further heat or other energy to continue the combustion process. In some circumstances, packaging waste with a high residual calorific value such as plastics can be mixed with non-combustible waste to produce an overall mixture that will burn without the addition of further energy.

Considerations regarding energy recovery include:

- Collection and sortation. Most packaging waste that comes from the domestic waste stream is contaminated with other waste and has to be sorted by mechanical means. Dense materials such as glass and potentially higher value materials such as aluminium and steel need to be removed. Paper and plastic contaminated with food residue may not be suitable for recycling but is suitable for energy recovery.
- Capital investment of incineration facility. Such equipment is only economically viable if sufficient waste is available for continuous operations.
- Site of the facility and environmental impact of energy recovery. Whilst the benefits of energy recovery may be appreciated, the old fashioned image of the smelly smoking chimney generates local resistance to the siting of energy recovery facilities.

5.5.4 Recovery by composting or biodegradation

The conditions for composting and biodegradation are fulfilled when the packaging complies with the following:

- Packaging should be largely combustible solids; that is, the residue after incineration should be less than 50% of the packaging. This figure is taken as indicating the organic content.
- The organic materials should be inherently and ultimately biodegradable materials, that is break down to carbon dioxide, mineral salts, biomass and water or methane. Chemically unmodified materials of natural origin such as wood, wood fibre, paper pulp and jute are accepted as biodegradable for these requirements.
- The packaging should disintegrate in the waste treatment process.
- The packaging should not retard or adversely affect the waste treatment process.
- The packaging should not degrade the quality of the resulting compost (Packaging (Essential Requirements) Regulations, Government Guidance Notes, January 2011).

Biodegradable, degradable and compostable

The terms biodegradable, degradable and compostable are often used interchangeably; however, each term has a distinct meaning.

- *Biodegradable* materials are capable of undergoing physical, chemical, thermal or biological decomposition such that most of the finished compost ultimately decomposes into carbon dioxide, biomass and water.

- *Degradable* materials will in a period of time, break down into smaller particles when exposed to heat, oxygen or visible or ultraviolet light.
- *Compostable* materials biodegrade through the action of naturally occurring microorganisms and do so within a specified time under specified conditions.

To be compostable an article must comply with BS EN 13432:

- The article must break down into particles and no more than 10% must be particles larger than 2 mm in size after 12 weeks under test conditions.
- The article must break down into water, carbon dioxide and biomass (called mineralisation).
- The resulting compost must have no negative effect on plant growth.
- The concentration of heavy metals or fluorine must not exceed specified limits.

It should be noted that only articles or products can comply with BS EN 13432, but materials themselves (e.g. polymers, plastics or compounds) cannot. This is because the dimensions may mean that disintegration would not take place within the time allowed of 12 weeks or mineralisation within the time allowed of six months. For example a 15 µm film may disintegrate within 12 weeks (and comply with the other requirements) but a 20 µm sample of the same film may not fully disintegrate. Thus the material cannot be claimed to be compostable, even though the 15 µm film can disintegrate fully.

Home compostable packaging

There is a need for distinction between home compostable and industrially compostable materials. Articles that degrade in an industrial composting vessel (high temperatures and air flow) may never degrade in a home compost heap. In addition to certification to BS EN 13432, it is also possible for a product to be deemed 'home compostable'. The Association for Organics Recycling has launched a Home Composting Certification Scheme in conjunction with AIB Vincotte in Belgium.

Degradable, biodegradable and bio-based plastics

Biodegradable or compostable plastics can be bio-based or petroleum-based, but bio-based plastics are not necessarily biodegradable (including conventional polymers made from bio-based monomers). (See Chapter 13 for further definitions and properties of bio-based plastics.) Whilst biodegradable plastics have an emphasis on disposal and compliance with BS EN 13432, bio-based plastics have an emphasis on origin of carbon constituents (renewable carbon as measured by C_{14} content). Bio-based plastics are chemically identical to petroleum-based plastics (of the same formula) and can be recycled together.

Degradable and biodegradable plastics in the waste stream

Compostable, degradable and biodegradable plastics need infrastructure for collection, sorting, identification and composting or anaerobic digestion, often in industrial composting facilities. Many compostable, degradable and biodegradable plastics will contaminate sorted plastics waste streams at a very low concentration and render the batch unsuitable for recycling as the final recycled product can have indeterminate properties. For example, less than 1% of polylactic acid bottles in the PET bottle waste stream can adversely affect the transparency of the recyclate PET.

Biodegradable and compostable materials are not suitable for landfilling. Properly constructed landfills are dry and anaerobic so that biodegradable materials, if they degrade at all, will produce methane, a greenhouse gas 21 times worse than carbon dioxide. This is undesirable except in the very few cases where the landfill is designed to produce methane gas as a fuel. Compostable plastics do not hamper the composting process because they are biodegradable, disintegrable and do not affect the quality of the final compost.

5.6 Environmentally responsible packaging

There is no such thing as a good or bad pack and there is no such thing as environmentally friendly packaging. A pack should only be considered in conjunction with its contents. Every human action has the potential to cause damage to the environment (that is to say every action can have an adverse environmental impact). In many cases the product is more environmentally damaging than the packaging and both product and packaging must be considered. The pollution caused by a litre of milk spilt down a surface water drain far outweighs the damage caused by an HDPE milk container in a landfill site. However, the use of the correct packaging can prevent the spillage and resultant pollution of milk and an HDPE milk container can easily be recycled.

An environmentally responsible pack is one that gets the product from production to consumption with minimum use of materials and energy, generating the least amount of waste. In summary, environmentally responsible packaging should:

- Be resource-efficient throughout the distribution chain
- Prevent product wastage
- Optimise packaging materials and energy.

This can be achieved by:

- Designing primary, secondary and tertiary packaging as an integrated unit
- Designing to minimise number of lorries on the road
- Designing for recycling when it yields a net gain in resources.

It is important to remember 'Packaging does not have life of its own. Packaging only exists to ensure goods arrive at the point of use in the appropriate condition. If there were no goods, there would be no need for packaging' (Dick Searle, the Packaging Federation).

5.6.1 Beware of 'greenwash'

Greenwash is the use of vague or unsubstantiated or incorrect environmental claims. The use of such phrases as 'environmentally friendly', 'can be recycled/recyclable', 'good for the environment' should be avoided. Defra has published an updated guide 'Green Claims Code Guidance' in February 2011. A green claim should be:

- Truthful, accurate, and able to be substantiated
- Relevant to the product in question and the environmental issues connected with it
- Clear about what environmental issue or aspect of the product the claim refers to
- Explicit about the meaning of any symbol used in the claim – unless the symbol is required by law, or is backed up by regulations or standards, or is part of an independent certification scheme
- In plain language and in line with standard definitions.

A green claim should not:

- Be vague or ambiguous, for instance by simply trying to give a good impression about general concern for the environment
- Imply that it commands universal acceptance if there is actually some significant doubt or division of scientific opinion over the issue in question
- Imply more than it actually covers, if the claim is only about limited aspects of a product or its production, or does not deal with a significant issue for that type of product
- Make comparisons, unless the comparison is relevant, clear and specific
- Imply that a product or service is exceptional if the claim is based on what is standard practice anyway
- Use language that exaggerates the advantages of the environmental feature the claim refers to
- Imply that the product or service is endorsed or certified by another organisation when it has not been.

5.7 Compliance with voluntary agreements

In the UK it is now possible to comply with a voluntary agreement such as the Courtauld Commitment. The Courtauld Commitment is a voluntary agreement involving close cooperation between WRAP (Waste and Resources Action Programme) and the UK grocery sector. The Commitment has operated in two phases: Phase 1 from 2005 to 2009 and Phase 2 from 2010 to 2012. The Commitment has proved to be a powerful vehicle for change. Its first phase resulted in real reductions in packaging and food waste, realising significant commercial savings. Over 50 major retailers, brand owners, manufacturers and suppliers have signed the agreement since its launch in July 2005. The signatories are working closely with WRAP to develop solutions across the whole supply chain, including innovative packaging formats, reducing the weight of packaging (e.g. light-weighting bottles, cans and boxes), importing in bulk rather than small individual containers, increasing the amount of recycled content in packaging, designing for recyclability, increasing the use of concentrates, establishing refill and self-dispensing systems and collaborating on packaging design guidance. They are also working on solutions for reducing food waste through innovative packaging, in-store guidance, and the Love Food Hate Waste consumer programme.

Through Phase 1 of the Commitment (2005-2009), the growth in UK packaging waste was halted and 1.2 million tonnes reduction in packaging and food waste was delivered. Of the original targets set, two of the three targets were achieved:

1. To design out packaging waste growth (zero growth achieved in 2008) and
2. To reduce food waste by 155,000 tonnes (this target was exceeded with 270,000 tonnes less food waste arising in 2009/10 than in 2007/08).

A third target, to reduce the amount of packaging waste over the same period, was not achieved. Total packaging consistently remained at approximately 2.9 million tonnes between 2006 and 2009, mainly because of a 6.4% increase in grocery sales volumes since the agreement began in 2005 and participating retailers taking a greater proportion of the overall market for beer and wine. However, on average, across the range of groceries bought, packaging has reduced by around 4% for each product, whether through using more concentrated detergents or lightweight cans. The results of the first phase of the Courtauld Commitment showed real progress on reducing food and packaging waste, and demonstrated how effectively governments and businesses can work together through responsibility agreements.

Over the course of the Courtauld Commitment there has been an increasing shift to life-cycle thinking and the embodiment of life-cycle parameters and measurements within the framework. Initially, the Courtauld Commitment began with simple tonnage metrics for packaging reduction. Phase 2 of the Courtauld Commitment (2010-2012) looks at the life-cycle of products from manufacture to how they are used in households and ultimate disposal. In Phase 2 the targets focussed on the carbon impact of packaging, waste from household food and drink, and waste across the supply chain. Measurement of the Courtauld Commitment 2 targets was from January 2010 to December 2012 with targets set against a 2009 baseline. The three targets were:

1. Packaging target – to reduce the weight, increase recycling rates and increase the recycled content of all grocery packaging, as appropriate. Through these measures the aim is to reduce the carbon impact of this grocery packaging by 10%.
2. Household food and drink waste target – to reduce UK household food and drink waste by 4%.
3. Supply chain product and packaging waste target – to reduce traditional grocery product and packaging waste in the grocery supply chain by 5% – including both solid and liquid wastes.

First year progress results show that signatories were already half way to achieving the packaging reduction target (5.1% reduction in year 1) and three quarters of the way to reaching the household food waste objectives (3.0% reduction in year 1). The supply chain impact was significantly less at only 0.4%, but this is a new area for the Commitment and will be an area of additional focus going forward.

5.8 Climate disruption

There has been much written and spoken about the impact of the human race on the climate of the planet. However, many scientists are of the opinion that the earth's climate is changing because of increased concentrations of carbon dioxide and other greenhouse gases. These gases trap heat in the atmosphere and can contribute towards an increase in average temperature, which in turn can lead to extremes of weather conditions, more rainfall than average and/or more periods of higher or lower temperatures than average. Other scientists say that the impact of solar cycles on the temperature of the earth has not been adequately taken into account.

5.8.1 Greenhouse gases

Greenhouse gases (GHGs) are so called because they contribute towards the greenhouse effect. The greenhouse effect describes the natural phenomenon where certain gases in the atmosphere increase the Earth's surface temperature due to an ability to trap heat, similar to the way in which glass traps heat in a greenhouse (Defra Environmental KPI Reporting Guidelines).

What is the problem with GHGs?

There is scientific evidence that the increase in atmospheric concentrations of GHGs due to human-induced (anthropogenic) GHG emissions is having a noticeable effect on climate. The increase in the natural process of the greenhouse effect caused by human activities is known as the enhanced greenhouse effect and leads to global warming (Defra Environmental KPI Reporting Guidelines).

What are the GHGs and where do they come from?

The list of greenhouse gases includes the following (Defra Environmental KPI Reporting Guidelines):

- Carbon dioxide (CO_2) – burning of fossil fuels
- Methane (CH_4) – waste and agriculture
- Nitrous oxide (N_2O) – agriculture
- Hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulphur hexafluoride (SF_6) – air conditioning, refrigeration and industrial processes.

However, not all these GHGs have the same global warming potential and, for ease of calculation, have a conversion factor expressed as carbon dioxide equivalents or CO_{2e}. From Table 5.2, it can be seen that one gramme of sulphur hexafluoride has the same global warming potential as 23.9 kilogrammes of carbon dioxide.

The Kyoto Protocol

At an international level, the United Nations Framework Convention on Climate Change (UNFCCC) and the Kyoto Protocol have established a framework within

Table 5.2 Relative impact – 100 year global warming potential*

GHG	% of UK emissions	Global warming potential
CO_2	80	1
CH_4	10	21
N_2O	8	310
HFCs	2.1	150–11,700
PFCs	0.1	6,500–9,200
SF_6	0.2	23,900

which many countries are taking action to limit or reduce GHG emissions. The Kyoto Protocol entered into force on 16 February 2005 and imposes a legally binding GHG emission reduction target on the UK of 12.5% of base year emissions between 2008 and 2012 (Defra Environmental KPI Reporting Guidelines).

UK emissions total

In 2008, UK emissions of the basket of six greenhouse gases covered by the Kyoto Protocol were provisionally estimated to be 623.8 million tonnes carbon dioxide equivalent CO_{2e}. This was 2% lower than the 2007 figure of 636.6 million tonnes (Department of Energy & Climate Change, 26th March 2009).

The Intergovernmental Panel on Climate Change (IPCC) is the leading body for the assessment of climate change, established by the United Nations Environment Programme (UNEP) and the World Meteorological Organization (WMO) to provide the world with a clear scientific view on the current state of climate change and its potential environmental and socio-economic consequences. There is however, speculation as to how much carbon dioxide and other GHGs contribute towards the phenomenon of climate change, and what the effects of climate change may be. The IPCC's 4th Assessment Report has been challenged, as it is alleged that errors have emerged after checking of the sources cited by the 2,500 scientists who produced the report. In an interview with *The Times* newspaper, Robert Watson (former Chairman of the Panel) said that all the errors exposed so far in the report resulted in overstatements of the severity of the problem.

Adaptation and mitigation

Mitigation is about reducing carbon emissions, to slow down climate change. Adaptation is about coping with the impacts of climate change.

The Stern Review

The Stern Review set out to provide a report to the UK Prime Minister and Chancellor assessing the nature of the economic challenges of climate change and how they can be met, both in the UK and globally. The Review was the most comprehensive review ever carried out on the economics of climate change. The conclusions, published in 2007, were:

- There is still time to avoid the worst impacts of climate change, if we take strong action now.
- Climate change could have very serious impacts on growth and development.
- The costs of stabilising the climate are significant but manageable; delay would be dangerous and much more costly.
- Action on climate change is required across all countries, and it need not cap the aspirations for growth of rich or poor countries.
- A range of options exists to cut emissions; strong, deliberate policy action is required to motivate their take-up.
- Climate change demands an international response, based on a shared understanding of long-term goals and agreement on frameworks for action.

However, following various United Nations Climate Change Conferences, no binding commitments have been reached to reduce greenhouse gas emissions.

5.8.2 The environmental impact of packaging and the concept of life cycle analysis for a total packed product

Both the Essential Requirements Regulations and the Courtauld Commitment focus on packaging minimisation. But what does that mean? Thinner materials could be used. But this could lead to physical product damage if there is now insufficient protection. It could lead to a reduction in shelf life and/or increased wasted product if shelf life is reduced due to higher oxygen transmission of a thinner film.

It may be possible to change from a glass container to a plastic container. But this could lead to a reduction in shelf life and/or increased wasted product if the shelf life is reduced due to a higher oxygen transmission of a plastic compared with glass. There is also the consideration that glass is easily recyclable through bottle banks, but in many circumstances plastic is less easily recycled.

It may be possible to reduce headspace in a pack, for example cereals. But this may lead to a lower production rate to allow the product to 'settle'. Whilst this may facilitate the use of a smaller carton and thus reduce pack weight, the overall cost may increase. Other techniques that will facilitate packaging reduction include:

- Use of refillable containers and refill packs (see re-use earlier).
- Reduction in water content of certain product such as liquid detergents, resulting in smaller and lighter pack for equivalent cleaning capability.
- Redesign of pack shape to give better pallet utilisation, for example a square profile of bottle with rounded corners instead of a cylindrical bottle.

There are many ways of measuring environmental impact and a method that is now commonly used is carbon footprinting. This links to climate change as the carbon footprint is expressed in grammes or kilogrammes of carbon dioxide.

5.8.3 What is a carbon footprint?*

A carbon footprint can be defined as the total greenhouse gas emissions caused directly and indirectly by an individual, organisation, event or product. This is broken down into:

- Direct emissions
- Emissions from use of electricity
- Indirect emissions.

Reasons to calculate your carbon footprint include:

- Managing emissions
- Reducing your footprint – minimising or preventing it
- Cost reduction
- Reporting
    - To customers
    - To comply with legislation
    - As part of corporate social responsibility (CSR)
    - To 'offset'.

This is where the differences between industries, products and competitors become more difficult to establish from published information. Differences include the following:

- Unit of measure: this is usually grams of CO_{2e} per unit of production, but could be expressed as per square metre of the site or per £ of sales.
- Scope: what is included? Direct and indirect, or only direct? Will electricity use be included?

The Defra Environmental KPI Reporting Guidelines provide guidance on these matters.

