6 Packaging of food in glass containers

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6.1 Introduction

6.1.1 Definition of glass

The American Society for Testing Materials defined glass as ‘an inorganic product of fusion which has cooled to a rigid state without crystallizing’ (ASTM, 1965).

Chemically, we know that glass is made by cooling a heated, fused mixture of silicates, lime and soda to the point of fusion. Morey says that, after cooling, it attains a condition which is continuous with, and analogous to, the liquid state of that substance, but which, as a result of a reversible change in viscosity, has attained so high a degree of viscosity as to be for all practical purposes solid (Morey, 1954).

We know that the atoms and molecules in glass have an amorphous random distribution. Scientifically this means that it has failed to crystallize from the molten state, and maintains a liquid-type structure at all temperatures. In appearance it is usually transparent but, by varying the components, this can be changed—as also can important properties such as thermal expansion, colour and the pH of aqueous extracts. Glass is hard and brittle, with a chonchoidal (shell-like) fracture.

6.1.2 Brief history

Glass beads and arrow heads have been found that date back to the bronze age, which started in the eastern end of the Mediterranean area around 3000 BC. Ornamental glass has been found in excavations in Egypt and Mesopotamia. The invention of the blow stick in Roman times led to the manufacture of hollow glass containers. Glass became one of the earliest forms of packaging. Container manufacture was mechanized in the United States in the late 19th century.

6.1.3 Glass packaging

The two main types of glass container used in food packaging are bottles, which have narrow necks, and jars and pots, which have wide openings. Glass closures are not common today, but were once popular as screw action
stoppers with rubber washers and sprung metal fittings for pressurized bottles, e.g. for carbonated beverages, and vacuumized jars, e.g. for heat preserved fruits and vegetables. Ground glass friction fitting stoppers were used for storage jars, e.g. for confectionery.

6.1.4 Glass containers market sectors for foods and drinks

A wide range of foods is packed in glass containers. Examples are as follows: instant coffee, dry mixes, spices, processed baby foods, dairy products, sugar preserves (jams and marmalades), spreads, syrups, processed fruit, vegetables, fish and meat products, mustards and condiments etc. Glass bottles are widely used for beers, wines, spirits, liqueurs, soft drinks and mineral waters. Within these categories of food and drinks, the products range from dry powders and granules to liquids, some of which are carbonated and packed under pressure, and products which are heat sterilized. Table 6.1 gives an overview of the proportions of containers made for the various usage sectors in the UK.

In the categories listed, there has been an overall increase of 28% approximately, in the number of glass containers made in the UK in the period 1993–2002. Within the range listed in Table 6.1, there has been a significant decrease (of around 50%) in the number of milk bottles mainly due to the reduction in doorstep milk delivery and its replacement with plastic and paperboard containers, sold through supermarkets, garage forecourts etc. The sector that has expanded significantly is for flavoured alcoholic drinks (Crayton, 2002).

6.1.5 Glass composition

6.1.5.1 White flint (clear glass)

Colourless glass, known as white flint, is derived from soda, lime and silica. This composition also forms the basis for all other glass colours. A typical composition would be: silica (SiO$_2$) 72%, from high purity sand; lime (CaO) 12%, from limestone (calcium carbonate); soda (Na$_2$O) 12%, from soda ash;

<table>
<thead>
<tr>
<th>Product</th>
<th>%</th>
<th>Trend in consumption</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beer</td>
<td>30</td>
<td>Rising steadily from early 1990s</td>
</tr>
<tr>
<td>Food</td>
<td>24</td>
<td>Steady in 1990s, now falling slowly</td>
</tr>
<tr>
<td>Spirits and liqueurs</td>
<td>18.5</td>
<td>Steady</td>
</tr>
<tr>
<td>Flavoured alcoholic beverages</td>
<td>16</td>
<td>Rapid from start in 1997 and rising</td>
</tr>
<tr>
<td>Soft drinks</td>
<td>6.5</td>
<td>Steady but below 1990s average</td>
</tr>
<tr>
<td>Milk</td>
<td>2</td>
<td>Steady</td>
</tr>
<tr>
<td>Wine</td>
<td>2</td>
<td>Steady</td>
</tr>
<tr>
<td>Cider</td>
<td>1</td>
<td>Steady</td>
</tr>
</tbody>
</table>

Source: Derived from data supplied by Rockware Glass.
alumina (Al$_2$O$_3$), present in some of the other raw materials or in feldspar-type aluminous material; magnesia (MgO) and potash (K$_2$O), ingredients not normally added but present in the other materials. Cullet, recycled broken glass, when added to the batch reduces the use of these materials.

