
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 had cooled to a rigid state without crystallising (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 that is continuous with, and analogous to the liquid state of that substance, but which, as a result of a reversible change in viscosity, as to be for all practical purposes solid (Morey, 1954). Many materials are capable of forming glasses including metals, but this publication will concentrate on the typical container glass composition based on sand, limestone and soda ash.

We know that the atoms and molecules in glass have an amorphous random distribution. Scientifically, this means that it has failed to crystallise from the molten state, and maintains a liquid-type structure at all temperatures. In appearance, glass containers are 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 conchoidal (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 mechanised in the United States in the late nineteenth century.

6.1.3 Glass packaging

According to the trade association Fédération Européenne du Verre D’Emballage (FEVE) the production of glass packaging in Europe in 2007 was 22.4 million tonnes, an increase of 4% compared with 2006. This amounted to a per capita consumption of 36 kg (Ellis, 2008).

Growth in the world glass packaging industry, according to a report by global industry analysts is expected to continue despite the emergence of packaging alternatives in North America and Europe (Wells, 2008).

The two main types of glass containers 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 pressurised bottles, e.g. for carbonated beverages, and vacuumised 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 are 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 water. 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 that are heat sterilised. Table 6.1 gives an overview of the proportions of containers made for the various usage sectors in the United Kingdom.

In the categories listed, there has been a steady increase of around 3% in units and 8% in tonnage terms, made in the United Kingdom over the period 2002–2007. Within the range listed in Table 6.1, milk bottles show a low proportion due to the decline in doorstep milk delivery and its replacement with plastic and paperboard containers, sold through supermarkets. Declines have also been seen in Flavoured Alcoholic Beverages and Foods. During the same period the industry has seen significant increases in the soft drink, ciders and wine sectors.

6.1.5 Glass containers

6.1.5.1 White flint (clear glass)

Colourless glass, known as white glass 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

Table 6.1 Proportions of glass containers made in the United Kingdom for various market sectors.

Product	% (based on tonnage)
Spirits	34
Beers	25
Foods	15
Soft drinks	11
FABs	6
Wines	6
Cider	2
Milk	1

Source: Supplied by British Glass (2006).

(Na₂O) 12%, from soda ash; alumina (Al₂O₃), present in some of the other raw materials or in a feldspar-type aluminous material; magnesia (MgO) and potash (K₂O), ingredients not normally added but present in the other materials. Cullet, and 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 (Fe₂O₃) rises and a pale green glass is produced. Chromium oxide (Cr₂O₃) 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 low-iron glass.

6.1.5.6 *Other colours*

Almost any coloured glass can be produced either by adjustment of the furnace operating conditions or by glass colouring in the conditioning forehearth, using specially made glass frits. However, the latter operation is an expensive way of producing glass, it commands a premium product price and is generally only used for high value products, such as premium spirits, etc.

6.2 ATTRIBUTES OF FOOD PACKAGED IN GLASS CONTAINERS

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

- *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. A survey of 6200 consumers in 12 European countries carried out by Insites for Fédération Européenne du Verre D'Emballage (FEVE) showed that 74% preferred glass to other packaging formats (Goldstein, 2009)
- *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
- *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 and it is odourless. Migration tests to indicate that glass packaging is virtually inert in regard to its use in direct contact with food (see Section 6.2.1.1)
- *design potential* – distinctive shapes are often used to enhance product and brand recognition
- *heat processable* – glass is thermally stable, which makes it suitable for hot filling and the in-container heat sterilisation and pasteurisation of food products
- *microwaveable* – glass is open to microwave penetration and food can be reheated in the container. The removal of metal closures is recommended before heating commences as a safety measure to prevent arcing
- *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 recognised 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 during processing and in 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 minimal secondary packaging. Glass is an elastic material and will absorb energy up to a point without deforming 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* – suitably designed glass containers are returnable and reusable with little degradation in performance. The glass in glass containers can also be recycled by using it in glass furnaces to make new glass containers. The proportion that can be added to the raw material input to the glass furnace is up to 60% for clear and amber glass and up to 90% for green glass. Significant savings in container weight, which save resources used to make and use the glass, have been achieved and continue to be 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 when in direct contact with food. From health and hygiene viewpoints, it is regarded as an optimal material for packaging food and drink products (FSA, 2002).

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. 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:

- (i) Aesthetic appeal.
- (ii) Quality perception.
- (iii) Preferred taste.
- (iv) Product visibility and associated appetite appeal.
- (v) Resealability.