5.9 Sources of further information and advice

Europen is The European Organisation for Packaging and the Environment. It is an industry and trade organisation open to any company with an economic interest in packaging and packaged products. It presents the opinion of the packaging value chain on topics related to packaging and the environment. Publications include *Understanding European and National Legislation on Packaging and the Environment*, available at: www.europen.be

INCPEN (Industry Council for Packaging and the Environment) is a non-profit, research-based organisation established in 1974 dedicated to: analysing the environmental and social effects of packaging; creating a better understanding of

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the role of packaging; and minimising the environmental impact of packaging. Publications include: *The Responsible Packaging Code of Practice, Packaging in Perspective* and *Pack Guide: a Guide to Packaging Eco-Design (GG908)*, produced by Envirowise and INCPEN, available at: www.incpen.org

WRAP (Waste & Resources Action Programme) works in England, Scotland, Wales and Northern Ireland to help businesses, individuals and communities reap the benefits of reducing waste, develop sustainable products and use resources in an efficient way. Useful reference material may be found on the WRAP website: www.wrap.org.uk

The Carbon Trust provides specialist support to help business and the public sector boost business returns by cutting carbon emissions, saving energy and commercialising low carbon technologies. By stimulating low carbon action, the Trust contributes to key UK goals of lower carbon emissions, the development of low carbon businesses, increased energy security and associated jobs. Publications include: *Carbon Footprinting*, available at: www.carbontrust.co.uk

The Packaging Federation is the 'over-arching' trade association for the UK packaging manufacturing industry. It is a unique representative body for companies and organisations in the UK packaging manufacturing sector and associated activities. Its website can be found at: www.packagingfedn.co.uk

The Association for Organics Recycling (AfOR) is the UK membership organisation committed to the sustainable management of biodegradable resources. It promotes the benefits of composting, digestion, and other biological treatment techniques and the use of biologically treated materials for the enhancement of the environment, business and society. Its website can be found at: www.organics-recycling.org.uk

Other useful publications include:

- Department for Business Innovation and Skills, *Packaging (Essential Requirements) Regulations Government Guidance Notes, January 2011*, available at www.bis.gov.uk
- British Standards Institute (BSI), *CEN Packaging Standards*, available at: www.bsigroup.com
- Department for the Environment, Food & Rural Affairs (Defra), *Environmental KPI Reporting Guidelines*, available at: www.defra.gov.uk
- Department for the Environment, Food & Rural Affairs (Defra), *How to make a good environmental claim, February 2011*, available at: www.defra.gov.uk

6
Packaging and marketing

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Abstract: This chapter examines the relationship between packaging and marketing. It defines marketing and marketing responsibility and examines the role of marketing in production-led, sales-led and marketing-led companies. It explains the main marketing responsibilities including identifying the need for a product, knowing the market, determining price, determining strategy for the distribution of a product and determining brand values.

Key words: marketing and packaging relationship, the marketing mix, market research tools, importance of a brand, importance of consistency of communication.

6.1 Introduction

The chapter evaluates the importance of a brand, and the various elements that make up a brand, including coherence, uniqueness, relevance, distinctiveness, market appeal and brand protection. The complete marketing mix is considered including product, price, promotion and place. The role packaging plays in product promotion and advertising is also considered. With the need for more detailed and complex information on packs, the importance of consistency of communication is evaluated with examples of how this can be achieved more effectively, including use of digital technology, global brand management and corporate identity manuals. The use of market research tools and techniques to identify customer needs including SWOT analysis, gap analysis, consumer research, demographics and socio-economic groupings, psychographics, consumer panels, test markets and competitor research are all considered, with the objective of achieving a successful new product launch.

6.2 Defining marketing

The Chartered Institute of Marketing defines marketing as: 'The management process responsible for identifying, anticipating and satisfying customer requirements profitably'. An alternative definition comes from The Dictionary of Marketing Terms, which describes marketing as 'the process of planning and executing the conception, pricing, promotion and distribution of ideas, goods and services to create exchanges that satisfy individual and organisational goals'. Whichever definition you favour, marketing encompasses everything to do with coming up with a product and service, making customers aware of it, making them want it and then selling it to them profitably. The important word here is 'profitably', because all marketing activity, whether market research, market development, promotional activities or advertising must ultimately be accountable to bottom-line profit-and-loss scrutiny. Without profit a company will simply go out of business and marketing management is but one facet of an organisation's management team. However, it is a fact that a business cannot succeed without marketing, although the precise role of marketing professionals will vary dependent on the nature of the business.

The role of the Marketing Department varies from organisation to organisation. Whatever the precise definition of the role, communication is a vital part of its mandate. The Marketing Department often has a better understanding of the market and customer needs, but should never act independently of the packaging technologist, product development or technical departments. Marketing needs to be involved wherever discussions take place regarding new pack or product development and other customer-related discussions. In recent years the introduction of digital media has brought an explosion in the number of channels marketers can use. However, the basic processes of understanding customer needs, developing appropriate products and providing fair and balanced information remain a vital part of marketers' role. Marketing is an integral part of any business, whatever the type of organisation.

6.2.1 Production-led companies

Some companies are production-led, i.e. in simple terms they sell only what they can make and innovation is not very high in the company's product strategy; an example would be a cement company whose product fulfils a basic requirement and is distributed and packed to provide only containment, protection and product information. This type of company usually has a core, commodity product. It may be constrained with regard to product and pack innovation. It may also concentrate on developing a unique or special service. It would rarely advertise or promote its products and services.

6.2.2 Sales-led companies

Some companies are sales-led, customer-driven, their packaging and marketing activity determined by customer requirements. Many packaging converters, particularly carton and label manufacturers and others supplying bespoke printed materials, come into this category. They produce to meet the customer's order and specification. Their vital need is to understand their customers' requirements and often their customers' customers. Opportunities exist in these types of companies for innovation in both product and service. It is vital for their sales forces to look, listen and be on the same wavelength as their customers' packaging technologists and product development teams.

6.2.3 Marketing-led companies

A large proportion of companies are marketing-led. This includes those selling food and drink, household products and toiletries, i.e. FMCG (fast-moving consumer goods) producers, plus companies selling other items such as clothing, textiles, household products, DIY and garden supplies, etc. Selling has been traditionally via supermarkets and stores, where the customer makes a self-selection, or via other selling methods such as printed catalogues and mail order. However, the advent of the world wide web (www) has changed much of this and it is now increasingly normal to purchase almost anything from the web.

6.3 The role of marketing

The marketing professional's role will include conducting the following activities:

- identifying the need for the product or service
- identifying the market sector
- determining the price
- determining the distribution strategy
- determining the brand values or the product and pack attributes.

6.3.1 Identifying the need for a product

It is among the marketer's responsibilities to identify the need for the product, whether it is existing or new. This is particularly crucial in new product launches because only 2% of those launched will ultimately succeed. Therefore the marketer must ask the the following questions:

- What is missing? Is there something which will give my product that USP (unique selling point). Look at the competition. What are their products like? How can I make mine different and better?
- What can be improved? If the product is an existing one, what can I do to improve it? Minor modifications, small design or functional changes can often transform something mundane and basic into a winner.
- Is there room for me in a crowded competitive market? Without a special feature or something which differentiates your product from the competition, the answer is probably 'no'! However, if you identify your target or niche sector and concentrate on that area alone, you may find you have something that can fill a gap in the market or, even better, supply a need which previously no one knew existed. However, to do this you will need to undertake market research, which will be dealt with later. All this has the ultimate objective of moving products or services from producer to consumer in a profitable way.

6.3.2 Identifying the market sector

It is essential to know and understand the market sector into which you are proposing to sell. Ask the following questions:

- Who are your potential customers? Do you have a database of names and addresses? Is the information up-to-date? You may be surprised to find that often it is out of date and therefore not useable. Companies change address and telephone number, and move location more often than you think. Do not launch until you are sure of your facts.

- How many customers are there and what is the value of the market? Be accurate and precise in your market assessment, this will determine many things including the investment to be made. Use accurate and reliable market data to undertake your market evaluation. Do not use old statistics otherwise you may make erroneous decisions.
- Where are your customers located? Sometimes there can be a distinct regional or local bias in markets. Know your market, know any regional variations and understand local needs.
- When do they want their products? Demand can be seasonal (e.g. Christmas or Easter) and a new product launch which is too early or too late can be disastrous. Timing is everything. Much of the information needed can be gathered by market research, or basic knowledge and understanding of the market.

6.3.3 Determining the price

To determine the price of any product it is essential to:

- Know the total cost of the product. No marketer can undertake pricing strategy without having a complete picture of start-up costs, manufacturing costs and other factors such as costs for a licence to produce in a particular country or territory.
- Know the development costs. The cost of research and development can be forgotten about or overlooked. This cost is a key part of any project, and can ultimately influence the final decision as to whether to proceed to a full market launch. Sometimes costs can be shared between the packaging producer and the customer to help reduce the burden of the development process, which can sometimes be protracted and difficult to define precisely in terms of time.
- Know the factors affecting cost. Things to consider include items which may be special one-off costs such as bespoke, customised tooling which may be expensive and involve long lead times. There may be special costs for artwork or origination which may make the product prohibitively expensive and therefore too costly for today's market. Whatever the extra cost is, be aware of it and build it into the whole costing model or matrix.
- What price will the market be prepared to pay? The more added-value features, the more the market will be prepared to pay for the product. The more the product is perceived as a commodity one, the less the opportunity for a higher price. It is also important to know the price of your competitors' products and pitch your price accordingly. Do not price yourself out of the market. However, a higher quality product will often require a higher price, by virtue of the extra costs involved in production. It will also require higher quality packaging with more added-value features.

6.3.4 Determining the distribution strategy

- Where will the product be sold? Traditionally sales have been through supermarkets, department stores and specialist retailers. Of course, the internet has changed much of this. New products are often ordered on-line, called off from warehouses and distributed direct to customers by fleets of lorries and delivery vans. The strategy adopted by marketers has therefore changed to reflect the speed, quick reaction and dynamism of the new channels of distribution. Out of stock is simply not acceptable today. 'Just-in-time' was the mantra for delivery of product some years ago. Today 'just-in-time' is almost too late.

- What selling methods are needed? Whereas before, catalogues and mail order were the alternative way to shop, rather than a visit to the supermarket or store, now the internet has created an unstoppable juggernaut of new sales patterns. Marketers must understand the new channels to market. Whatever method they choose, they must be ready with products and packaging which are lighter in weight, more vibrant in colour and design and more environmentally acceptable, to meet the needs of a greener and faster moving world. Often selling by a combination of all these methods will be required today.
- What size of pack? There are many factors to consider here, including the size of the original bulk pack, the secondary pack and the tertiary pack. Shelf-space is at a premium today and ultimately no marketer wants his or her product to be tucked away behind others on the shelf in the store. Success in achieving widespread distribution will depend on many things, not least of all the benefit of a multi-million-pound marketing and promotional budget. However, once in the stores, the size and shape of the pack will play an important part in the final decision on shelf location. One of the key factors in deciding pack size is perception of value. The pack must reflect the size or shape of the product contained. Too large or too small a pack in relation to the product it contains will have detrimental effects in terms of sales success. You can only add value so far by size of pack, and after that it becomes counter-productive.

  An important influence on pack size is the amount of product information that is now required to be displayed on the pack itself. Ingredients, weights, preservatives, nutritional information, quantification and explanation of terms such as 'low in sugar' are now all listed. Control of information stems from a number of UK and European labelling standards and guidelines. Use by, best before, storage conditions, business name and address, place of origin, instructions for use and batch numbers are now required. With a global market, much of this information has to be displayed in more than one language. When deciding on a pack size it is essential that all the above information is included, in a clear and concise way. The pack size must reflect the size of product, but it must also be sufficiently large to cover all compulsory and legal information requirements. However, this is only the start because a marketer needs to ensure that his or her product's brand identity, its logo, and any special promotional offers are all included on the pack in the correct way. This is a complex area and a balance has to be maintained between retaining brand identify and ticking all the boxes from a legal and statutory viewpoint.
- What are the display requirements? A new product launch or a re-launch of an existing product will benefit from point-of-sale display and special merchandising. The marketing responsibility here is to ensure the display retains the original

design features of the pack and that the brand values are maintained in terms of shape, style, logo and other features.
- Telling the consumer about the product. A new product launch will benefit from a launch event, something which is done on a large scale to tell the world about the exciting new product about to hit the market.
- Advertising media. Traditionally this took the form of national, trade, technical, local and regional press, or, if the product is a new or existing major consumer brand, national TV, cinema or radio. The advertising spend on TV has been affected in recent years by the internet, which is seen by many as a more cost effective way to reach a modern audience, who get their information via electronic means rather than from traditional media.
- Timescale. The successful launch of a new product depends much on the roll out and the ability to get the product into the store at a pre-determined time and date. It is no good having a high profile advertising and promotional campaign, letting the consumer know about a new product, only to visit a local store and find it is still not on the shelf. It is the marketer's responsibility to ensure the new pack is available in sufficient quantity to meet the demands of an eager and expectant consumer.

6.3.5 Determining the brand values

It is essential for marketers to discover what product and pack attributes will appeal to the market. For example, novelty or unusual pack features may appeal to children, added-value innovative features may appeal to consumers purchasing premium products. There is a whole array of consumer research techniques to discover which pack style or feature appeals to different groups of consumers. These will be investigated later in the chapter.

6.3.6 The relationship between packaging and marketing

Marketing and packaging are complementary functions in any organisation. This is particularly true in FMCG producers, where the link between the two can be vital, particularly in the launch of new products which involve packaging of a technical nature. The packaging technologist can play an important part in guiding the marketer through the design, product development, production and cost implications of choosing a new type of packaging. Whilst the marketer might understand the overall features of a new package, the packaging technologist can fully explain every function and ensure that the marketer makes the correct decisions, from a technical viewpoint. The relationship goes much further than this in some organisations, leading to the creation of a role within the company of Packaging/Marketing Specialist, whereby one person with sufficient knowledge of both functions undertakes a combined role. It will require a considerable amount of technical and commercial knowledge to aspire to this role, but the benefits can be considerable.

6.4 Branding and the impact of packaging on product promotion and advertising

A brand is a mark of authenticity, something which imparts an intrinsic value to a product. It is a guarantee of reliability, a mark of quality and inherent goodness. Iconic, long-lasting brands are truly special. It is fascinating to look at market leaders from 1925 and see how many are still in a leadership position. Here are some of them:

- Breakfast cereals – Kellogg's
- Chocolate – Cadburys
- Razors and shaving products – Gillette
- Soft drinks – Coca-Cola
- Tea – Liptons.

These are names which have a massive brand equity and kudos. This is reflected in the way these companies go about their marketing activities. It goes without saying that a brand should be fiercely protected. This is vital as the brand name differentiates one product from another. Arguably it is a promise, a commitment that the product being purchased is intrinsically good.

A brand consists of:

- the product itself
- the brand name
- promotion
- advertising
- overall presentation
- methods of distribution and sale.

If your product is the same as everyone else's, there is little encouragement to buy yours rather than theirs. If your packaging is the same as everyone else's you will devalue your brand and lose your brand identity. However, this issue becomes more complex when faced with the growth in retailers' own brands. Arguably these are not branded products as such, more taking their brand values from the presence and integrity of the retailer's name. In this instance the retailer is the brand and the customer's confidence in the individual product derives from the confidence the consumer has in the retailer's name and brand identity.

This has been further extended or indeed confused by the launch of retailer sub-brands, 'value' or lower cost lines, and added-value premium lines which intrinsically convey messages of superior quality, often by their packaging. In the lower cost brand market, Sainsbury's 'basics' range is a good example as is their 'Taste the Difference' in the added-value sector. Much of what has been discussed here comes down to the packaging and the product perception by virtue of the packaging style, quality or image.

The elements of a brand are:

- coherence
- uniqueness
- relevance

- distinctiveness
- market appeal
- it must be protectable.

Coherence

Consistency of communication of a brand is vital. This can be through several different strata: across advertising and packaging, across product range, and throughout product life.

Uniqueness

What makes a brand or product special? It might be the special structure/shape, form or material. What is its function and what feelings or emotions does it evoke? Are these feelings good or bad?

Relevance

What is the brand's relevance to peoples' needs? Is the brand still one which consumers wish to purchase? The brand can become the badge and often it is its package shape or design which signals the desirability of the brand. All Nescafe Coffee jars still have a distinctive shape which differentiates them from other coffee.

Distinctiveness

A brand must stand out. A consumer's product attention in the store whilst looking at the shelf will last 7 seconds at maximum. Some 68–80% of purchasing decisions are made whilst facing the product on the shelf. In a food superstore there are at least 16,000 products on display and in a traditional department store there are 30,000–40,000 items. It is therefore essential that a brand must be recognisable. Customer research has revealed that colour is often the first thing which attracts. Colour can be detected in the store shelf from as much as 10 metres away. From 4 metres the shape of the pack becomes discernible and only from 1 metre does the customer identify the brand. What the package needs therefore on the shelf is shape, colour, strong graphics and branding. However, the brand must balance the need to 'stand out', with the requirement of reassurance, recognition and customer awareness. Too much change in a brand identity is not always good.

Market appeal

A brand must continue to differentiate a product from the competition. It is essential that it achieves that vital commodity – product differentiation at the point of purchase, i.e. a uniqueness of product. A brand can do this by its packaging. A brand must also make the customer want to buy it. Of course, national brand loyalty has declined in recent years, almost to the extent that supermarket loyalty (influenced by the incentives which stores have introduced, such as loyalty cards) has become an important factor in purchasing decisions. However, a brand which still conveys a strong image and identity will provide an important incentive to make consumers want to buy it, once they are in the store. Procter and Gamble's 'Ariel' and Unilever's 'Persil' may face own brand competition but they are still iconic products, aided by their packaging and brand identify.

A brand must be protectable

It should contain all the elements of legal information, plus product constituent details and bar codes for ease of identification. These are all part of the 'brand equity'.

6.5 Branding and the marketing mix

The key elements of the marketing mix are:

- product
- price
- promotion
- place.

Product

The first impression of a product is its packaging. If the packaging conveys an aura, an impression of quality via its shape, graphics, use of colour or print, it is going a long way towards protecting its brand integrity. The product and the packaging can become intertwined and become one and the same to the consumer. In some cases the packaging can often overtake the product in terms of priority and importance to the overall concept.

Price

The price is determined by the position required by the brand. A high-quality product, demanding a high price, will also require the high-quality presentation available from high-quality packaging materials. A lower quality or commodity product will not have as high a profit margin and thus not be able to sustain the cost of expensive packaging or design. A product's price often communicates as much to the consumer as its advertising or promotion. Consumers perceive a product's value based on its price in many situations. Some forms of packaging, which were once considered to be new or innovative, over a period of time became less high value and therefore moved into the commodity market category. An example of this is PET bottles in the beverage sector, particularly soft drinks.