6.1.5.2 *Pale green (half white)*
Where slightly less pure materials are used, the iron content (Fe$_2$O$_3$) rises and a pale green glass is produced. Chromium oxide (Cr$_2$O$_3$) can be added to produce a slightly denser blue green colour.

6.1.5.3 *Dark green*
This colour is also obtained by the addition of chromium oxide and iron oxide.

6.1.5.4 *Amber (brown in various colour densities)*
Amber is usually obtained by melting a composition containing iron oxide under strongly reduced conditions. Carbon is also added. Amber glass has UV protection properties and could well be suited for use with light-sensitive products.

6.1.5.5 *Blue*
Blue glass is usually obtained by the addition of cobalt to a low-iron glass. Almost any coloured glass can be produced either by furnace operation or by glass colouring in the conditioning forehearth. The latter operation is an expensive way of producing glass and commands a premium product price. Forehearth colours would generally be outside the target price of most carbonated soft drinks.

6.2 *Attributes of food packaged in glass containers*

The glass package has a modern profile with distinct advantages, including:

- *Quality image* – consumer research by brand owners has consistently indicated that consumers attach a high quality perception to glass packaged products and they are prepared to pay a premium for them, for specific products such as spirits and liqueurs.
- *Transparency* – it is a distinct advantage for the purchaser to be able to see the product in many cases, e.g. processed fruit and vegetables.
- *Surface texture* – whilst most glass is produced with a smooth surface, other possibilities also exist, for example, for an overall roughened ice-like effect or specific surface designs on the surface, such as text or coats of arms. These effects emanate from the moulding but subsequent acid etch treatment is another option.
• Colour – as indicated, a range of colours are possible based on choice of raw materials. Facilities exist for producing smaller quantities of non-mainstream colours, e.g. Stolze’s feeder colour system (Ayshford, 2002).

• Decorative possibilities, including ceramic printing, powder coating, coloured and plain printed plastic sleeving and a range of labelling options.

• Impermeability – for all practical purposes in connection with the packaging of food, glass is impermeable.

• Chemical integrity – glass is chemically resistant to all food products, both liquid and solid. It is odourless.

• Design potential – distinctive shapes are often used to enhance product and brand recognition.

• Heat processable – glass is thermally stable, which makes it suitable for the hot-filling and the in-container heat sterilization and pasteurization of food products.

• Microwaveable – glass is open to microwave penetration and food can be reheated in the container. Removal of the closures is recommended, as a safety measure, before heating commences, although the closure can be left loosely applied to prevent splashing in the microwave oven. Developments are in hand to ensure that the closure releases even when not initially slackened.

• Tamper evident – glass is resistant to penetration by syringes. Container closures can be readily tamper-evidenced by the application of shrinkable plastic sleeves or in-built tamper evident bands. Glass can quite readily accept preformed metal and roll-on metal closures, which also provide enhanced tamper evidence.

• Ease of opening – the rigidity of the container offers improved ease of opening and reduces the risk of closure misalignment compared with plastic containers, although it is recognized that vacuum packed food products can be difficult to open. Technology in the development of lubricants in closure seals, improved application of glass surface treatments together with improved control of filling and retorting all combine to reduce the difficulty of closure removal. However, it is essential in order to maintain shelf life that sufficient closure torque is retained, to ensure vacuum retention with no closure back-off during processing and distribution.

• UV protection – amber glass offers UV protection to the product and, in some cases, green glass can offer partial UV protection.

• Strength – although glass is a brittle material glass containers have high top load strength making them easy to handle during filling and distribution. Whilst the weight factor of glass is unfavourable compared with plastics, considerable savings are to be made in warehousing and distribution costs. Glass containers can withstand high top loading with minimal secondary packaging. Glass is an elastic material and will absorb energy,
up to a point, on impact. Impact resistance is improved by an even distribution of glass during container manufacture and subsequent treatment.

- **Hygiene** – glass surfaces are easily wetted and dried during washing and cleaning prior to filling.
- **Environmental benefits** – glass containers are returnable, reusable and recyclable. Significant savings in container weight have been achieved by technical advances in design, manufacture and handling.