6.3 GLASS AND GLASS CONTAINER MANUFACTURE

6.3.1 Melting

Glass is melted in a furnace at temperatures of around 1500°C (2732°F) and is homogenised 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 shutes and deflectors into the forming machine, also known as the IS or individual section machine, where it enters the parison, or blank mould. The parison mould is connected to the neck finish mould, mounted in an inverted position. The parison is formed by either pressing or blowing the gob to the shape of the parison mould, at the same time forming the finish. The parison is then reinverted, placed into the final mould and blown to the shape of the final mould, from where it emerges at a temperature of approximately

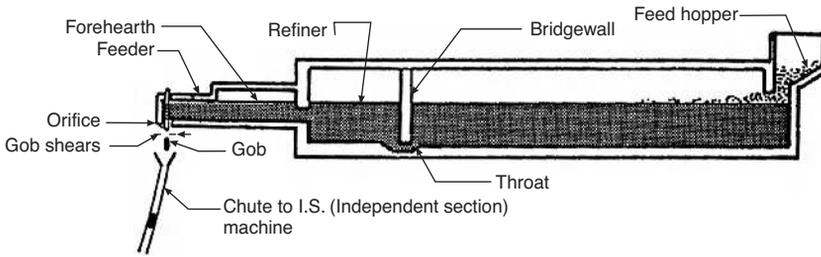


Fig. 6.1 The feeder – molten glass is extruded through the orifice at a predetermined rate and is cropped into a solid cylinder known as a gob. (Courtesy of The Packaging Society.)

650°C (1200°F). Glass containers are produced by either the ‘press and blow’ process, or the ‘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 best suited to jars with a neck finish size ≥ 35 mm (≥ 1.25 "); the other two processes are more suited to produce bottles with a neck finish size of ≤ 35 mm (≤ 1.25 ") (Fig. 6.3).

The ‘narrow neck press and blow’ process offers better control of 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 glass container in two stages, known as the hot end and cold end treatments, 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

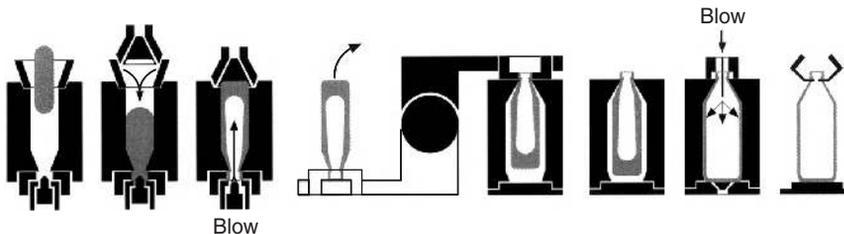


Fig. 6.2 The blow and blow forming process. (Courtesy of Ardagh Glass.)

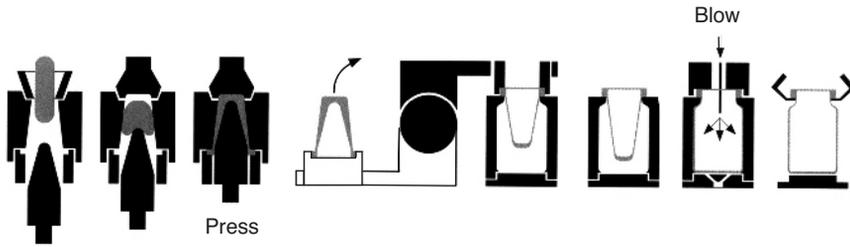


Fig. 6.3 The wide mouth press and blow forming process. (Courtesy of Ardagh Glass.)

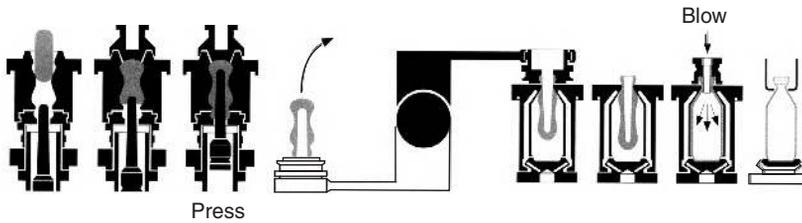


Fig. 6.4 The narrow neck press and blow forming process. (Courtesy of Ardagh Glass.)