The profitability of a product is the difference between the selling price and the total cost of getting the product to the point-of-purchase. Packaging can make a major contribution to profitability both by influencing the price which can be commanded for the product and by its direct effect on total product cost. The cost of packaging includes not only the bought-in packaging material costs but also development costs including special tooling, artwork and origination.

Promotion

The promotion is essentially the communications strategy of a marketing plan. It refers to the activities used to get the consumer to recognise the product and be encouraged to buy it in preference to others. Promotion refers to the advertising which takes place both when the product is launched and later on to sustain and grow its sales. Promotional activities might also include:

- public relations and press
- direct marketing and mailings
- promotional events
- product and company marketing material, e.g. brochures, leaflets, etc.
- premium give-away items
- sales force promotional activity, designed to generate individual sales by each salesperson.

Other promotional activity is more direct and usually occurs at the point-of-purchase in the supermarket. This can take the form of 'money off' packs, added-value offers involving extra product for the same or special price, samples, the classic 'BOGOF' (buy one get one free) offers, or the offer of free/reduced price gifts. Packaging is often the major vehicle for promoting such activities. Another technique which helps to promote the brand and protect its authenticity is range extension, i.e. by adding other variations of the same product. For example, people have been eating Kellogg's cornflakes at breakfast time for more than 100 years. The company's 'Special K' brand – aimed at people managing their weight – has been around for 50 years. There are now at least 10 different varieties and to cater for the 'on-the-go' breakfast market there is a range of 'Special K' cereal bars. Kelloggs is trusted by consumers. It was the most trusted cereal maker in eight European countries from 2007 to 2011, according to the Reader's Digest Trusted Brands Survey. This means consumers are more resistant to moving to cheaper or own-label brands. Kelloggs are keeping their brand protected by emphasising that value can be obtained from more than cheaper prices. However, they are still at great pains to make clear in their advertisements that they have been making cereals for 100 years, reconfirming iconic brand status.

New media, particularly the Internet, has provided a new tool for marketing, communication and promotion. The communication aspects of the new media are immense, allowing brands to launch websites to reinforce messages which are also contained in their product packaging. To use the Kellogg's example again, 'Special K' is using the web to communicate its healthy lifestyle programme. Its 'My Special K' website includes a personal plan for ideas and advice in the whole area of healthy living. Brand integrity is therefore a key part of this process.

Place

The place is not only where the product is sold, but also refers to the distribution method and the way in which the product is merchandised. The strategy behind how a product is distributed and sold is a very important element of the marketing mix. For example, do you want your product to have wide distribution and be sold everywhere? Or do you want to create a niche market, in a more exclusive up-market sector? For traditional store and supermarket merchandising, the part packaging has to play here is in ensuring that the product arrives at the point-of-purchase in good condition so that it will still attract consumers to make the purchase. It must also maintain its function of protecting/preserving the product throughout its use.

6.6 Promoting the brand

The essential elements of packaging in the marketing mix are the brand name, the logo (which frequently refers to the brand name), the colour of the pack, its shape, size and texture. The Coco-Cola brand name, for example, is recognised world-wide because of its distinctive typeface and shape of the iconic Coco-Cola bottle, which gives the brand its own persona or identity. As a result of this you are never in doubt that the product is one from Coca-Cola.

Achieving the correct product persona is vital in persuading the target audience to buy the product. Deciding on the elements of that persona can only be undertaken when the needs and desires of the target audience are fully understood. This is the key role played by market research, which we will deal with later in the chapter.

Advertising is the most visible and highly remembered part of a marketing campaign, apart from the pack itself. Adverts frequently use images of the pack or incorporate features of the design to link the two together in the minds of the customer. With a distinctively shaped container and/or an attractive graphic design, the recognition potential of the pack on the store shelf is greatly enhanced and helps to rekindle the message delivered in the advertisement.

It is also necessary to identify which types of media to be used to carry any advertising message. This essentially is the media plan and can include magazines, newspapers, billboards, web banners, radio adverts, TV adverts, sponsored TV and radio programmes, cinema adverts, posters and flyers, directory listings and in-store displays. The TV advertisement has traditionally been the most effective way of reinforcing brand messages. However, this medium has suffered in recent years as the use of new media has risen. TV advertising is expensive and with the rise of digital communications and the ability of the computer to receive more complex and animated information, brand reinforcement using pack images is increasingly being made by this route. According to a survey produced by The Internet Advertising Bureau (IAB) and Pricewaterhouse Coopers in 2011, internet advertising in the UK increased by 13.5% to £2.26 billion. This is a 27% share of the total advertising market.

The recognition process is aided by the use of additional advertising material at the point-of-purchase. This may take the form of shelf-edge cards, store displays and other devices, such as references to promotional activity to attract the attention of the customer and assist the product launch. However, it must be remembered that the pack itself acts as on-going advertising medium in front of the consumer, reinforcing the need for good presentation and instant brand recognition.

6.7 The importance of consistency of communication

A brand image is a powerful commodity. How a company is perceived will influence a consumer's disposition and his or her readiness to buy the company's products. When a consumer purchases a branded product he or she is identifying with that image, i.e. with the perception of a brand. The image is essentially part of the product. Brand image, integrity and consistency of communication are therefore most important factors in the packaging and marketing interface and should never be overlooked. Consistency of communication must be maintained across all facets of advertising and packaging, over the complete product range and indeed through the entire life of a product.

6.7.1 Global brand management

The supply chain has been revolutionised in the last 10 years thanks to the Internet and digital communications. Global brands have global brand management, handling every facet of the complex process which brings packaging to the retailer and ultimately the consumer. All of this should ensure greater consistency of communication. However, in the case of packaging the need for global consistency through all the stages of design, product development, print and final conversion to finished pack has never been greater, and arguably never more delicately positioned. Get this process wrong in the minutist of ways and the consequences can be catastrophic, leading to a devaluation of brand equity.

6.7.2 Use of digital technology

During the past 10 years or more, a large number of packaging producers and FMCG companies have set up production sites in Eastern Europe, the Far East and even further afield. Some multinational companies have moved all corporate and production operations to new overseas sites where costs are much lower. The way these organisations develop global marketing and packaging strategies is diverse. However, what they have all found is that the use of digital technology is driving them to improved business efficiency. They have found that the same digital technology has enabled them to better control the consistency of communication in terms of global pack design, advertising, promotion and point-of-purchase because it can all be viewed electronically, proofed, amended and, only then when agreed by all, finally printed and converted into a finished pack for a world market. The greater benefit here is speed of response and cost savings.

6.7.3 Corporate identity manuals

Corporate identity or brand manuals (or 'Corporate Bibles' as they are sometimes called) are an ideal way to ensure that consistency of communication is adhered to, once a branded image has finally been produced in all its forms. By this method every aspect of use of brand – logo, colours, typeface, font, size of lettering, etc. – are all laid down in terms of what can and cannot be done. Every department and function in the organisation should retain a copy of the manual and use it as an important point of reference to ensure correct reproduction of identity and image at all times.

The responsibility for managing this document will normally belong to the Marketing Department. They will need to liaise closely with the packaging technologist to ensure the rules governing communication of a protected brand name or logo are being strictly adhered to, most particularly on the pack itself. With the multiplicity of printing methods and packaging substrates in which branded packaging appears today (from glass, metal, folding cartons and labels to corrugated cases, rigid plastics and flexible plastics), it is vital that a consistency of image is maintained in all the ways in which a brand appears on any one package at any one time. An inconsistency in a global brand in terms of colour of pack, style or use of logo across different packaging materials, for what should be the same consistent recognisable image, can have devastating effects for the brand owner, ultimately devaluing the brand.

6.7.4 Brand consistency and complex information

The need to be consistent in brand communication is complicated today by the need for complex and detailed information to appear on any pack. Features for more robust methods of product tracking and traceability, much of which is required by legislation and regulation, now appear. The strict legal requirements for consumer information must be clearly displayed on the outside of the package, allowing customers to check before purchasing exactly what is inside. In the case of the food market they will need to know where the goods come from and even detail about whether allergic reactions could result. Nutritional information is now listed in some cases, and more recently carbon footprint details. All of this means that consistent communication will become more difficult to achieve. On a small area of a pack a brand image and identity will require careful control and management to ensure it is accurately and precisely displayed, amongst all the other legal and mandatory information. Nevertheless, it must be adhered to at all times. The marketer and the packaging technologist will need to work closely together to ensure everything is included and the brand integrity is consistently maintained.

In the pharmaceutical market the leaflet label containing all statutory and legal information, including product contents, has proved to be a major benefit to ensure all these details are correctly displayed. The marketer will need to ensure this information is accurate, not least of all because it is normal today for many leaflets to be printed in multiple languages, for international/global markets. This all comes down again to consistency of communication and the importance of retaining pack and brand integrity.

6.7.5 The role of marketing communications agencies

Often today FMCG producers employ marketing communications or design agencies to create much of the image and brand identity which appears on packs. With multi-million-pound budgets, specialists with creative skills are often needed to convey high-profile messages to sophisticated audiences. Whilst their role is important, ultimately it is the in-house marketer's responsibility, working closely with the packaging technologist and other functions in the company, to ensure that image consistency, in all pack formats, is maintained at all times.

6.8 Use of market research tools and techniques to identify customer needs

The marketing process starts in many companies with the concept or idea of a new product. It ends when the product is ultimately bought again by the consumer. However, to get to this final stage, many processes have to be gone through. In the definition of marketing provided by the Chartered Institute of Marketing the words identifying, anticipating and satisfying customer requirements are used. The market research phase of any new product launch is the 'identifying' part of this definition, because identifying in this instance means to look at or understand the requirements of the market. This can only be effectively achieved by thorough market research.

6.8.1 Product viability

If the idea is a new one, much market research and evaluation has to be carried out to determine whether the idea or the product concept is viable, both economically and technically. Equally, if the product is a change or modification to an existing one, clear objectives have to be drawn up to establish the criteria for the change. For example:

- What are the expected benefits of the change?
- What is the timescale?
- What are the reasons for the change?

6.8.2 Assessing consumer needs

In assessing consumer needs, the marketer is assisted by market research and the many tools available to him or her. Without doubt, intuition, flair or 'gut feel' still have a role to play. Often a new idea or concept for a pack starts life just like that – a thought at an unlikely time which sparks off a discussion or debate in the company. However, today, in the highly competitive FMCG market, analytical assessment of consumer needs and desires is vital. It is a fact that the majority of new product launches fail. The figure is as low as a 2% success rate in many areas. Only products which are well researched, fit the market needs and are well packaged and promoted will ultimately be successful. Market research can be carried out at any stage of marketing activity.

It will normally start with researching a market to find out any areas of demand. It will continue with researching the segments or sectors of the market.

6.8.3 SWOT analysis

As an initial evaluation of a company's competitive position, SWOT analysis is a valuable market research tool. It stands for Strengths, Weaknesses, Opportunities and Threats. Normally strengths and weaknesses are determined by internal factors, whereas opportunities and threats are determined by external factors. Strengths can help improve your product, market share or performance. Weaknesses can contribute towards losing competitive advantage, market share or financial performance. Opportunities and threats are factors which exist in the market. One example is a competitor launching a new product which could impact significantly on sales values. Arguably this could be a threat and an opportunity, depending on how this is viewed. It could be an opportunity to launch a superior more advanced alternative product or a threat because it could take sales away from your company's product.

6.8.4 Gap analysis

Research can then continue into specific segments of the market. Gap analysis (finding out where there are pockets of demand for specific products or services not being currently met) is a very useful technique. It is first necessary to decide how to judge the gap over time, for example by market share, profit, sales and so on. Then ask two simple questions – 'where are we now?' and 'where do we want to be?'. The difference between the two is the gap. The next stage is to close the gap and decide on methods as to how this can be achieved. Strategic gap analysis and tactical gap analysis will help in this process.

6.8.5 Market segmentation

Gap analysis is followed by researching prospects in those specific segments identified, to find out details of size, price, variety, colour and so on, of a product which will be acceptable to potential customers. This will not only lead to more customers being reached who will ultimately buy the product, but also reduce the number of potential competitors to be faced. Finding a niche market can often be the key to success for small, medium and sometimes even large companies. Some niche markets will be very distinct, others will be more subtle. The product could also cross several market segments and marketing activities might need to be adjusted as a result.

6.8.6 Consumer research

During the stages of product and pack development, there will be further research to test performance in use and consumer reaction. Consumer panels are a very useful way to gauge reaction to different pack concepts. A variety of new pack designs can be presented to the panel and their feedback to each new idea is often a very important factor in deciding whether to proceed to market with a new idea or concept. A range of shapes, materials, colour and print options will be presented. Opinions or preferences already expressed in a company about a potential new pack can often be reinforced or, indeed, refuted by this method. During the launch of a new product, research will also be used to test the effectiveness of advertising and promotional campaigns to see how well the product is being received.

6.8.7 Demographics

When researching a product or a market sector there are various ways of segmenting the information for ease of analysis. One of these techniques is known as demographics. It works by dividing the population into categories. This essentially sorts the population by:

- gender
- occupation
- family size
- age
- education
- socio-economic status.

In the UK this is normally done according to job function or occupation of the head of the household or chief income earner, as shown in Table 6.1. Retired persons who have a company pension or private pension, or who have private means are graded on their previous occupation.

In addition to the standard categorisation, Mintel, the international market research group, also analyses the consumer research it undertakes in another way. 'Lifestages' are derived from analysis of Mintel's own consumer research and are split into four main groups:

- Pre-family/no family – age under 45 who are not parents.
- Family – any age with at least one child under 16 still at home.
- Third age – aged 45–64 with no children aged under 16.
- Retired – aged over 65 with no children aged under 16.

Mintel has also created special groups of consumers to typify consumer habits in

Table 6.1 UK socio-economic status classifications

Socio-economic group	Occupation of chief income earner
A	Higher managerial, administrative or professional
B	Intermediate managerial, administrative or professional
C1	Supervisory or clerical and junior managerial, administrative or professional
C2	Skilled manual workers
D	Semi and unskilled manual workers
E	All those entirely dependent on the state long term, through sickness, unemployment, old age or other reasons

the early years of the twenty-first century. Some Mintel reports also use consumer research analysed by ACORN category. This is a geo-demographic segmentation method, using census data to classify consumers according to the type of residential area in which they live. Each postcode in the country can, therefore, be allocated an ACORN category. With all these tools at their disposal, the marketer should be well armed with information to make informed decisions about potential pack success.

6.8.8 Psychographics

However, there are many other factors which influence purchasing decisions, such as personal preferences, which are not identified by demographics. This is where psychographics becomes a useful tool, because it gives information on what actually motivates people. Psychographics is a term used in marketing to describe consumer buying motivation and behaviour. Psychographics essentially segments a market for marketing purposes by classifying potential customers by their attitudes and values. It investigates what makes a consumer want to buy a product.

Even though you may have determined your demographic group, people within that group still have very different perceptions about the benefits or value of a particular product and will be motivated for different reasons. These differences are known as psychographics. The need is to determine not only who will buy your product, but what makes them want to buy it. Psychographic information such as spending patterns, whether consumers are brand conscious, what influences their buying behaviour and what promotional methods they respond to most, are all essential pieces of information.

As stated, the ultimate objective is to investigate and determine what makes the consumer want to buy a product. For example, is it because the product is:

- environmentally responsible?
- a natural proposition?
- a nutrition statement?
- a low fat, low-calorie product?

Psychographics is a valuable tool to identify motivation factors. Market research is a tool to help identify the need. It then helps to answer whether a proposed product or offering meets that need. For example:

- Does the product work and is it better in performance than previous ones?
- If it is new, does it perform better than the competition?
- Does the consumer like it and are the features appealing?
- Would the consumer buy it compared to others in the market?

6.8.9 Consumer panels and consumer research

Market research, particularly at the consumer panel/consumer research stage, can provide answers to some vital questions, in deciding whether a product or pack will succeed. Market research will reveal whether the target consumer recognises the offering. It will tell us:

- Does the product stand out on the shelf when put side-by-side with other potential new packs or the competitors' products?
- Is the product clearly identified, do the consumers know immediately what the brand is or the name of the manufacturer?
- Does it present the expected image; are the brand values, graphics, logo, print and design consistent with the brand equity of the product?

Tests may be conducted using new packs against old, new packs against the competition and new packs against variations or alternatives to each other. The 'winner' is normally the most preferred option, although there is rarely an outright winner. Such testing or research panels are conducted after researchers have identified a suitable group of people and recorded reactions to the packs.

For new product development, as well as researching the effectiveness of a design, it is essential to test that the product meets the needs of the consumer from a perception viewpoint, as well as in reality. Does it deliver all the emotional benefits which are expected? Does it provide the correct perceived value? Is it correctly positioned in the marketplace? The elements which make up this positioning can be assessed and categorised in many ways.

Research can be conducted by consumer panels, sometimes in town centres or shopping malls, or products can be given to individual consumers who are asked to try them at home and report their findings. The information derived from these tests helps the marketing professional to fine-tune the product and the packaging to give a greater guarantee of success when finally launched. All this is essential so as to avoid unnecessary cost. An unsuccessful new product launch will cost many millions, in the case of a major FMCG producer brand launch. The research will also reduce the chance of failure, because extensive research and investigation has been conducted into the viability of the new pack or concept before it is actually launched.

6.8.10 Test markets

Test markets are another way to avoid the large financial cost of failure. By this method a smaller launch, sometimes regional (such as in a particular commercial TV region), will be undertaken. The feedback from the consumer reaction in this area will help the FMCG company decide whether they can proceed to a full-blow national or international launch. If the response is negative, the full launch can be cancelled and large amounts of money saved.

6.8.11 Competitor research

Competitor research can play a vital part in any decision to launch a new product or modify an existing one. Marketing strategy must reflect what the market is looking for in terms of new packs (e.g. lightweight, environmental benefits, less material content) and what the pricing policy should be. Successful positioning of a new product in the market can only be achieved if its market position and perception have been fully evaluated against its competitors. Also any promotional campaign will need to be effectively planned and researched so that a new product's advertising is sufficiently different from that of its competitors. All of this is essential because, as we already know, most new product launches fail. Without market research the likelihood of failure is even greater.