### 6.2.1 Glass pack integrity and product compatibility

#### 6.2.1.1 Safety
Migration studies on glass have shown it to be an inert material as regards its application to packaged foods and, from a health and hygiene viewpoint, it is regarded as an optimal material for containing food and drinks.

#### 6.2.1.2 Product compatibility
Glass containers are noted for the fact that they enable liquid and solid foods to be stored for long periods of time without adverse effects on the quality or flavour of the product.

### 6.2.2 Consumer acceptability
Market research has indicated that consumers attach a high quality perception to glass packaged products. Recent findings of a report on consumer perceptions carried out by The Design Engine, on behalf of Rockware Glass, concluded that there are five key and largely exclusive benefits for food packaging in glass (The Design Engine, 2001), namely:

1. aesthetic appeal
2. quality perception
3. preferred taste
4. product visibility and associated appetite appeal
5. resealability.

### 6.3 Glass and glass container manufacture

#### 6.3.1 Melting
Glass is melted in a furnace at temperatures of around 1350°C (2462°F) and is homogenized in the melting process, producing a bubble-free liquid. The molten glass is then allowed to flow through a temperature controlled channel (forehearth) to the forming machine, where it arrives via the feeder at the correct temperature to suit the container to be produced. For general containers,
suitable for foods and carbonated beverages, this would be in the region of 1100°C (2012°F).

6.3.2 Container forming

In the feeder (Fig. 6.1) the molten glass is extruded through an orifice of known diameter at a predetermined rate and is cropped into a solid cylindrical shape. The cylinder of glass is known in the trade as a gob and is equivalent in weight to the container to be produced. The gob is allowed to free-fall through a series of deflectors into the forming machine, also known as the IS or individual section machine, where it enters the parison. The parison comprises a neck finish mould and a parison mould, mounted in an inverted position. The parison is formed by either pressing or blowing the gob to the shape of the parison mould. The parison is then reinverted, placed into the final mould and blown out to the shape of the final mould, from where it emerges at a temperature of approximately 650°C (1200°F). A container is said to have been produced by either the press and blow or blow and blow process (Fig. 6.2).

In general terms, the press and blow process is used for jars and the blow and blow process for bottles. An alternative, for lightweight bottles, is the narrow neck press and blow process. The press and blow process is generally

![Figure 6.1](image1.png)  
**Figure 6.1** The feeder – molten glass is extruded through the orifice at a predetermined rate and is cropped into a solid cylinder known as a gob (courtesy of The Institute of Packaging).

![Figure 6.2](image2.png)  
**Figure 6.2** The blow and blow forming process (courtesy of Rockware Glass).
best suited to produce jars with a neck finish size of $\geq 35\text{ mm} \ (\geq 1.25''$); the other two processes are more suited to produce bottles with a neck finish size of $\leq 35\text{ mm} \ (\leq 1.25'')$ (Fig. 6.3).

The narrow neck press and blow process offers better control of the glass distribution than the blow and blow process, allowing weight savings in the region of 30% to be made (Fig. 6.4).

### 6.3.3 Design parameters

One of the design parameters to be borne in mind when looking at the functionality of a glass container is that the tilt angle for a wide-mouthed jar should be $\geq 22^\circ$ and that for a bottle $\geq 16^\circ$. These parameters are indicative of the least degree of stability that the container can withstand. (For other design parameters, see Figs 6.5 and 6.6.)

### 6.3.4 Surface treatments

Once formed, surface treatment is applied to the container in two stages: hot end and cold end treatment, respectively.

#### 6.3.4.1 Hot end treatment

The purpose of hot end surface treatment is to prevent surface damage whilst the bottle is still hot and to help maintain the strength of the container. The
most common coating material deposited is tin oxide, although derivatives of titanium are also used. This treatment tends to generate high friction surfaces; to overcome this problem, a lubricant is added.

6.3.4.2 Cold end treatment
The second surface treatment is applied once the container has been annealed. Annealing is a process which reduces the residual strain in the container that has been introduced in the forming process. The purpose of the cold end treatment is to create a lubricated surface that does not break down under the influence of pressure or water, and aids the flow of containers through a high speed filling line. Application is by aqueous spray or vapour, care being taken to prevent entry of the spray into the container, the most commonly used lubricants being derivatives of polyester waxes or polyethylene. The surface tension resulting from this treatment can be measured by using Dynes indicating pens.