6.9 Sources of further information and advice

- The Chartered Institute of Marketing, Moor Hall, Cookham, Maidenhead, Berkshire SL6 9QH, UK.
- Imber J and Toffler B-A, *The Dictionary of Marketing Terms*, 3rd edn, Barron's Educational Series Inc., USA.
- The Internet Advertising Bureau, 14 Macklin Street, London WC2B 5NF, UK.
- Mintel Group Ltd, 11 Pilgrim Street, London EC4V 6RN, UK.
- The Reader's Digest Trusted Brands Survey, The Reader's Digest Association Limited, 11 West Ferry Circus, Canary Wharf, London E14 1HE, UK.

7
Glass packaging

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Abstract: Glass is one of the oldest packaging materials and still maintains an important place today. This chapter covers the production of glass and its forming into containers for packaging, including an overview of the decoration processes used. Glass quality is discussed, including typical defects, and useful points for container design are given.

Key words: borosilicate, decolourisers, ultraviolet, soda glass, cullet, furnace, forehearth, lehr, gob, blow-and-blow, press-and-blow, narrow neck press-and-blow, parison, baffle, plunger, neck ring, neck finish, annealing, surface coating, head space, frosting, danner process, vello process, ampoules, vials.

7.1 Introduction

Although glass shares some characteristics of a supercooled liquid in which the state of flow has ceased, it is generally described as a solid below its glass transition temperature. As mentioned in Chapter 1, it is one of the oldest packaging materials. Commercial glass is made with silica (quartz) which is the principal component of sand. It requires high-purity silica sands from special deposits. For soda lime glass, as used in packaging, this is mixed with substances such as soda ash and limestone. A typical composition of soda lime glass, and key properties, are shown in Table 7.1. Mixing silica and sodium compounds produces sodium silicate, also known as 'water

Table 7.1 Typical composition and properties of soda lime glass

Composition/properties	
Chemical composition (% by weight):	
Silica (SiO_2)	70–74
Sodium oxide (Na_2O)	12–16
Calcium oxide (CaO)	5–11
Aluminium oxide (Al_2O_3)	1–4
Magnesium oxide (MgO)	1–3
Potassium oxide (K_2O)	≈0.3
Sulphur trioxide (SO_3)	≈0.2
Ferric oxide (Fe_2O_3)	≈0.04
Titanium dioxide (TiO_2)	≈0.01
Properties:	
Glass transition temperature, T_g(°C)	573
Coefficient of thermal expansion (ppm/K, ~100–300°C)	9
Density at 20°C (g cm^{-3})	2.52
Heat capacity at 20°C (kJ kg^{-1} K^{-1})	0.49

glass'. Adding calcium compounds makes this substance insoluble. Aluminium oxide (alumina) improves the durability of glass. Glass surfaces may also be treated with titanium, aluminium or zirconium compounds to increase their strength and allow thinner and lighter containers. Boron compounds (borax, boric oxide) give glass low thermal expansion and high heat-shock resistance. Other substances help reduce the time and temperature required for melting as well as the presence of gas bubbles.

In addition to these substances, decolourisers such as nickel, cobalt or selenium, are added to mask any colour produced by impurities such as iron. Lead compounds improve the clarity of the glass. In addition to white flint (clear) glass, the standard colours produced in the industry are:

- green, achieved by adding chromium compounds
- amber or brown, achieved using iron, sulphur and carbon for amber glass.

Amber glass is able to filter out ultraviolet (UV) light and is primarily used for UV-sensitive products such as beer and some pharmaceuticals. It is possible to produce glass in other colours by adding coloured frits at the forehearth, for example white opal (using fluorides), blue (using cobalt oxide) and red (using selenium, cadmium and antimony sulphide).

7.2 Advantages and disadvantages of glass as a packaging material

One of the advantages of glass is that it is inert to most chemicals. Foods do not react with it to produce hazardous or undesirable compounds which might either contaminate or taint the food. The fact that glass is impermeable to gases and water makes it ideal for long-term storage of foods or beverages vulnerable to spoilage from exposure to oxygen and moisture. Although glass is generally classed as inert, sodium and other ions will leach out over extended storage times which may be relevant for some pharmaceuticals such as injectable liquids. The European Pharmacopoeia (EP) has stipulated three types of specialist glass for pharmaceutical applications with specific limits to the level of titratable alkalis:

- Type 1: a borosilicate glass which meets the most stringent extractable standard. A disadvantage is the higher melting point of this glass type, requiring a furnace temperature of 1750°C, which increases the cost of the glass.
- Type 2: a soda lime glass formula that has been 'sulphated' at 500°C in the annealing oven (lehr) to reduce alkali solubility at the glass surface. The treatment produces a discoloured, hazy appearance.
- Type 3: a conventional soda glass that has been tested and shown to meet a specified extractives level. In North America, soda glasses not meeting type 3 qualifications are classed as USP type NP.

These glass types are used mostly for the manufacture of ampoules and vials, typically containing injectable drugs. Different countries specify different test methods and acceptable standards of glass for pharmaceutical use. Results which meet the requirements of the European Pharmacopoeia may not be sufficient for other national standards such as the United States Pharmacopoeia (USP) and/or the Japanese Pharmacopoeia. This underlines the importance of knowing the market in which a product is destined to be used.

In pristine condition, immediately after forming, glass is some 20 times stronger than steel but much of this strength is lost through the development of sub-microscopic flaws as it cools which lead to stresses and weaknesses in the glass. However, despite this, the rigidity of glass as a material means that glass containers are resistant to pressure which, for example, makes them appropriate for carbonated drinks or foods requiring a partial vacuum to prevent microbiological spoilage. The rigidity of glass also gives glass containers vertical strength which allows stacking. Glass is stable at high temperatures and is resistant to thermal shock (providing it has been correctly annealed), making it suitable for hot-fill and retortable products. Its stability means it does not degrade, making it suitable for long-term storage of foodstuffs such as preserves.

The appearance of glass is also an advantage. Its transparency is useful where product visibility is important. Because of a long tradition of decorative glassware, glass can be used to convey a high-quality image, e.g. in the perfume sector. Glass can be moulded into various shapes, though rounded, cylindrical shapes are preferred for maximum strength.

The main disadvantages of glass are its high density (2.5 g/cc), resulting in relatively heavy containers, and its brittle quality. When damaged, glass shatters. Broken glass produces sharp fragments and splinters which can present a serious safety hazard. Critical faults in the production, filling, transport and storage of glass containers include cracks and chips or bubbles which create weak container walls vulnerable to breakage. Because of this potential safety hazard, glass containers are typically inspected at various points during the manufacturing process, using automated inspection equipment to check 100% of the production.

Although the raw materials for glass are relatively low cost, glass manufacture requires significant amounts of heat. High energy costs thus affect the total cost, although the effect of this can be reduced through using recycled glass (known as cullet) in glassmaking. Glass can be recycled by simply heating it until molten and then reforming a container without loss of strength or quality, or the production of harmful by-products. It can be recycled repeatedly in this way, and of all the major packaging materials, is possibly the one most associated with recycling due to the availability of bottle banks where consumers can dispose of used glass containers which can then be collected for reprocessing.

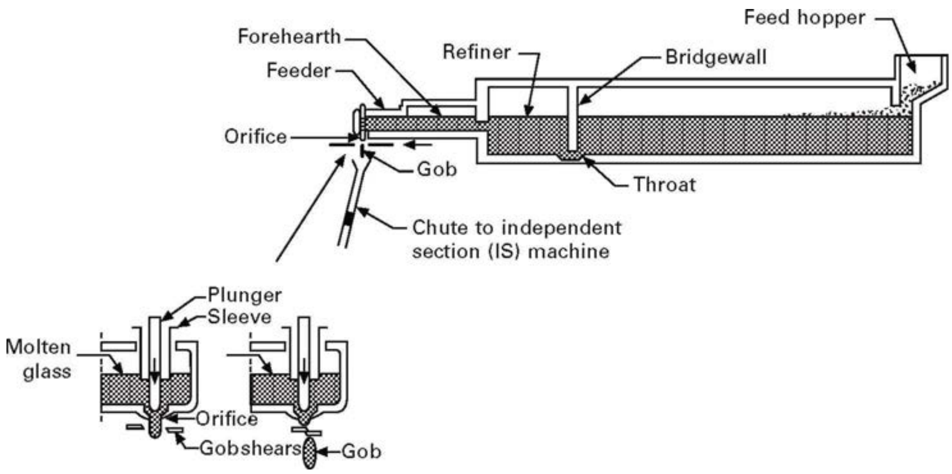
The smooth, hard, inert surface of glass also makes it relatively easy to clean whilst its heat resistance makes it easy to sterilise. These properties are of particular relevance for the reuse of glass containers; once collected and returned to the packer filler they can be cleaned, inspected and sent out again for filling. However, the cleaning processes can have a significant environmental impact (use of energy, water and cleaning chemicals, and production of effluent) and this must be considered when deciding whether to use single-trip or multi-trip glass containers. In addition, there is the cost of transporting empty bottles back to the packer filler to consider, as well as the capital investment needed for the cleaning and inspection equipment.

7.3 Glass manufacture

Commercial glass is made in specialist furnaces able to generate the very high temperatures required for processing (1,350–1,600°C). Fuel used depends on local availability; gas-fired furnaces are common in the United Kingdom, other sources will be more appropriate elsewhere. Furnaces need to be large and to run almost continuously if they are to operate profitably. A typical furnace holds up to 500 tonnes of glass and produces about 200 to 400 tonnes in 24 hours. As a result specialist glasses (including those with more unusual colours) are more expensive to produce than mass-produced standard grades and colours.

The ingredients are weighed and mixed before being fed to the furnace. Most modern glass container plants have automated (continuous) batch plants to feed the furnaces. As has been noted, an important ingredient is cullet from previous glass containers. Cullet enhances the melting rate and so significantly reduces the energy requirements of glass production. Each 10% of cullet added to a batch reduces the energy requirement by approximately 2.5%. Cullet can be used in percentages as high as 80% of the ingredient batch, although 30–50% is more common, resulting in energy savings ranging from around 10% to 20% or more. Colouring agents may be added at this point or at a later stage via the forehearth.

Figure 7.1 shows a cross section of a typical glass furnace. The mixed ingredients are fed into the furnace by hopper. As the materials are heated, the bridgewall traps impurities which rise to the surface of the molten glass. The forehearth brings the temperature down to around 1,100°C and by now the molten glass has a consistency which means it can be gravity-fed through chutes to the bottle-forming machines. Molten glass flows through draw-off spouts with orifices ranging from 12 to 50 millimetres, depending on the container size. Water-cooled mechanical shears below the orifice, which are synchronised with the draw-off flow rate and speed of the bottle-forming machine, cut 'gobs' of molten glass. Each gob makes one container.



7.1 Cross section of glass furnace and gob-forming process.

Higher production speeds are achieved by the use of double, triple or even quadruple gobs to feed one forming machine.

7.4 Forming glass containers

Automatic production of glass containers usually requires a minimum run of three days for efficient and economic operation depending on the size of the forming machine. Depending on their geometry, glass containers are made by three different processes:

- blow-and-blow
- press-and-blow
- narrow neck press-and-blow.

All processes require two moulds (made from cast iron):

- a blank mould that forms an initial shape
- a blow mould to produce the final shape.

The blank mould forms the finish (the part that receives the closure), the neck and a partially formed body known as a parison. A blank mould assembly comes in a number of sections:

- a guide for inserting the gob (funnel)
- a seal for the gob opening once the gob is settled in the mould
- the blank mould cavity (made in two halves to allow parison removal)
- the finish section (neck ring assembly)
- blowing ports to supply air.

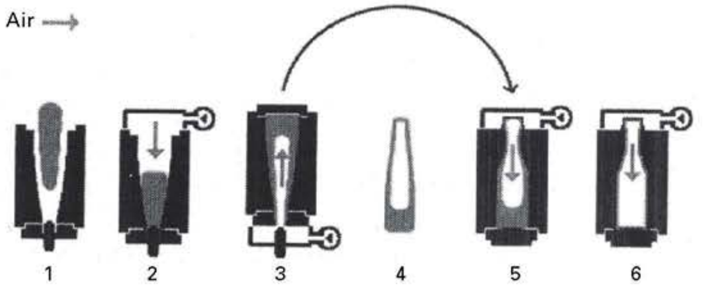
Usually between 6 and 40 identical moulds constitute a 'set' for one bottle-making machine, costing up to £50,000 or £60,000, depending upon the number of machine sections and the complexity of the containers being produced. Each mould set has a number that is formed on the bottles made by that mould. Independent section (IS) machines are the most commonly used type of forming machines throughout glass container manufacture.

In the blow-and-blow process, the container is blown in the following sequence (see Fig. 7.2):

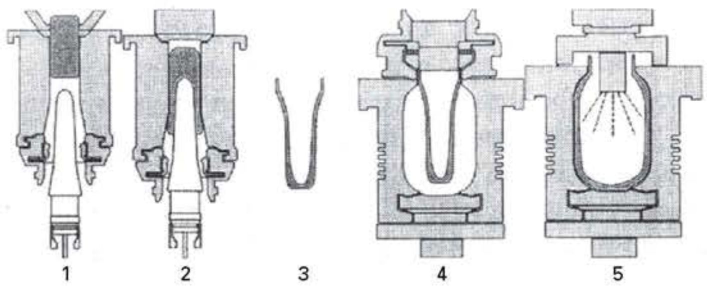
1. The gob is dropped into the upturned blank mould through the guide.
2. The 'funnel' is replaced by a baffle (which prevents the glass from escaping) and air is blown into the mould (known as the settle blow) to force the glass into the finish section at the bottom. At this point the neck finish is formed.
3. Air is forced through the newly-formed neck orifice, expanding the glass upwards into a bottle pre-form (known as 'parison'). This is the counter blow stage.

4.–5. The parison is removed from the blank mould, using the neck ring fixture, and rotated through 180 degrees for placement into the blow mould.

6. The final blow of air in the blow mould forces the glass to conform to the



7.2 Container forming by the blow-and-blow process. 1, gob enters parison mould; 2, settle blow to form finish; 3, counter-blow to complete parison; 4, blank formed; 5, blank transferred to blow mould; 6, final shape blown.



7.3 Container forming by the press-and-blow process. 1, gob drops into parison mould; 2, plunger presses parison; 3, parison completed; 4, parison transferred to blow mould; 5, final shape blown.

shape of the blow mould. The bottle is cooled so that it can be placed on the conveyor that takes it to the annealing oven.

In the press-and-blow process used to produce wide mouth jars, the process is similar except that the parison is pressed into shape with a metal plunger rather than being blown into shape (see Fig. 7.3):

1. The gob is dropped into the upturned mould.
2. The plunger presses the parison into shape.
3. The parison is completed.
4. The parison is transferred to the blow mould.
5. The final shape is blown.

For some wide mouth containers, the final blow is replaced by the application of vacuum to the wall of the mould to produce the final bottle shape.

Traditionally, the blow-and-blow process was used for narrow-necked bottles and the press-and-blow process for wide-mouthed jars. The third process, narrow neck press-and-blow (NNPB) is now being used to produce bottles with narrow neck finishes. Like press-and-blow, it uses a metal plunger, but this is much smaller. The plunger allows good control of glass distribution, resulting in containers which are significantly lighter in weight than those produced by the conventional blow-and-blow process, thus reducing cost and environmental impact.

7.5 Annealing

The moulding process relies on the glass being sufficiently hot and pliable. When the bottles leave the moulds, the temperature is about 450°C. If containers were left to cool down on their own, the low thermal conductivity of glass would mean that the interior would cool more slowly than the outside. As a result, cooling would be uneven and stresses would develop in the container walls. To avoid this, containers are transferred by conveyor to an annealing oven, known as a 'lehr' immediately after removal from the blow mould. A lehr is a belt which passes slowly through a long oven (up to 30 metres in length). The glass temperature is initially raised to 540–570°C to relieve the stresses and then gradually cooled to minimise reforming of stresses, until the containers emerge at the end of the lehr at about 60°C. They are then allowed to cool down further before packing. Improperly annealed glass has a high risk of breakage when subjected to further processing. Good annealing is also essential for thermal shock resistance.

7.6 Surface coating

Once cooled, the container surfaces are relatively smooth and pristine, though the outer surface is slightly rougher than the inner as it mimics the grain of the finely machined cast iron mould surface. Pristine glass has a comparatively high coefficient of friction. As a result, surface scratching (known as 'bruising') can occur when bottles rub together on high-speed filling lines. Scratched glass has significantly reduced breakage resistance and thus, to minimise this problem, containers are usually surface coated. Two coatings are used:

- a primer or bonding coat (e.g. tin or titanium tetrachloride), applied at the entrance to the lehr ('hot-end' coating).
- a friction-reducing coat applied at the exit to the lehr ('cold-end' coating).

Various formulations are available, depending on end use, including oleic acid, monostearates, waxes, silicones and polyethylenes. Any labelling adhesive needs to be compatible with the coating used.

7.7 Inspection

Given the potential safety hazards of broken glass, glass containers are routinely subjected to 100% inspection. Following annealing, containers are single-filed from the lehr belt by means of an unscrambler and fed through a number of inspection operations:

- Bottle spacer: this machine is pre-set to create a space between the bottles on the conveyer to avoid bottle-to-bottle contact.
- Squeeze tester: each bottle is passed between discs which exert a force to the body of the container. Any obvious weakness or crack in the bottle will cause it to fail completely with the resulting cullet being collected by a return conveyor running underneath, and recycled.

- Bore gauger: with this machine, it is possible to carry out three measurements – internal and external diameter at the neck finish entrance and the height of the bottle.
- Crack detector: bottles outside specification are automatically rejected by means of a pusher positioned downstream from the gauger. This machine can also detect uneven sealing area (land) on wide-mouthed containers.
- Wall thickness detector: by focusing a beam of light onto areas of the container where defects are known to occur from previous visual examination, any crack will reflect the light to a detector which will trigger a mechanism to reject the bottle. Typically, up to eight detectors can be found on one machine which is useful for eliminating bottles with cracks and crizzles in the finish. By using the dielectric properties of the glass, the wall thickness can be determined by means of a sensitive head which traverses the body section of the container. A trace of the wall thickness can then be obtained and bottles falling below a specified minimum will be rejected automatically.
- Hydraulic pressure tester: used for containers destined to be filled with carbonated beverages.
- Visual check: bottles are also passed in front of a viewing screen as a final inspection.

New methods of determining glass container quality are now being utilised, including automatic hot-end inspection before annealing. Advanced photoelectric methods for determining critical faults such as the very occasional glass inside or stuck plug (a piece of glass, usually very sharp, projecting inwards just inside the neck bore) are now being used. Computer methods for sensing and storing all the measurement information obtained from inspection machines are being used, with the results passed to the forming section for adjustment if necessary.

7.8 Tolerances

Tolerances for variation in any given characteristic will depend on size and container design. British Glass has agreed tolerances on glass containers and the following examples are taken from their Tec 9 booklet 'General Guidelines for the Use of Glass Containers'. Further details are available in Tec 4 'Glass Container Tolerances' and Tec 6 'Accurate Determination of Glass Container Capacity':

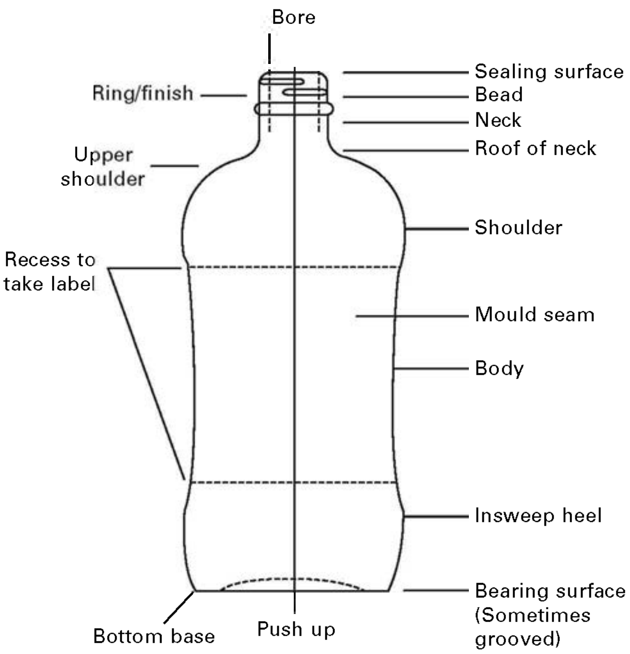
- Capacity (average of 12 random samples):
  Up to and including 100 ml, tolerance ± 2.7 ml
  Up to and including 200 ml, tolerance ± 3.8 ml
- Body dimensions:
  Diameter Up to and including 25 mm, tolerance ± 0.8 mm
  Up to and including 50 mm, tolerance ± 1.1 mm
  Height Up to and including 25 mm, tolerance ± 0.7 mm
  Up to and including 100 mm, tolerance ± 1.0 mm
- Verticality (important for good performance during filling and capping):

Up to and including 120 mm in height, tolerance ± 2.2 ml
Up to and including 200 mm in height, tolerance ± 3.4 ml
(Note: tolerances for all the above vary for intermediate ranges.)

7.9 Container design

As Fig. 7.4 illustrates, containers are typically designed with cylindrical shapes and rounded edges. This is partly because viscous glass flows most easily into moulds with smooth, round shapes. Cylindrical containers are the easiest shape to manufacture since they are an expansion of the circular parison. They are also easy to handle on high-speed filling and labelling lines. They can be accurately positioned in a spot-labeller via an indexing label lug on the container exterior.

Cylindrical containers also have greater strength-to-weight ratios and better material utilisation than irregular shapes. The relative strengths of different shaped glass containers are shown in Table 7.2. Table 7.3 shows the greater weights of irregular to cylindrical container shapes. Square or angular shapes and sharp corners are difficult to form properly and more prone to weaknesses and faults. Indeed, rectangular containers typically have a round finish to minimise these problems. There are standard dimensions for cylindrical bottles which can be mass produced cheaply and ordered as required. It is also important in designing container shapes to have as low a centre of gravity and as broad a base as possible to maximise stability. Tall, narrow designs with a non-circular profile are vulnerable to tipping over whilst



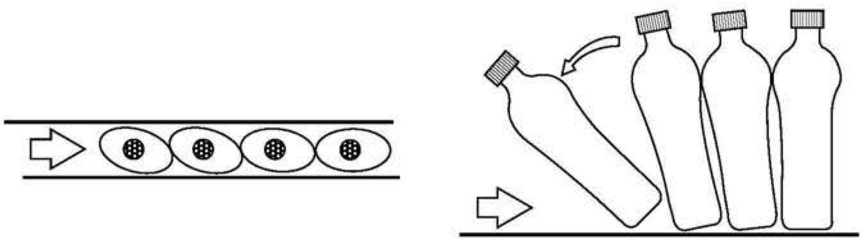
7.4 Glass container nomenclature.

Table 7.2 Relative strengths of differently shaped glass containers

Container shape	Ratio of relative strengths
Cylindrical	10
Elliptical (2:1)	5
Square with round corners	2.5
Square with sharp corners	1

Table 7.3 Relative weights of cylindrical and irregularly shaped containers

Capacity	Cylindrical	Irregular
30 ml	45 g	55 g
340 ml	225 g	285 g
455 ml	285 g	355 g
905 ml	455 g	565 g



7.5 Shingling of glass containers will cause toppling and breakage on the filling line.

being moved or bunching together (a process called 'shingling' – see Fig. 7.5). These requirements also affect the design of the base (see below).

It is important to ensure the design is appropriate to the product. Issues relating to different kinds of product include the following:

- Gaseous liquids: Carbonated soft drink and beer bottles must be able to withstand internal gas pressures of 340 kPa for soft drinks and 820 kPa for beer. Bottle designs for these products are always cylindrical and have gently curving radii in order to maximise bottle strength.
- Viscous liquids: If products are dispensed by pouring, a gradually tapered and smooth neck provides good control over pouring. Some designs include a ridge on the neck to catch and hold drips which can then be wiped away. If the product is dispensed with a spoon (e.g. honey), a round, squat design is best to allow easy access.
- Semisolids: Semisolids (e.g. pastes) often need to be packed in round, squat jars to allow easy access by a spoon or knife. A simple, cylindrical design is best, avoiding corners which would be difficult to access and without a shoulder or neck to trap product. This leaves a wide 'mouth' that also makes access easier.
- Granular solids: Powdered and granular materials (e.g. coffee) usually come in wide-mouthed jars to facilitate both filling and dispensing. To protect the

contents from air and moisture, a seal often needs to be adhered to the top of the neck finish. A smooth, flat and sufficiently large area is needed to ensure an effective seal. Products such as instant coffee can vary in density but are filled to a declared weight, resulting in varying fill heights. A stippled container neck or the use of an appropriately placed label will obscure the actual fill level.

- Tablets: Since the pattern of filling is less predictable, with varying fill heights depending on how the tablets fit on top of each other, these are usually packed in simple cylindrical or rectangular containers. The design of neck needs to make it easy to dispense tablets singly if required, and to allow some margin for both varying fill heights and any wadding or sealing materials used to protect the tablets in transit.

7.9.1 The container finish

As has been noted, the container finish is designed to take the closure (e.g. screw cap). Finishes are broadly classified according to features such as diameter (expressed as the nominal inside diameter in millimetres) and sealing method. Standards for finish sizes and tolerances are established and are followed by both glass container manufacturers and closure manufacturers (see Chapter 15). Faults affecting finishes include 'overpress', where a small ridge of glass is formed on the sealing surface of the finish, or a 'choked bore', where excess glass occurs inside the finish, restricting access.

7.9.2 The container neck and shoulder

The neck design is an important part of overall container design because it has a major influence on the rate and efficiency of filling as well as the ease with which the end user can dispense the product. Filling operations are discussed in Chapter 20. A head space may be needed to facilitate filling, provide for thermal expansion or allow a vacuum necessary to control spoilage. Differences in fill level are readily visible in containers with long, narrow necks.

Blending of the neck and upper shoulder is important to container integrity and good design. The lower shoulder is a particularly vulnerable point since it is the area most likely to come into contact with other containers during filling and packing. The contact area should be as large as possible and extra thickness may be required. Container designs often include a thickened 'protruding' shoulder to protect the container and to minimise contact between containers during handling.

7.9.3 The container body

Containers are often designed with label panels that are recessed to ensure accurate placing of the label and to prevent scuffing. Cylindrical containers are easier to label than other shapes. Many apparently straight-walled containers actually have a slight (0.08 mm) 'hourglass' inward curve.

7.9.4 The container heel and base

The heel is the point at which the body of the container meets the base. Like the lower shoulder, the heel is another vulnerable area which comes into contact with other containers. To ensure maximum strength, the heel should start as high from the base as possible. In large containers, the body is blended to the heel while in small containers the heel is blended to the base. Heel tap is a manufacturing defect where excess glass is distributed into the heel.

The diameter of the base should be as large as possible to ensure stability. The centre of the base is usually domed upwards (known as the 'push-up') to create an outer ring (bearing surface) on which the container rests. This gives the container greater stability than a completely flat surface and makes it less likely to slip. It also reduces the surface area exposed to friction as the container is moved through filling and closure processes, and then packing, transport and retail display. In many designs the bearing surface is grooved for extra stability and strength. Bases may also be designed to make stacking easier, with the base fitting either into or around the cap of another container.

7.10 Decoration and labelling of glass containers

Stippling can be used for decorative effect, especially where product visibility is not an issue. Stippling can be produced by creating the design in reverse on the interior surface of the blow mould. Smooth glass surfaces are significantly weakened by surface scratches. A stippled surface pattern helps reduce this effect. A cut-glass effect can be obtained in the same way, provided the depth of the V-shaped grooves does not exceed 25% of the groove width. The cut-glass effect enhances the appearance of clear glass without impairing product visibility.

A frosted appearance can be produced by etching with hydrofluoric acid (a relatively costly process) or by sandblasting. Ceramic frosting is achieved by spraying the exterior with a ceramic paint or frit made from a ground glass and oil mixture, followed by firing. During firing, the oil evaporates and the ground glass is fused to the surface.

It is important to design a container with labelling in mind. Label panels must be large enough for the label design. As has been noted, they are often recessed to allow more accurate positioning and to protect the label from scuffing. Labelling is easier on curved surfaces, making labelling of cylindrical containers faster than flat designs, particularly if more than one face is being labelled. Wet-glue labels are widely used on glass containers, either as wraparound labels, or 'spot' labels applied to specific areas, e.g. front, back and neck. Self-adhesive labels, using paper or plastic films, are also suitable. Labels can be applied to virtually any location on a container, provided the contour is in one plane.

Screen printing can be used to apply decoration directly to the container surface. In most instances, the inks are fired on to produce an extremely durable design. There are colour limitations however, due to the temperature of the firing operation, and process printing is not possible. Metallic silver and gold effects can be achieved, albeit at an increased cost. Ceramic decals are another decorating option.

7.11 Other glass-making processes

Sealed glass containers such as vials or ampoules, which are used in the pharmaceutical industry are made from pre-formed tubing stock rather than by blowing. Ampoules are designed to be broken open at one end to dispense their contents, either by scoring at that point to weaken the glass or by coating with a ceramic paint that causes a stress concentration. Vials are small containers with a rubber seal which can be pierced by a needle to withdraw the contents. Standard ampoule and vial sizes range from 1 to 20 ml. Glass tubing is manufactured by the following processes:

- Danner process: This process produces a continuous glass tube or rod. It can make tubing of 1.6 mm to 66.5 mm diameter at a draw-off rate of up to 400 metres per minute for smaller diameters. Glass flows from a forehearth of a furnace as a hot ribbon down a sleeve onto a rotating hollow shaft or blow pipe. The ribbon is wrapped around the sleeve to form a smooth layer of glass which flows down the sleeve and over the tip of the shaft. Tubing is formed by blowing air through a blow pipe with a hollow tip.
- Vello process: Glass flows from a forehearth into a bowl or reservoir in which a hollow bell-shaped vertical mandrel rotates in a ring which allows glass to flow via the annular space to give a continuously emerging tube. Blowing air is fed via the end of the bell where there is a hollow tip. The dimensions of the tubing are controlled by the glass temperature, the rate of draw, the clearance between the bell and the ring, and the pressure of the blowing air.

To produce the ampoule or vial, the tube is cut to length then flamed to red heat, after which it can be shaped or sealed by the use of various shaping tools. Since these processes can introduce strain, an annealing process is again necessary to give reasonably strain-free containers. Tubular glass generally produces even, thin-walled containers and can be pre-gauged to give specific wall thicknesses. Specialised, low volume items such as decorative tableware and high quality glassware are manufactured by semi-automatic processes, often involving mouth-blowing and manual cutting.

7.12 Sources of further information and advice

- The British Glass Manufacturers Confederation, (British Glass), 9 Churchill Way, Sheffield S35 2PY. Tel. +44 (0)114 2901850.
- The British Bottlers Institute, P.O. Box 16, Alton, Hampshire GU34 4NZ. Tel. 01420 23632.
- Glass Packaging Institute (USA): www.gpi.org
- Owens Illinois: http://www.united-glass.co.uk/about_oi.aspx?id=1352
- GTS Ltd Report to the FSA (June 2003) A03029 – Investigation of the significant factors in elemental migration from glass in contact with food.
- CCFRA GMP Guide – CCFRA – Guide No. 18 – Safe Packaging of Food and Drink in Glass Containers: Guidelines for GMP 1998 (edited by David Rose and Robert Glaze).

8
Rigid metal packaging

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Abstract: This chapter discusses rigid metal packaging. After an introduction on the history of metal packaging and its main markets, it reviews raw materials and the safety and quality issues associated with them, the manufacture of rigid metal containers, closures, cost issues, container specifications and decorating processes. It concludes by looking at environmental issues affecting rigid metal containers.

Key words: metal packaging, metal can, can end, processed food, seaming, draw and wall iron (DWI), draw and redraw (DRD), metal coating, metal decorating.

8.1 Introduction to metal packaging

8.1.1 Brief history of metal packaging

Tinplate is one of the oldest packaging materials and was originally used for round, square and rectangular boxes and canisters. In the early 1800s, following the offer of a prize by Napoleon Bonaparte for the first person to develop a way of preserving foods, the first heat processed tinplate food cans in the world were made, filled, processed and sold to the public in Bermondsey, East London. This had a great impact on society and the technology soon spread to the United States where it was developed into a continuous production process.

In the early 1900s there was a major step forward when a method of mechanically attaching the ends to the food can replaced the inefficient soldering system. This improved both the speed of operation and food safety aspects. The first aerosol can was patented by Erik Rotheim (Norway) in 1929. Following this, in 1933/36 three-piece soldered side seam beer cans became available in the United States following the repeal of the Prohibition Laws and the development of suitable internal coating materials.

Shortage of tinplate in Switzerland during the Second World War led to development in the use of aluminium for creating seamless can shapes. As the result of this work, some 20 years later, in 1963, the first thin wall draw and wall ironed (DWI) aluminium beer cans were sold in the United States. Construction of similar thin wall cans in tinplate for both drinks and food followed over the next 15 years. Ernie Fraze and ALCOA developed the first easy-open can end in 1962.

In 1975 the Wire Mash (WIMA) welded side seam system was developed with an overlap small enough for three-piece food and drink cans to be made at high speed. This heralded the demise of the soldered side seam can. In 1997 shaped and embossed draw and wall ironed drinks cans were introduced. This was closely followed in 2000 by the commercialisation in Japan of the first bottle shaped thin wall can with metal reclosable screw cap.

8.1.2 Markets for metal packaging

The world market for metal containers is a little over 400 billion units. This embraces packs for food, drink, aerosols, dry and technical products. Most food cans are for wet products such as meat, fish, vegetables, fruit, rice, milk-based and recipe products, and all these need to be heat processed immediately after filling to sterilise the food for long shelf life, usually a minimum of three years. Drinks cans may contain carbonated or non-carbonated liquids. Many drinks require low level heat processing, such as pasteurisation, to ensure adequate shelf life of the product. Aerosols contain fillings ranging from personal care and toiletries through foodstuffs to household, paint and building products. Dry products include powdered foods, tea leaves, wrapped foods (candies, sweets), and non-food items. Many of these are highly decorated containers and used as promotional containers where they may be secondary packages containing, for example, a glass bottle of spirits. Cans for general line technical products are designed to hold liquids, mostly for household or industrial use. This range of containers includes tapered and parallel sided drums of up to 50 litre capacity.

As already mentioned, in 2000 the first thin wall metal bottles with reclosable screw caps were introduced for beer and soft drinks in Japan. Lower cost versions are now being developed and being marketed in both Europe and the United States. The processes for making aluminium aerosol cans are also used for forming collapsible tubes for medical products. Metal caps and closures are used for closing containers made from glass or plastic as well as those made from metal. Metal packaging is particularly suitable where a high quality of external decoration is required, as the hard surface of metal allows a very clear image to be generated.