*Figure 6.5* The parts of a glass container. (Reproduced, with permission, from Giles, G.A. (1999), *Handbook of Beverage Packaging*, Blackwell Publishing (Sheffield Academic Press), Oxford.)
Labelling compatibility should be discussed with either the adhesive supplier or the adhesive label supplier depending on the type of label to be used.

6.3.4.3 Low-cost production tooling
The tooling cost for a glass container is approximately one-fifth that of a plastic container. Whilst the numbers produced per cavity are lower than for plastic, this can be advantageous, because the design can be modified or completely revamped in a much shorter time-span than plastic; thus, the product image can be updated and the product marketability kept alive. The numbers produced per mould cavity vary depending on the number of production runs required, the complexity of the shape and the embossing detail. In general, 750,000 pieces can be produced from a complex mould and 1,000,000 pieces from a mould of a simple round shape. There can be upwards of 20 moulds per production set.
6.3.4.4 Container inspection and quality

As with packaging in general, quality assurance is needed to ensure that consumer safety, brand owner’s needs and efficiency in handling, packing, distribution and merchandising are achieved.

Quality assurance needs are defined and incorporated into the specification of the glass container at the design stage and by, consistency in manufacture, thereby meeting the needs of packing, distribution and use. Quality control, on the other hand, comprises the procedures, including on-line inspection, sampling and test methods used to control the process and assess conformity with the specification.

The techniques used can broadly be defined as chemical, physical and visual.

Chemical testing by spectrophotometry, flame photometry and X-ray fluorescence is used to check raw materials and the finished glass. Small changes in the proportions and purity of raw materials can have a significant effect on processing and physical properties.

Physical tests include checking dimensional tolerances, tests for colour, impact strength, thermal shock resistance and internal pressure strength. Visual tests check for defects that can be seen (Sohani, 2002).

The list of possible visually observable defects is quite long and though most of them are comparatively rare, it is essential that production be checked by planned procedures. The categories of these defects comprise various types of cracks, glass strands (bird swings and spikes), foreign bodies and process material contamination from the process environment, mis-shapes and surface marks of various kinds. For a comprehensive list, see Hanlon et al., Handbook of Package Engineering pp. 9-24–9-26.

Defects are classified as being,

- critical, e.g. defects which endanger the consumer or prevent use in packing
- major, e.g. defects which seriously affect efficiency in packing
- minor, e.g. defects that relate to appearance even though the container is functionally satisfactory.

Visual inspection on manufacturing and packing lines is assisted today by automatic monitoring systems, as shown in Figure 6.7, where this is appropriate. Systems are available for container sidewall inspection using multiple cameras that detect opaque and transparent surface defects (Anon, 2002). Infrared cameras can be used in a system to examine containers directly after formation (Dalstra & Kats, 2001). On the packing line, claims have been made that foreign bodies can be detected in glass containers running at speeds up to 60000 capped beer bottles per hour (Anon, 2001).

An X-ray system such as that from Heimann Systems Corp. (Eagle Tall™) is designed for the automatic inspection of products packed in jars. The system
Figure 6.7 Principles of production line inspections. (Reproduced, with permission, from John Wiley & Son Inc.)
can detect foreign materials such as ferrous and stainless metals, glass particles, stone, bone and plastic materials. This equipment runs at 100 m min$^{-1}$.

### 6.4 Closure selection

Closures for glass packaging containers are usually metal or plastic, though cork is still widely used for wines and spirits. Effecting a seal is achieved either by a tight fitting plug, a screw threaded cap applied with torque in one of several ways or a metal cap applied with pressure and edge crimping. Hermetic or airtight sealing can be achieved by heat sealing a flexible barrier material to the glass usually with an overcap for protection and subsequent reclosing during use. The aluminium foil cap applied to a milk bottle is one of the simplest forms of closure.

All these closures are applied to what is known as the *finish* of the container. This may seem an odd name for the part of the container which is formed first but in fact this name goes back to the time of blowing and forming glass containers by hand when the rim was the last part to be formed and therefore called the *finish*.

Four key dimensions determine the finish as shown in Figure 6.8. Industry-wide standards for these dimensions have been agreed upon. The contour of glass threads are round, and closures, both metal and plastic, with symmetrical threads will fit the appropriate containers.