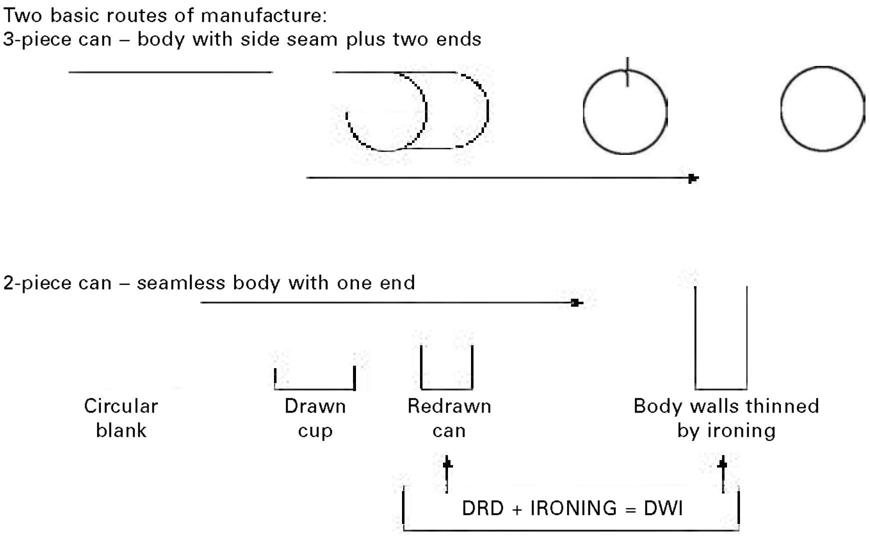
8.1.3 Common formats for metal cans

Metal cans are mostly constructed by one of the following two basic methods, which are fully described in Section 8.3. Figure 8.1 shows these two basic systems:

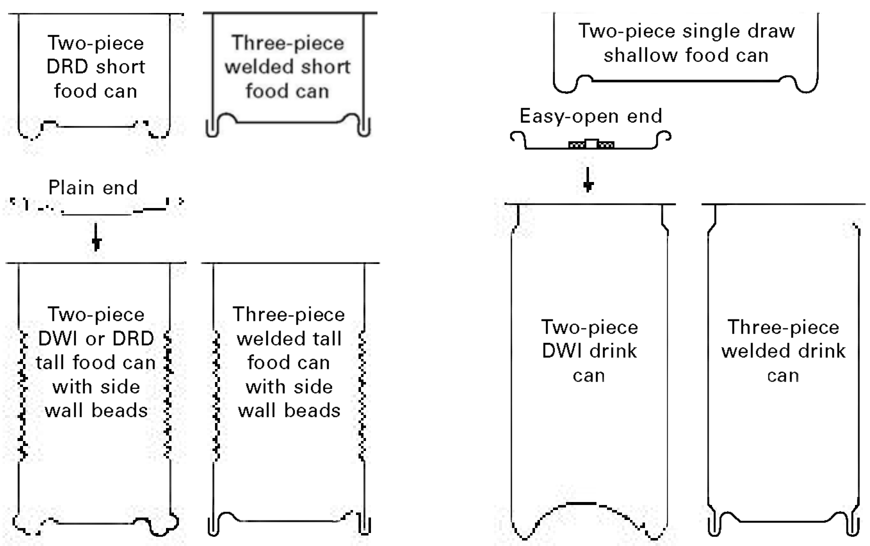
- Three-piece can – comprising a cylindrical body rolled from flat rectangular sheet with the side seams overlapped and joined using electric resistance welding and two ends mechanically joined to produce a closed container.
- Two-piece can – comprising a seamless cylindrical can body with one integral end (base) shaped from a flat disc and the other end mechanically joined to produce a closed container.

The geometric relationship between can diameter and height helps to define which can format is most appropriate for which manufacturing process. This relationship may be described as:

- Tall cans Height greater than diameter (e.g. beer can)
- Short cans Height equal to or slightly less than diameter (e.g. tuna can)
- Shallow cans Height significantly less than diameter or width (e.g. sardine can).



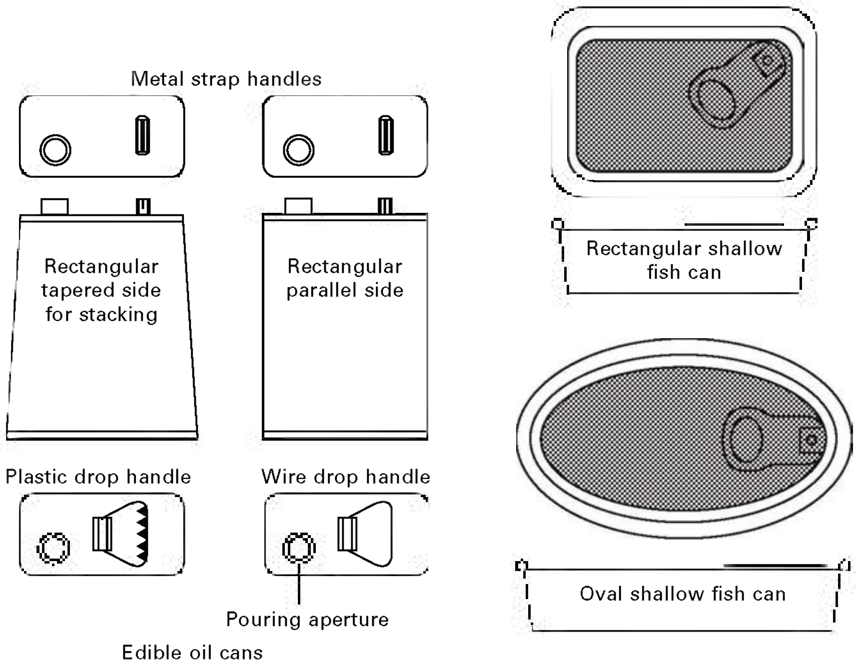
8.1 Can body manufacture.



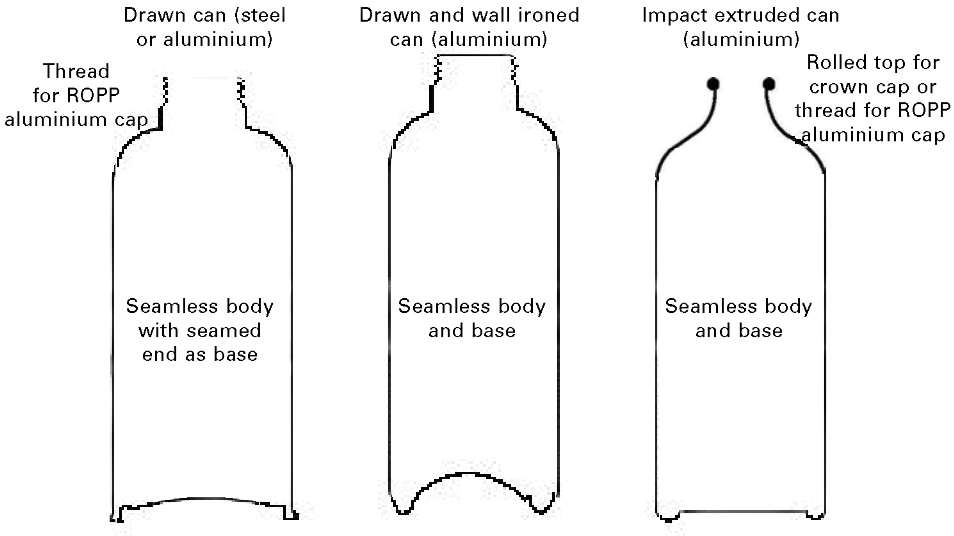
8.2 Typical processed food and drink cans. From Coles R *et al.*, *Food packaging technology*, 2003, Blackwell. Courtesy of Blackwell Publishing.

Three-piece welded can-making systems will form tall, short or shallow cans with good metal usage efficiency. Within the two-piece seamless can-making systems, there are three variations, two (draw and wall iron, and impact extrusion) are particularly suited to making tall cans while the third (draw-redraw) uses metal more efficiently when limited to making short or shallow cans. Figure 8.2 describes typical cross sections of processed food and drink cans and the appearance of the different height to diameter ratios. Figures 8.3, 8.4 and 8.5 describe the typical cross sections of non-round food, bottle and aerosol cans, respectively.

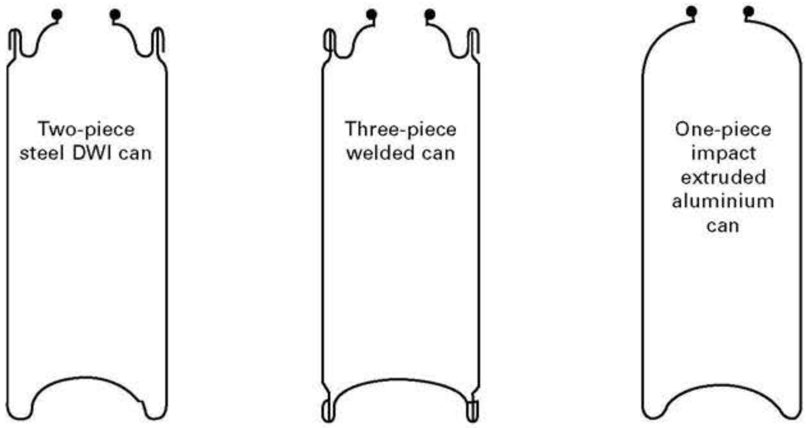
Most cans for food, drink or for use as aerosols or collapsible tubes have circular cross sections because these can be made, filled and ends seamed on at much higher



8.3 Typical non-round food cans. From Coles R *et al.*, *Food packaging technology*, 2003, Blackwell. Courtesy of Blackwell Publishing.



8.4 Typical bottle cans.



8.5 Typical aerosol cans prior to fitting of valve mechanism. Courtesy of Pira International.

speeds than those having non-round cross sections. Historically, a range of standard can diameters has been developed for each of the food, drink and aerosol markets. This was necessary in order to limit the number of different tool sets held by can makers and fillers and to limit the number of different end diameters that need to be manufactured. In the food and drink sectors, the various size ranges have been developed to produce a set of can volume capacities to provide varying portion sizes to suit the demands of the consumer markets, while minimising the number of containers having similar or nearly similar capacities.

The three-piece can-making process may be used to form any shape or size of container. Within two-piece systems, the can-making processes are less flexible in terms of making different can sizes because the investment in tooling dedicated to one can diameter and height is greater than that for three-piece can making.

A third system of forming metal containers is similar to the three-piece method but is restricted to use in making general line non-performance containers, which by definition are not required to hold liquids or pressure. These are often referred to as made-up containers and can be built from more than three pieces of metal. The main differences are that the two parts of the side seam are joined by just folding them together into a mechanical lock seam (described in detail in Section 8.3.5) and that the forming tools can be designed to make virtually any practical cross section. These types of containers do not generally fall into standard size ranges of either height or diameter.

Metal caps and closures are initially formed as shallow drawn containers before special shapes and lining/sealing materials are added to provide the necessary functions of the finished component. Because of the large quantities produced, these are generally made in standard diameters to suit the range of container neck sizes.

8.1.4 Process performance of metal cans and ends

Metal containers are manufactured from either packaging steel or aluminium. The choice will depend on the duty that the can has to perform as well as the can geometry and the method of production. Most metal containers are designed to hold liquid, or solids in liquid, at pressure, vacuum or normal atmospheric pressure, the exceptions being those designed for dry products or as decorative containers only. Information about metal selection is included in Section 8.5.

Metal cans are relatively low cost, thermally stable, strong, rigid, opaque, easy to process on high-speed lines and readily recyclable. As a packaging material, metal offers a total barrier to gas, moisture and light. These attributes make metal packaging particularly appropriate for long-term storage of perishable products at ambient conditions. Other important characteristics of metal are its stiffness, strength and ductility which permit simple forming operations and allow the containers to withstand the high mechanical loadings experienced during heat processing of foods and storage of carbonated drinks or aerosol products in conditions of high ambient temperature.

Strength is also of great importance when constructing containers to carry dangerous substances such as some organic solvents. For conveying such products across international borders by land, sea or air, the United Nations has developed a special set of regulations specifying the design of metal containers for the carriage of dangerous goods.

Metal's attractive appearance allows many graphic design possibilities and this, coupled with the hardness of the surface, makes it possible to reproduce images which are extremely sharp and detailed. Organic coatings are often applied to the metal surfaces to prevent corrosion due to chemical action with certain products or the external environment. These coatings are also used to help preserve foods safely and prevent dissolution of metallic elements into foodstuffs.

In addition to being able to store products at high pressures, aerosol containers have to be constructed to facilitate the operation of filling with both product and propellant and to allow for attachment of the valve-dispensing unit at the top of the vessel. Where product and propellant are not allowed to mix, then special arrangements such as the enclosing of the product in a flexible bag have to be incorporated.

8.2 Raw materials

The main raw materials used in metal can making are packaging steel, aluminium and organic coatings in either liquid or solid form. The coatings are used to protect the metals from chemical interaction with the products packed in the containers and, where necessary, the external environment. The coatings also help to prevent dissolution of unwelcome elements and taint from the metals into the product.

8.2.1 Metals for packaging – steel and aluminium

Steel results from the purification of liquid iron. In this process liquid iron, tapped from the base of a blast furnace into which iron ore, limestone and coke have been fed, is poured into a converter vessel. After the addition of scrap steel, oxygen is then blown into the iron to burn out all the impurities and lower the level of carbon. Whereas cast iron is a very dense and brittle material, low-carbon steel can be reshaped by mechanical rolling into very thin sections. As the steel is being rolled from a thick slab to a thin section suitable for can making its hardness and strength increase by work hardening following cold rolling steps. At times during this process the metal has to be reheated (annealed) to reduce the hardness to permit further cold rolling to take place and for the correct final combination of thickness and strength to be achieved. At this stage the metal is called blackplate, which may then be used for the manufacture of packaging where the contents will not corrode the steel. Examples of this are drums for oils, waxes and grease.

The anti-corrosion properties of steel for packaging are enhanced by the addition of tin to the surface. This is applied electrolytically (electroplated) to both surfaces of the metal while in coil form and after all shaping has been completed. An alternative metallic coating, also applied electrolytically, is electro chrome (ECCS – electro chrome coated steel) often known as tin-free steel. This material is often slightly less expensive than tinplate but must have an organic coating applied to give a complete corrosion-resistant system. It has particularly good adhesive properties.

Aluminium for light metal packaging is used in a relatively pure form with manganese and magnesium added to improve its strength properties. Aluminium is the third most abundant element and the ore from which it is extracted is bauxite. Aluminium oxide (alumina) is extracted from the other ores present in bauxite before the smelting process begins. This process requires considerable electrical energy to produce aluminium on a commercial scale. Primary and scrap aluminium are then brought together in a furnace to purify the liquid metal. It is then filtered through porous ceramic blocks for cleaning prior to casting into ingots. The faces of the ingot that will become the finished surfaces of the coil are both ground off (scalped) to remove surface imperfections and to provide clean surfaces ready for rolling. The metal is then reheated and hot rolled to an intermediate thickness. It is then allowed to cool in air for two to three days at which stage it is fully soft. Final cold rolling takes place to achieve finished thickness and hardness without further heat treatment.

8.2.2 Management of corrosion

When using steel or aluminium containers for packing wet products, some of which may also be subject to heat processing, consideration must be given to the likelihood of corrosion taking place on the inside walls of the cans due to chemical action of the product and how this may be prevented. Additionally, the external surfaces may be subject to corrosion due to excessive humidity in the atmosphere or during heat processing in steam/water systems.

For steel-based containers the presence of metallic tin on the surface always improves the corrosion resistance whether or not organic coatings are also in place. ECCS (tin-free steel) will give excellent corrosion prevention provided that an adequate layer of organic coating is in place as a seal coat. The oxide which forms naturally on the exposed surfaces of aluminium does provide some resistance to corrosion but this is insufficient for wet products, so all internal surfaces of these containers must normally be coated. Section 8.2.3 describes some exceptions to this requirement.

Organic coatings are applied to the internal container surfaces to form an inert barrier between product and metal to prevent chemical actions due to the nature of the product and to prevent dissolution of metallic elements into the product. The weight of coating and, where appropriate, the weight of tin applied to steel may be varied to suit the specific conditions in the can.

For three-piece welded side seam cans, it is necessary to leave the surfaces of tinplate forming the weld overlap free of any coating to ensure the weld is sound. After the weld has been made the previously unlacquered parts of the inside wall, including the weld itself, may then be coated with lacquer to produce a can where the internal surfaces are totally lacquered. This process is called side striping, the coating being applied by spray, roller or as a powder and then cured by a blast of hot air applied to the outside of the can body. There are some can material/product combinations where a side stripe lacquer is not necessary.

Bi-metallic corrosion can take place between aluminium and steel under certain circumstances. Where filled cans are fully heat processed after filling, it is necessary to use similar metals for both can and end to prevent this form of corrosion taking place. This applies whether the metals are coated or not. For drinks cans where only low level pasteurisation takes place, there is no problem when using aluminium ends on steel can bodies.

8.2.3 Food contact issues

When packing food or drink into metal containers, it is very important that the product packed and the container internal surfaces are compatible with one another so that no unwanted or uncontrollable chemical reactions take place between the two. This is clearly most important with wet foods and liquids. However, even for dry products, there will be situations when compatibility has to be considered. Internal lacquers on the can body and ends, as described in Section 8.2.4 below, are used to prevent basic chemical actions taking place. In addition to this, to ensure that food safety is not compromised in any way, where a lacquer protection system is in place, this must also prevent dissolution of undesirable chemical elements from either the coating itself or the metal substrate.

A number of food items, particularly meat and fish, contain sulphur. During the heat processing cycle low level reactions can take place between sulphur and tin or iron to create sulphides which are black in colour. These can take place across the surfaces of the coating if the weight is insufficient or if an incorrect coating specification has been used. While the sulphide products are not hazardous, they can impart stains to light coloured foodstuffs.

In the UK approximately 25% of cans for processed foods are supplied as plain cans, i.e. with no organic coating applied over the internal tin surface. This is done to improve the colour and flavour of white fruits and tomato-based products. As well as allowing low level dissolution of tin into the products, the presence of free tin on the surface of the tinplate helps to remove any oxygen remaining in the headspace of the can. These in turn help to retain the original colour of the products and provide a more piquant flavour. In the UK the maximum level of tin in the product is limited by law to 200 ppm. When a plain can is used in this way, the product shelf life must be set to prevent tin levels exceeding the maximum permitted level. As drink cans are designed to permit the user to consume the product directly from the can, it is critical that the external container surfaces which come into contact with consumers' lips are also considered to be food safe.

As an aid to understanding the background to current food contact regulations, the following extracts have been taken from Section 8 of *Guide to good manufacturing and hygiene practices for metal packaging in contact with food* (European Metal Packaging, 2009).