**Figure 6.8** Standard finish nomenclature (courtesy of The Institute of Packaging).
Careful choice of closure is essential. Too large a closure can create leakage due to the force generated upon it either from internal gas pressure or from heating during processing of the product. Too small a closure may well introduce an interference fit between the minimum through bore on the glass container and the filler tube. The types of closure available fall into three main categories:

1. normal seal
2. vacuum seal
3. pressure seal.

### 6.4.1 Normal seals

Normal seals, that is those used for non-vacuum/non-pressure filled products, comprise composite closures of plastic/foil, for products such as coffee, milk powders, powder and granular products in general and for mustards, milk and yoghurts.

Glass lends itself both to induction and conduction sealing without prior treatment of the glass finish, but is considered suitable only for dry powders and products, such as peanut butter and chocolate spreads, which do not require a further heating process.

Crimped seals using foils, used for instance on milk containers, have been used for a long time, and are cost effective.

### 6.4.2 Vacuum seals

Vacuum seals are metal closures with a composite liner to seal onto the glass rim. They can be pressed or twisted into place, at which time a vacuum is created by flushing the headspace with steam. They lend themselves quite readily to in-bottle pasteurization and retort sterilization and sizes range from 28 to 82 mm. For beverages, sizes are usually in the 28–40 mm range.

### 6.4.3 Pressure seals

Pressure seals can be metal or plastic with a composite liner to make the seal, and can either be pressed or twisted into place. They include:

- preformed metal, e.g. crown or twist crown
- metal closures rolled-on to the thread of the glass
- roll-on pilfer proof (ROPP)
- preformed plastic screwed into position with or without a tamper evidence band.
Selecting the correct glass finish to suit the closure to be used is essential. Advice on suitability should be sought from both the closure and the glass manufacturers before the final choice is made.

6.5 Thermal processing of glass packaged foods

Glass containers lend themselves to in-bottle sterilization and pasteurization for both hot and cold filled products. Subject to the headspace volume conditions being maintained and thermal shock ground rules being observed, no problems will be experienced.

In general terms, hot-fill products filled at 85°C and then cooled will require a minimum headspace of 5%, whilst a cold filled product requiring sterilization at 121°C will require a 6% minimum head space. In all cases the recommendations of the closure supplier should be obtained before preparing the design brief. It should be noted that the thermal shock of glass containers is twice as high when cooling down as when warming up. To avoid thermal shock, cool down differentials should not exceed 40°C and warm up differentials should not exceed 65°C.

Internal pressure resistance. A well-designed glass container can withstand an internal pressure of up to 10 bar (150 pounds per square inch), although the norm required rarely exceeds 5 bar. It is also capable of withstanding internal vacuum conditions and filling of thick concentrates, with steam-flushing of the headspace to produce the initial vacuum requirements for the closure seal.

Resealability. Preformed metal, rolled-on metal and preformed plastic closures can all be readily applied to the neck finish of a glass container. Prise-off crown closures offer no reseal, whilst the twist-off crown satisfies reseal performance within reason.

6.6 Plastic sleeving and decorating possibilities

Glass containers can accept a wide range of decorative formats, i.e. labelling, silk screen printing with ceramic inks, plastic sleeving, acid etching, organic and inorganic colour coating and embossing (with good definition, especially for carbonated products). The rigidity of the container offers a good presentation surface for decorating, which is not subject to distortion from internal pressure or internal vacuum (Ayshford, 2002).

When plastic sleeving the container, it is essential to test the sleeving film under in-bottle pasteurization temperatures to ensure that no secondary movement of the sleeve occurs. Care should also be taken not to exceed the stretch limits of the film by ensuring the maximum and minimum diameters of the area to be sleeved do not fall outside the stretch ratios of the film specification.
Sleeving also offers fragment retention properties, should the container become damaged in use.

6.7 Strength in theory and practice

The theoretical strength of glass can be calculated and it is extremely high. In practice, the strength is much lower due to surface blemishes, such as micro-cracks, which are vulnerable stress points for impacts such as occur during handling and on packing lines. Work has therefore been concentrated on:

- improving the surface to reduce defects
- improving surface coatings in manufacture
- avoiding stress during manufacture and use.

Major investigations of packing line performance, noting all breakages, and using techniques such as high speed video, can lead to improvements in performance by eliminating stress points.