8 Food contact regulations

8.1 Introduction

Although, increasingly, metal packaging for foodstuffs and foods packed in metal are traded globally, there remains no global food contact legislative approach. The two major regulatory systems for control of materials and articles for use in contact with food are those of the EU and US (FDA), although detailed harmonised EU legislation for coated and uncoated metal packaging is still awaited. Food contact legislation is continually developing. Therefore, the information in this chapter may only remain current for a short time, and should be seen as the position as of 2008, after which this should only be used as a guide. To obtain more information regarding the current regulatory position of metal packaging, particularly as it relates to individual Member States, the appropriate European or national member state trade association (e.g. EMPAC for light metal packaging), or appropriate consultant organisations should be consulted.

8.2 Harmonised European regulations

Within the EU, materials and articles intended for use in contact with food are partly regulated at the EU level through harmonised Regulations and Directives, and partly at the member state level through their own legislation and recommendations. Wherever harmonised EU legislation exists, EU member states cannot maintain their own independent measures except in cases of specific derogation based on demonstrable risk to inhabitants of that member state. As EU harmonised legislation continues to develop, the importance of individual national member state measures will decrease.

The core of EU legislation on food contact materials and articles is the 'Framework' Regulation (EC) No. 1935/2004 which sets out in Article 3 the fundamental requirement that substances should not pass into the food at levels that may be harmful to health; or that may adversely alter the composition of the food; or that may lead to a deterioration in its organoleptic qualities. Furthermore, this regulation lays out intended means of detailed regulation of materials and articles by material type.

8.3 National regulations in the EU

The different member states within the EU have a wide range of approaches to the regulation of food contact materials and articles. As EU harmonised legislation evolves, it will replace member state legislation, but until that process is complete (and there is no certainty when that will be achieved for coated metal packaging), it is recommended that the various national metal packaging trade associations be consulted regarding the individual member state legislation in force.

8.4 USA regulations

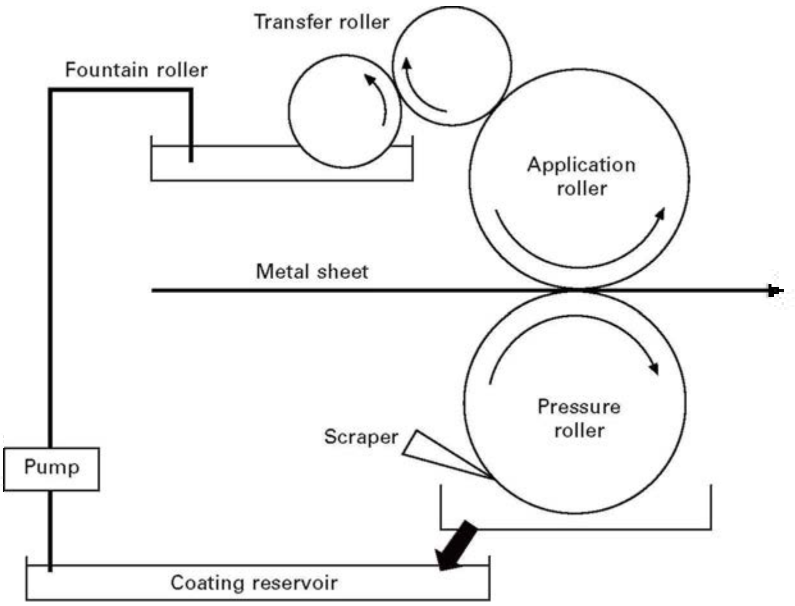
US legislation of food contact materials and articles is managed by the Food and Drugs Administration (FDA) under the Code of Federal Regulations (CFR) Title 21 parts 170–199 in which potential migrants are considered as indirect food additives. These regulations have developed over many years and have a wider scope than the EU legislation. Under FDA, all types of food contact materials and articles are covered including coatings. Historically, the FDA regulations have been considered the most important global reference point for demonstrating the compliance and safety of packaging. With the evolution of EU legislation on food contact materials and articles, the relevance of FDA compliance in the EU is decreasing, but for materials such as coatings which are still not covered by harmonised detailed EU legislation, compliance with FDA remains an important element in the overall management of safety and compliance. Additionally, FDA compliance remains important globally.

8.2.4 Coating materials and their application

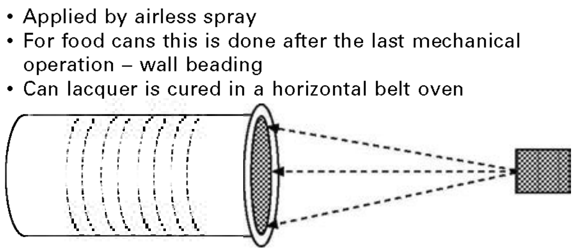
Coating materials are applied to the metal surfaces either in liquid or solid form (as powders, laminates or hot extrusions). This may be done prior to the metal forming operations, i.e. as coil or cut sheet, or after forming when the container or end has a three-dimensional shape.

Liquid coatings are organic-based materials comprising resins with combinations of solvent and water-based carriers to ensure good control of applied weight together with satisfactory wetting, adhesion and curing properties. The resin forms the hard coating that remains on the metal surface after the curing has been completed. Depending on the chemistry of the coating, curing may be achieved by the application of heat or by subjection to ultraviolet (UV) light. However, the method of curing is designed into the coating and cannot be changed later. The choice of curing method is dependent on many factors such as product packed, type of heat processing employed, the type of can and how it is used by the consumer. Historically, regulations have prevented UV coatings being used in food contact applications but some of these regulations are now being relaxed following evaluation work recently completed by the FDA. Nevertheless, for the foreseeable future, it is unlikely that UV coatings will be approved for the internal coating of heat processed food cans.

Liquid coatings may be applied by roller coating or airless spray and generally form part of the can-making operation. Figure 8.6 describes the process of roller coating the top side of a metal sheet while Fig. 8.7 shows how lacquer is applied by airless spray to the inside surfaces of a seamless can. During heat curing the coated product passes through a tunnel oven where the liquid carriers are first evaporated leaving the residual resin to be cured, by chemical cross-linking, into a hard but flexible surface.



8.6 Coater for applying lacquer to sheets. Courtesy of Pira International.



8.7 DWI food can internal lacquering.

Typically the total time for this operation is approximately 20 minutes. Ultraviolet curing is achieved by passing the wet surface of the metal sheet under a UV lamp at high speed. This creates an instant cure.

Powder coatings are 100% resin and contain no solvent or water carriers. Application is by spraying the dry powder followed by heat curing as part of the can-making operation. This process allows heavier coating weights to be applied than can be achieved by a single coat of liquid.

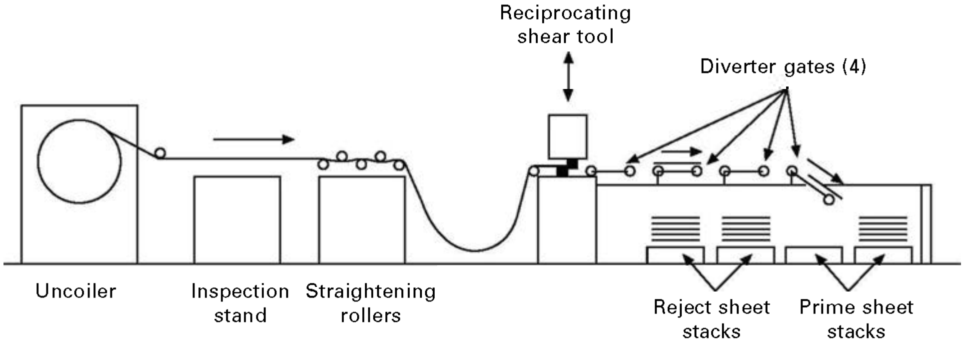
Polymer films, whether as laminates or direct extrusions, are normally applied by the metal manufacturer, as the most efficient way of achieving this is in a coil-to-coil operation. New systems are being developed which use pre-coated tin-free steel or aluminium for two-piece can manufacturing, either drawn or drawn and ironed. These systems may be single- or multi-layer polymers but in all cases are based on polyethylene terephthalate (PET). The main advantage of these systems is that all the processes of applying the polymers to the metal substrate take place under controlled conditions in the factories of the metal manufacturers. These then simplify the can-making process, eliminating can washing and in-line internal and external coating operations.

8.3 Manufacture of rigid metal containers

The formation of shaped can bodies from flat metal is carried out in one of two basic processes which are described as three-piece or two-piece processes. The numbers three and two refer to the number of separate pieces of metal required to construct a fully closed container. Two-piece cans may also be described as seamless cans because the base and side walls are constructed from one piece of metal without any joins in the open top container.

8.3.1 Three-piece welded cans

Three-piece welded cans for food, drink, general line decorative and industrial cans, as well as aerosols, are only constructed from steel-based materials as thin gauge aluminium cannot be welded by this process. Most of these are made from tinplate as ECCS (electro chrome coated steel), otherwise known as tin-free steel, is difficult to weld with consistency without first removing the metallic coating. Coils of tinplate, after receipt from the steel maker, are cut into sheets approximately one metre square to suit the dimensional capacity of the downstream equipment for coating and printing. After this process, which is shown in Fig. 8.8, the sheets are cut, by slitting, into rectangular blanks from which individual can bodies are made. The area in the vicinity of the weld is left without coating or print to ensure that a sound weld is made. In the welding body forming machine, each blank is rolled into a cylinder with the two longitudinal edges overlapping by approximately 0.4 mm. Using electric resistance spot welding, where alternating current passing through the metal seam heats up the material, the tinplate is softened sufficiently for the two edges to be squeezed together to form a sound joint. Each peak of electric current creates a spot of weld. As the length of the cylinder passes between the electrode rollers, a series of overlapping spots is created to form a continuous weld. If necessary, a side



8.8 Coil cutting operation. Courtesy of Pira International.

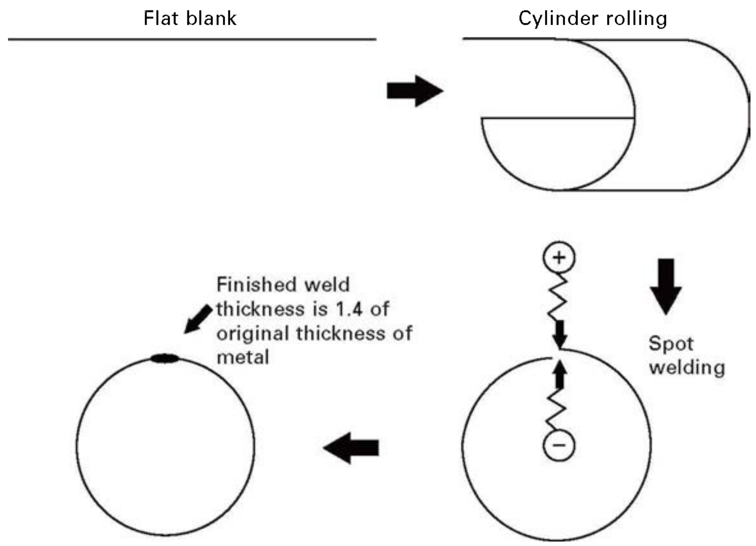
stripe coating is applied over the weld area at this time. The forming and welding process is described in Fig. 8.9.

All three-piece cans now pass through a flanging process where both ends of the cylinder are flanged outwards to accept the can ends. Drinks and aerosol cans are usually necked in prior to flanging. This process reduces the diameter of both ends of the cylinder, before the flange is formed, which in turn allows ends to be fitted which, after seaming, are smaller in overall diameter than the can body. This in turn reduces the cost of the end and the space taken up by the seamed body. Some three-piece food cans have the bottom only necked in to permit safe stacking of one filled can on top of another.

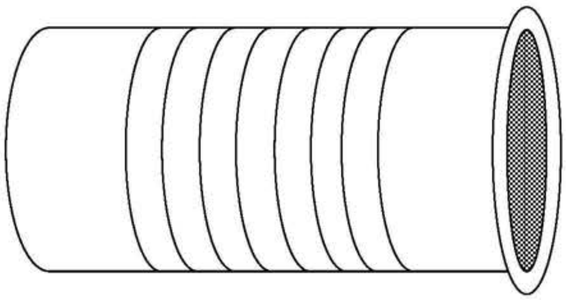
Where food cans are going to be heat processed (retorted) after filling and where the can height is greater than its diameter, it is usually necessary to form circumferential beads in the can body wall to increase the hoop strength to resist implosion of the can during the earlier part of the process. These wall beads are shown in Fig. 8.10. The basic points of heat processing are described in Section 8.3.8.

At this point one end is now mechanically seamed onto the cylinder to create an open ended container ready for filling. This end is called the maker's end. Where easy-open ends are used, it is common for this to be fitted as the maker's end, thus allowing it to pass through the finished can testing process. The mechanical seaming process is described in Section 8.3.7. The end fitted by the packer after filling is called the canner's end. Before packing onto pallets, all cans are pressure tested to check for the presence of cracks, pinholes or weak welds. The full process sequence of making three-piece welded cans is shown in Fig. 8.11.

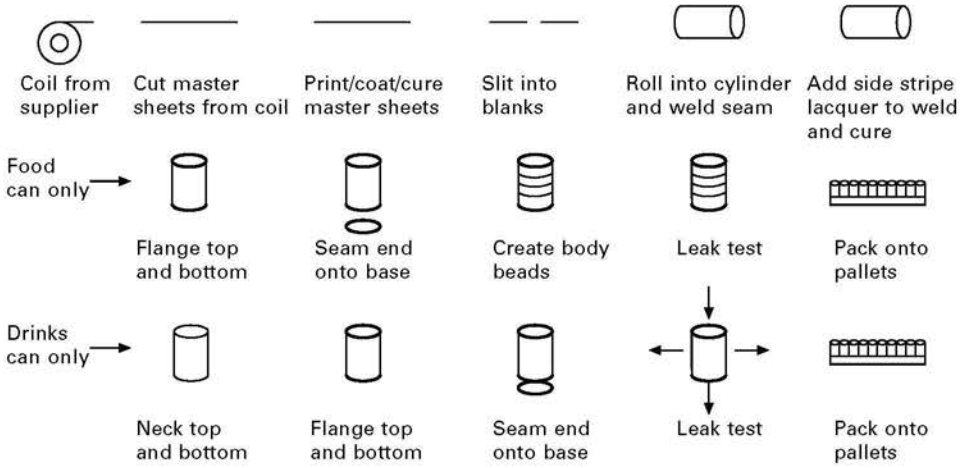
This three-piece can-making process will form cans of all diameters and heights provided the correct tooling is installed and the appropriate size of forming/welding machine has been employed. The welding process can only generate bodies of circular



8.9 Three-piece can forming and welding. Courtesy of Pira International.



8.10 Can wall beading.



8.11 Three-piece can process flow.

cross section, therefore, where non-round, i.e. square, rectangular, etc., or slightly tapered bodies are required, the circular body must be reshaped after completion of the welding process.

Where shallow cans (height less than diameter) are to be made by this process, they can become unstable when being transported on conveyors with the can axis horizontal, which is necessary during the body forming and welding process. To overcome this, the body blank size may be increased so that multiple bodies (say 2–4, depending on the maximum blank size capacity of the welding machine) may be incorporated in the one blank. As the multiple sized blank is rolled into the cylinder it is partially scored through at the points where the formed can will be separated into the individual short bodies. After the welding (and side striping/curing) operation is complete, the long cylinder is taken into a parting machine where it is split into the individual short bodies. From this point onwards during the completion of the can-making process the bodies are conveyed with the axis in the vertical position.

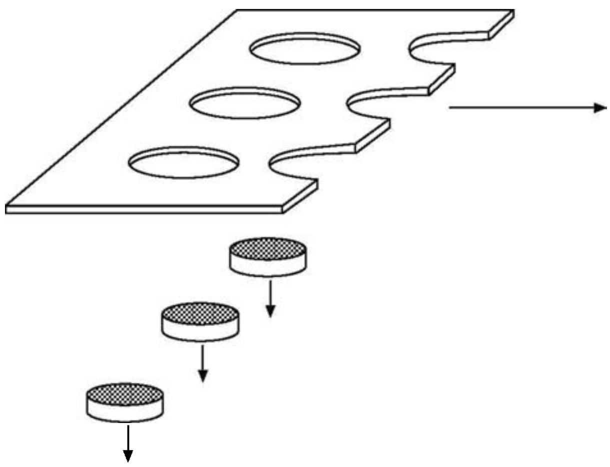
8.3.2 Two-piece single drawn and multiple drawn (DRD) cans

Drawn and redrawn (DRD) cans are used for food (particularly processed fish products) and general line cans and may be made from steel or aluminium. In most cases, the metal is coated internally and externally and printed, if necessary, prior to the can-forming operation, as the presence of these materials on the metal surface provides some degree of lubrication to aid the forming. Lubricants such as waxes may need to be added to the outside surface to enhance this.

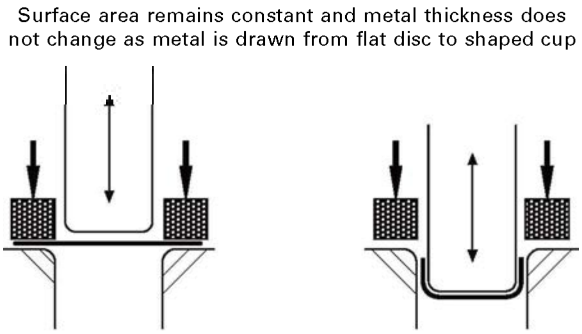
As an alternative to the use of liquid organic coatings, metal may be supplied in coil form either pre-laminated with polymer film or with polymer coatings hot extruded directly onto the metal surface. In these cases, where printing is not required, the coated coil may be fed directly into the can-forming press.

As coil printing for cans is not considered practical, coils of metal are supplied plain and cut into sheets ready for coating and printing. These processes are identical to those described above for three-piece welded cans. Because the metal blanks for DRD cans cut from the sheets will be either round or oval, metal wastage can be minimised by replacing the straight cut shear in the sheet-cutting machine with one having a castellated cut. The castellations must be designed to fit closely to the shape of the blanks across the width of the sheet. This process is called 'scroll cutting'.