Broken bottles can be reconstructed and thereby demonstrate the type of impact which caused the failure, such as whether it occurred at a slow or fast rate or whether it was caused by an external, or internal, pressure related fault. The strength of a glass container is also dependent on shape and thickness. The inter-relationship can be subjected to computer modeling as a design-aid to:

- identify vulnerable features in a proposed design
- calculate the effect of modifying the design
- simulate the effect of lightweighting by reducing thickness.

Specific tests can be carried out on containers to check:

- vertical crushing (relevant to stacking)
- internal pressure (relevant where proposed contents are packed under pressure as with carbonated drinks)
- thermal shock (relevant for hot-filling, pasteurization and sterilization).

Thermal shock relates to heat transfer and as glass is a very good insulator, heat is conducted slowly across the walls when a hot liquid is filled. Another important heat related property is the dimensional change per degree change in temperature, which is low for glass. This property is also subject to the glass formulation, e.g. Pyrex is a well known type of glass with an even lower heat expansion compared with standard white flint soda glass. This is achieved by replacing some of the soda with boric oxide and increasing the proportion of silica.

It has been recognized that achieving an even distribution of glass in the walls of a container is the major factor in successfully reducing weight whilst maintaining adequate strength.
6.8 Glass pack design and specification

6.8.1 Concept and bottle design

Leading glass manufacturers have state-of-the-art design expertise and systems that can be readily integrated with design house concepts to design a container which meets the requirements of branding, manufacture, filling and distribution under recommended good manufacturing practices and procedures.

The brand manager/packaging technologist can now quite readily bring together all the expertise necessary to produce a food container of the ultimate design, cost and quality to meet all their needs.

An understanding of the product specification and the filling line requirements is essential at the concept design stage. The information required includes:

- type and density of the product
- carbonation level, if required, in the product
- closure type/neck specification required
- quantity to be filled
- type of filling process (hot-fill/cooled, hot-fill/pasteurized, ambient-fill/sterilized or any combination of these processes)
- is the container to be a specified volume-measuring container?
- what type of filler is to be used (volumetric or vacuum-assisted)?
- what is the filler tube size/diameter?
- is the container to be refillable or single-trip?
- speed of the filling operation, i.e. bottles per minute
- impact forces on the process line (for ultra lightweight designs, line impact speed should not exceed 25 inches per second)
- what pallet size is to be used in the distribution of filled stock?
- is the depalletizer operation sweep-off or lift-off?

From this information, the glass manufacturer can select the correct finish and closure design, surface treatment requirements, the type of pack to be used for distribution to the filling line and the handling systems. Wherever possible, the body size of the container should ensure a snug fit to the pallet, since any overhang of the glass beyond the edge of the pallet could result in breakage in transit, whilst underhang on the pallet could lead to instability. Compression, tension strapped packs can be accommodated together with live bed deliveries. This creates a highly efficient delivery system with minimal stock-holding on site, by means of just-in-time (JIT) deliveries.

Ever more challenging briefs are demanding more from packaging materials. It is well known that consumers have an innate, high quality perception of glass packaging. This emotional connection between consumer and brand is highly valued by food and drink consumers. Add to this the ability of glass to
be formed into unique shapes with a wide range of decoration techniques and it is clear why glass is also the preferred choice for designers. With increased emphasis on production speed and efficiency, design freedom decreases.

**Low volume.** For low volume, limited or special edition products, the design freedom is high, as hand operated or semi-automated processing lines are used. Bottles may be produced using single gob machines and have a high (+0.8) capacity to weight ratio.

**Main stream.** For main stream production volumes, design freedom decreases, with automatic filling lines and bulk distribution being important. Bottles will be produced using larger double gob machines and have capacity to weight ratios of around 0.6–0.7.

**High volume.** For high volume brands, which probably have multinational distribution, the design freedom is strictly controlled to ensure compatibility with very high speed (+1000 bpm) filling lines. These brands will be produced using the largest double and triple gob NNPB machines and have capacity to weight ratios down to 0.5. A full circle design process creates a range of radical design options and a common sense view on the likely costs and implications of each concept. This ensures all design options are fully explored and the best design solutions are rapidly brought to the market.

**Concept design.** A concept design team focuses on the packaging as a brand communication tool. Using brand analysis they ensure the pack is as active as possible, at the point of sale and in use, in communicating the brand’s value and positioning. Concept designers are able to work very closely with a customer’s design agency, supporting the design process so that a wide range of creative options are explored, yet at the same time highlighting the practical consequences of the design options. This allows realistic, balanced decisions to be made at the earliest possible stage of the project.

**Product design.** Taking computer information from the concept designers, or any design agent, product designers apply a series of objective tests to the design to ensure it is fit for the purpose. These include stress analysis to check retention of carbonated products, packing line stability, and impact analysis to assess the containers’ filling line performance. Strength for stacking and distribution is also checked. On completion of these tests a detailed specification of the design is issued and a 3D computer model displayed. The 3D computer model is used to create exact models for market research and to seek approval for new designs.

**Mould design.** The mould design team translates the product specification into mould equipment that will reproduce the container millions of times. Depending on the manufacturing plant and the process to be used, the mould equipment will vary. The level of precision required for modern glass container production is extremely exacting and has a direct effect on product quality.
The product design computer model is used to control all aspects of the
design, ensuring exact replication of the design into glass. The design is now
ready to be transferred to the mould makers.

Production. Quality information from each production run is fed back to the
product and mould design teams to ensure best practice is used on all designs
and that design teams are up to date with improvements in manufacturing
capability. This closes the full circle.

6.9 Packing – due diligence in the use of glass containers

Receipt of deliveries. Glass containers are usually delivered on bulk palletized
shrink-wrapped pallets. A check should be made for holes in the pallet shroud
and broken glass on the pallet, and any damaged pallets rejected. The advice
note should be signed accordingly, informing the supplier and returning the
damaged goods.

Storage/on-site warehousing. Pallets of glass must not be stored more than six
high, they must be handled with care and not shunted. Fork-lift trucks should
be guarded to prevent the lift masts contacting the glass. Where air rinser
cleaning is used on the filling line, the empty glass containers should not be stored
outside. Pallets damaged in on-site warehousing must not be forwarded to the
filling area until they have been cleared of broken glass.

Depalletization. A record should be made of the sequence and time of use of
each pallet and the product batch code. Plastic shrouds must be removed with
care to prevent damage to the glass; if knives are used, the blade should be
shrouded at all times, so as not to damage the glass. It is necessary to ensure
that the layer pads between the glass containers are removed in such a way as
to prevent any debris present from dropping onto the next layer of glass.
Breakages must be recorded and clean-up equipment provided to prevent any
further contamination.

Cleaning operation

- Air rinse. The glass must be temperature-conditioned to prevent conden-
sate forming on the inside, which would inhibit the removal of cardboard debris. The air pressure should be monitored to ensure that debris
is not suspended and allowed to settle back into the container.
- On-line water rinse. Where hot-filling of the product takes place, it is
essential to ensure that the temperature of the water is adequate to
prevent thermal shock at the filler, i.e. not more than 60°C (140°F)
differential.
- Returnable wash systems. The washer feed area must be checked to
ensure that the bottles enter the washer cups cleanly. A washer-full of
bottles must not be left soaking overnight. In the longer term this would
considerably weaken the container and could well create a reaction on the bottle surface between the hot end coating and the caustic in the washer. Where hot-filling is taking place, it is necessary to ensure that the correct temperature is reached to prevent thermal shock at the filler.

**Filling operation.** Clean-up instructions should be issued and displayed, so that the filling line crew know the procedure to follow should a glass container breakage occur and the need to record all breakages. It is essential to ensure that flood rinsing of the filler head in question is adequate to prevent contamination of further bottles. It is necessary to ensure that filling levels in the container comply with trading standards’ requirements for measuring containers.

**Capping.** Clean-up instructions on the procedure to follow should breakage occur in the capper should be issued and displayed, and all breakages recorded. The application torque of the caps and vacuum levels must be checked at prescribed intervals, as must the cap security of carbonated products.

**Pasteurization/sterilization.** It is necessary to ensure that cooling water in the pasteurizer or sterilization retort does not exceed a differential of more than 40°C (104°F), to prevent thermal shock situations. The ideal temperature of the container after cooling is 40°C, which allows further drying of the closure and helps prevent rusting of metal closures. Air knives should be used to remove water from closures to further minimize the risk of rusting.