Whether from coil or sheet, the metal is fed into a reciprocating press with either single or multiple forming tools. At each forming station the press first cuts a disc (blank) and, while in the same station, then draws this into a shallow can (cup) as shown in Fig. 8.12. During the drawing process, the metal is reformed from a flat sheet into a three-dimensional can while retaining the same surface area. It follows from this that the metal thickness throughout the whole of the can is the same as the starting gauge of the metal coil. During the reforming process the metal flow is controlled by a circular pressure pad to prevent wrinkles being formed in the side wall. Figure 8.13 describes the basic drawing process. The width of the coil/sheet



8.12 Cup making for DRD and DWI cans.



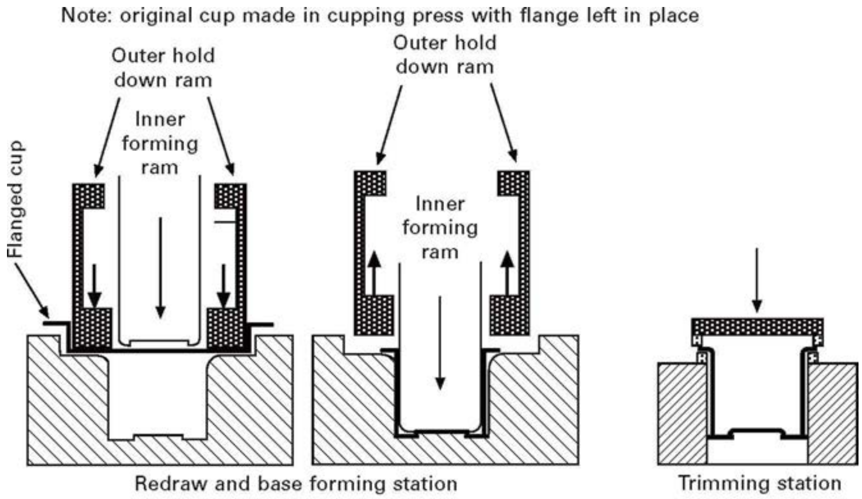
8.13 Drawing a can from flat metal.

used must match the width across the number of toolsets installed. Where multiple tooling is installed, each stroke of the press will generate a cup from every installed tool. For minimum wastage of metal the circular blanks are close packed with their centres set at 60 degrees to each other.

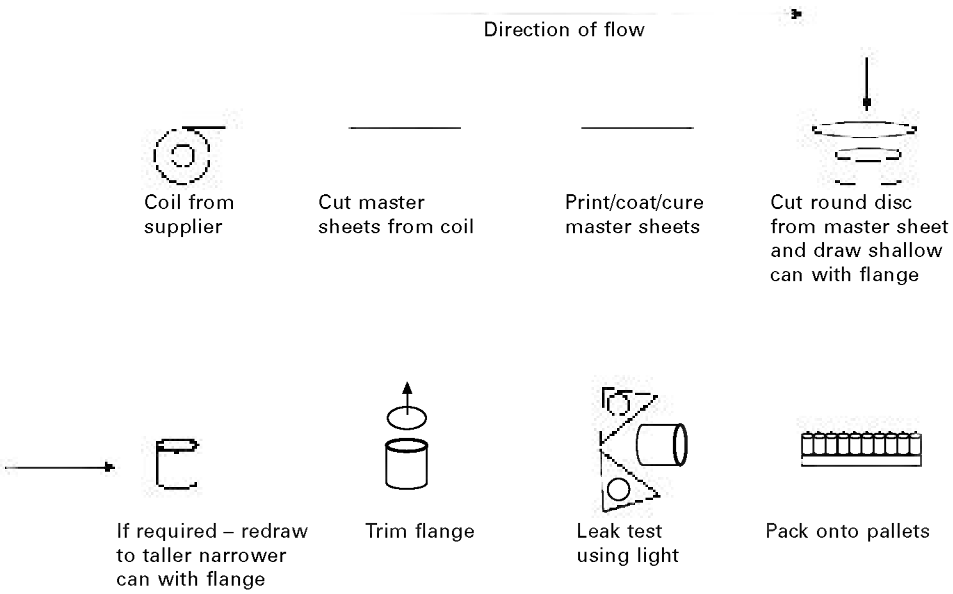
Alternative methods for feeding sheets are called stagger feed systems. In these, the edge of the sheet remote from the press is held by gripper fingers which are mounted onto feeding arms moving in two dimensions in the horizontal plane. With, say, a single installed tool it is then possible to feed the sheet forward and sideways through the tool so that every blank is cut from a sheet even though the width of the sheet is equal to that of multiple blanks.

The drawing tool may be configured to leave the side wall straight or to leave a flange in position. The can produced from this single draw may now be at its finished dimension, in which case a straight walled can will need to have a flange formed at the open end. Where the flange was left in position during the initial draw, it may be necessary to trim it using a circular cutting tool to ensure the flange width is consistent enough to make a satisfactory seam. For production of a deeper can, the drawing operation may be repeated (redrawing) in a second station with appropriate sized tooling; however, as for the first draw, the surface area of the deeper can and the wall thickness of wall and base will still be unchanged from that of the original disc of metal. The redrawing process sequence is shown in Fig. 8.14. The full process sequence of making DRD cans is shown in Fig. 8.15. The DRD process may also be used to form taper wall flanged cans as well as aluminium or steel taper thin wall trays to which heat sealed foil lids are applied.

For deeper cans where the height is approximately equal to the diameter, it is usually necessary to form the can in at least two steps, as described above, because there is a limit as to how far the metal can be reformed in one step. This is called the limiting draw ratio. The single drawing process is also used for making folded aluminium baking trays and takeaway containers. In these processes the metal is allowed to fold on itself as the blank is reformed into the shape of the container. Testing of all cans for minor cracks or pinholes is part of the manufacturing process and for two-piece (seamless) cans is achieved in a light-testing machine. This measures the amount of light passing across the can wall using high levels of external illumination.



8.14 Redraw can forming. Courtesy of Pira International.



8.15 DRD can process flow.

8.3.3 Two-piece drawn and wall ironed (DWI) cans

DWI cans are used for food, drink and aerosol cans and are normally made from uncoated aluminium or tinplate. However, DWI processed food cans are only made from tinplate as thin wall aluminium cans do not have sufficient strength to withstand the external pressure imposed during the heat process cycle. In addition, DWI aerosol cans are currently only made from tinplate.

It can be seen from Fig. 8.1, which shows the basics steps in the DWI can-making process, that the first steps in forming this can, from coil to redrawn cup, are virtually identical to those used in the DRD process described above. However, the main differences are:

1. the tinplate is always fed directly from the coil into the blanking and first drawing, and
2. the coil is uncoated because subsequent wall thinning (ironing) operations are so severe that the coating would be stripped off the metal surface. Because of this, a water soluble synthetic lubricant is applied to the coil prior to the cup blanking/ drawing operation. Application of coatings and print (where appropriate) later in the process are an integral part of the DWI can-making process.

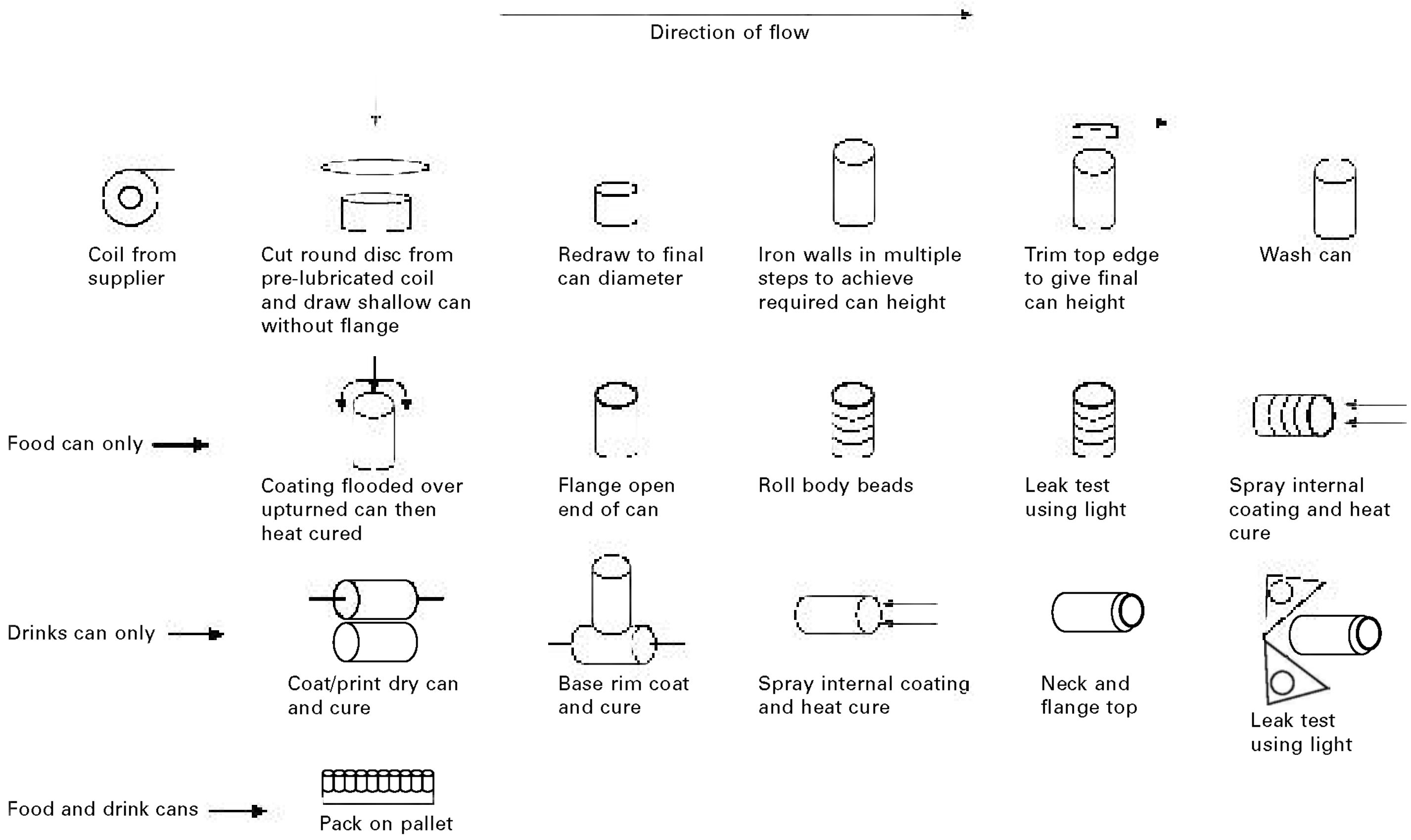
The full process sequence of making DWI cans is shown in Fig. 8.16.

The shallow cups are now fed into a number of parallel body-making machines which convert them into tall thin wall cans. In this process the cup is first redrawn into a taller cup having a diameter equal to that of the finished can. Following this the taller cup is rammed through a series of ironing rings which have internal diameter marginally less than the outside diameter of the can wall but not less than the inside diameter of the can. There are usually three or four rings in the sequence each having a smaller diameter than the ring preceding it. As the cup passes through these rings the wall thickness is progressively reduced to approximately half or one third of the original starting thickness depending on the finished height of can required. Because there is no loss of metal in the process the can height is increased as the walls are thinned. This is a cold forming process but the friction generated heats up the metal. During ironing the can body is flooded with the same type of lubricant used in cup forming. As well as assisting the ironing process, the lubricant cools the can body and flushes away any metallic debris. These forming steps are shown in Fig. 8.17.

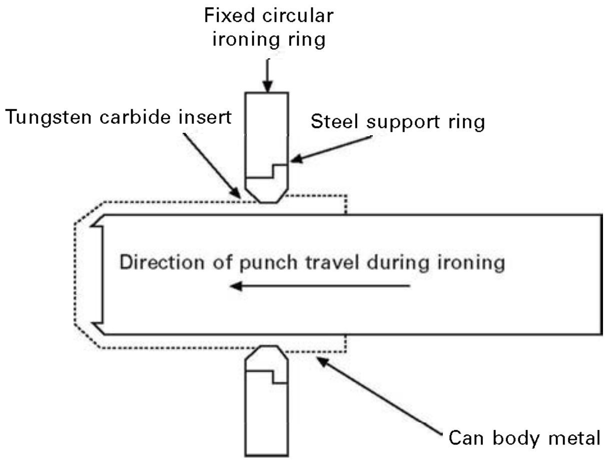
After forming the full height can body, the uneven top edge of the can is trimmed to leave a clean edge and a can of the correct overall height. Trimmed cans now pass through chemical washers to remove traces of lubricant and prepare the metal surfaces for internal and external coating (or printing in the case of drink or aerosol cans).

For DWI food cans, where paper labels are normally applied, an external clear coating is next applied by flood coating as the cans are conveyed under waterfalls of clear lacquer. This protects the external surface and base against corrosion and provides a slightly lubricated surface to improve can mobility during product filling and final packing operations. The coating is cured by heating in a hot air oven. The open end of the can is now flanged ready to accept the can end and this is followed by the addition of circumferential beads to increase the hoop strength of the can wall. The need for beading is described below in Section 8.3.8. After light testing, as described for DRD cans, an internal coating is applied using an airless spray system. This coating is cured in a hot air oven.

For DWI drink and aerosol cans, where the external surface is normally printed in line, a clear or pigmented base coat is first applied to provide a good surface for the acceptance of printing inks. A circular can printing machine is now used to apply



8.16 DWI can process flow.



8.17 Wall ironing through one ring. Courtesy of Pira International.

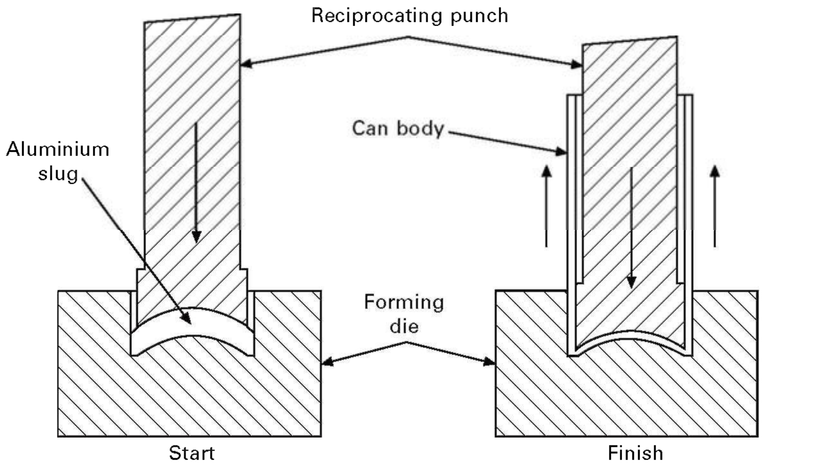
the complete label design around the can body using up to eight colours. The inks are cured either in a hot air pin chain oven or by passing across UV light lamps, depending on the type of ink chemistry being used. Internal coating and curing is by airless spray and hot air oven, as for food cans. Following this, a coating is applied to the external base rim and then cured. These cans are next necked in at the open end to reduce the diameter of the end or ring (in the case of aerosol cans) fitted and then flanged. The reduced neck size allows lower cost ends to be fitted and reduces the maximum diameter of the can to that of the body. (Without necking, the diameter over the finished end seam is greater than the diameter of the body.) The finished cans are all now passed through a light-testing machine, as described for DRD cans.

8.3.4 Two-piece impact extruded cans and tubes

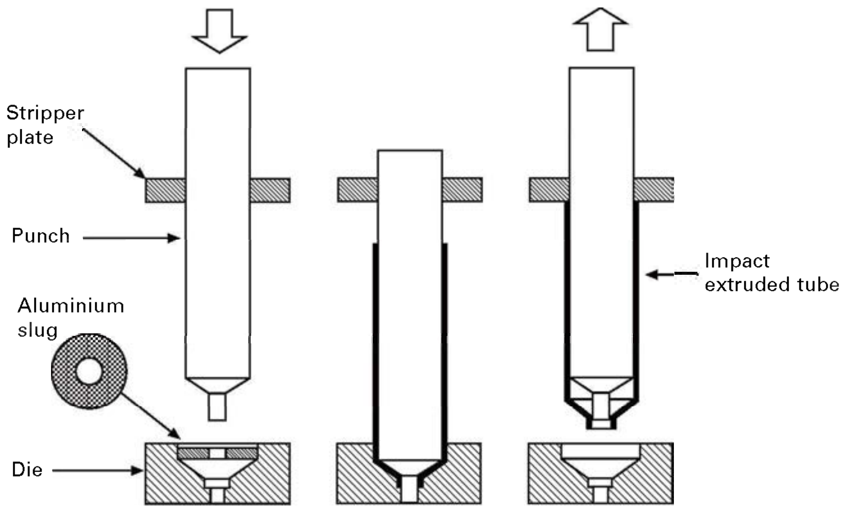
The process of impact extrusion is restricted to containers made from aluminium only as it is not possible to form steel cans in this way. Historically, this process has been used for aerosols, rigid and collapsible tubes. In recent years shaped bottles for drinks have been introduced where the forming process has been based on that used for aerosol production.

In this process a thick disc equal in diameter to the outside of the finished container is punched out from aluminium plate. The disc thickness is such that its mass/volume is equal to that of the untrimmed can body. The disc is placed in the bottom of a die and a reciprocating punch having maximum diameter equal to the inside diameter of the container is driven into the disc at high speed. The cold metal is forced out of the die block and flows up the side of the punch until the end of the stroke. This process is described in Fig. 8.18.

The same process is used for forming collapsible tubes. However, in this case the base of the die is modified to allow formation of the tube nozzle with or without a sealing membrane and the starting disc shape is also modified as shown in Fig. 8.19. As the forming process work hardens the tube wall, it is necessary to soften this by



8.18 Impact extrusion process. Courtesy of Pira International.



8.19 Impact extrusion of collapsible tubes.

application of heat (annealing), after forming, so that the finished tube is capable of being squeezed and rolled up during use.

Further manufacturing steps, including coating and printing, are similar to those used for DWI drinks cans. The only exception to this is that necking and flanging are replaced by a multi-step forming process, to shape the top of the container from full body diameter to that required to accommodate the ultimate can closure device, as shown in Fig. 8.20. This could be a flange on which to crimp an aerosol valve mechanism, a rolled edge to accept a crown end or a screw neck to accept a ROPP™ (roll-on pilfer proof) cap.