**Labelling.** Where self-adhesive labels are to be used, all traces of condensate must be eliminated to obtain the optimum conditions for label application. Adhesives must not be changed without informing the glass supplier, since this could affect the specification of adhesives/surface treatments.

**Distribution.** It is essential to ensure that the arrangement of the glass containers in the tray, usually plastic or corrugated fibreboard, is adequate to prevent undue movement during distribution, that the shrink-wrap is tight and that the batch coding is correct and visible.

**Warehousing.** The pallets of filled product must be carefully stacked to prevent isolated pockets of high loading that might create cut through in the lining compound of the container closures, as this would result in pack failures.

**Quality management.** The procedures of good management practice in the development, manufacture, filling, closing, processing (where appropriate), storage and distribution of food products in glass containers discussed in this chapter have been developed to ensure that product quality and hygiene standards are achieved along with consumer and product safety needs. Their application indicates due diligence in meeting these needs. It is essential that all procedures are clearly laid down, training is provided in their use and that regular checks are made on their implementation.
Companies can demonstrate due diligence by achieving certification under an accepted Quality Management Standard, such as ISO 9000. In the UK, the British Retail Consortium (BRC) and The Institute of Packaging (IOP) have cooperated in the publication of a Technical Standard and Protocol (see ‘Further reading’ section), which can be integrated with their ISO 9000 procedures. The BRC is a trade association representing around 90% of the retail trade and the IOP is the professional membership body, established in 1947, for the packaging industry. The IOP has amongst its objectives the education and training of people engaged in the packaging industry. This Technical Standard and Protocol requires companies to:

- adopt a formal Hazard Analysis System
- implement a documented Technical Management System
- define and control factory standards, product and process specifications and personnel needs.

6.10 Environmental profile

6.10.1 Reuse

Glass containers can be reused for food use. However, there is only one well established household example in the UK – that of the daily doorstep delivery of fresh milk in bottles and the collection of the empty bottles. There are wide disparities in the number of trips that can be expected depending on the location, with around 12 trips per bottle being the national average. The decline of doorstep delivery has been rapid over the last decade but the system of reuse is well established. In the licensed trade, and in most places where drinks are served to customers, the drinks manufacturers operate returnable systems.

6.10.2 Recycling

Glass is one of the easiest materials to be recycled because it can be crushed, melted and reformed an infinite number of times with no deterioration of structure. It is the only packaging material that retains all its quality characteristics when it is recycled. Using recycled glass (cullet), in place of virgin raw materials, to manufacture new glass containers reduces

- the need to quarry and transport raw materials
- the energy required to melt the glass
- furnace chimney emissions
- the amount of solid waste going into landfill.

In order to recycle glass, it must first be recovered. In the UK, glass is brought by consumers to bottle banks. Currently, approximately 600 000 t/a are
recovered – a figure which must increase sharply if the UK is to meet increased European Union targets for glass recovery at currently generated levels of glass container waste. Currently the recycled content of the average glass container is around 33%. The recycled proportion is higher for green than for clear containers and reflects the proportions of clear and green glass taken to bottle banks by the public. Green glass may now contain as much as 85–90% recycled glass.

6.10.3 Reduction – lightweighting

In the period 1992–2002, it is claimed that the average weight of glass containers has been reduced by 40–50% (source: Rockware Glass). This is an average reduction. Some brand owners still retain heavy containers, e.g. spirits and liqueurs, and this causes the progress made by the glass industry to reduce the weight of packaging to be understated.

6.11 Glass as a marketing tool

Glass packaging supports brand differentiation and product identification by the use of:

- creative and unique shapes and surface textures
- ceramic printing, acid etching and coating
- labelling, both conventionally and by plastic shrink sleeving.

Glass can be readily formed into a multiplicity of shapes to provide shelf appeal. Jars may be designed to be table presentable and have convenience in handling features, and bottles have been redesigned to reflect changing drinking habits. Printed pressure sensitive plastic labels using adhesives which are as clear, or transparent, as glass can be used to give a no label effect. Precision in manufacturing and subsequent rigidity of glass containers enable them to meet EC measuring container regulations in terms of capacity (volume) and product give-away through overcapacity or container expansion.

Current developments include the use of metallic, thermochromic, photo-chromic finishes, UV activated fluorescent and translucent inks and the ability to incorporate embossed, foiled, velvet textured and holographic materials. These finishes are compatible with laser etching and offer the possibility of permanent traceability coding.

References