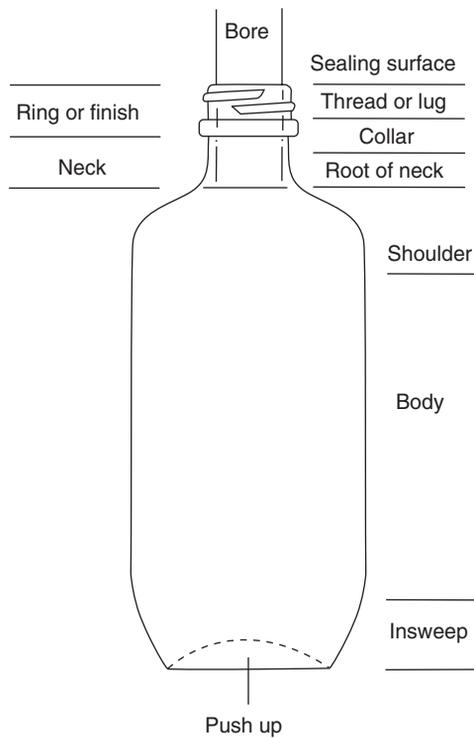


Fig. 6.5 The parts of a glass container. (Reproduced from Giles (1999), with permission of Blackwell Publishing Ltd.)

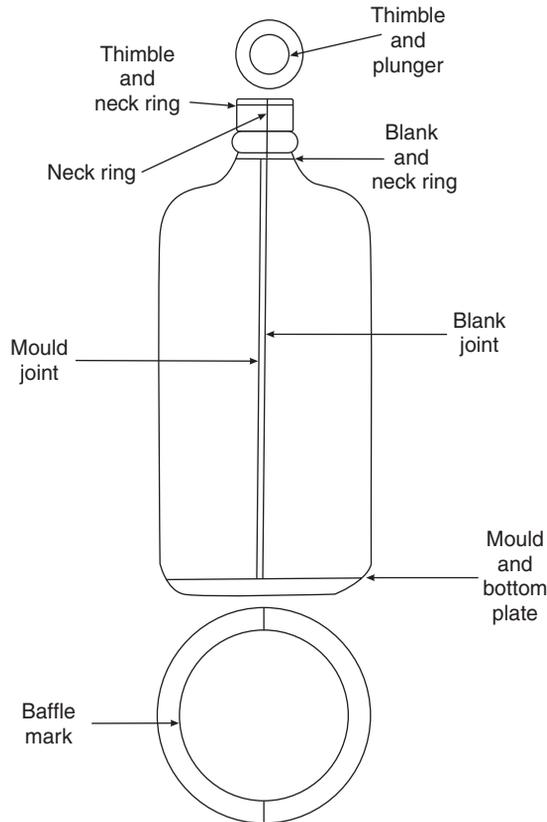


Fig. 6.6 The positions of the moulding joints of the glass container. (Reproduced from Giles (1999), with permission of Blackwell Publishing Ltd.)

deposited is tin oxide, although derivatives of titanium have also been used. This treatment tends to generate high friction surfaces; to overcome this problem, a lubricant is applied.

6.3.4.2 Cold end treatment

A second surface treatment is applied once the container has been annealed. Annealing is a process that 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 are derivatives of polyester waxes or polyethylene.

Labelling compatibility should be discussed either with the adhesive supplier or the adhesive label supplier depending on the type of label to be used since labelling efficiency can be affected if the label adhesive is not compatible with the type and level of cold end coating 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 tooling and the product image and marketability can be updated quickly. The number of containers or pieces produced per mould cavity can 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 a million pieces from a mould of a simple round shape. As mould materials and metal coating techniques are continually being improved, this figure will continue to rise. There can be upwards of 40 moulds per production set, as ten section 'quad' (4 moulds per section) sections are now in use for some types of containers.

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 are used to 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 Packaging Engineering, pp. 9–24 to 9–26.

Defects are classified as being:

- critical, e.g. defects that endanger the consumer or prevent use in packaging (CETIE, 2007)
- major, e.g. defects that seriously affect efficiency in packaging
- minor, e.g. defects to relate to appearance even though the container is functionally satisfactory

Visual inspection on manufacturing and packaging lines is assisted today by automatic monitoring systems, as shown in Fig. 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 60 000 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 can detect foreign materials, such as ferrous and stainless metals, glass particles, stone and plastic materials. This equipment runs at 100 m/min.

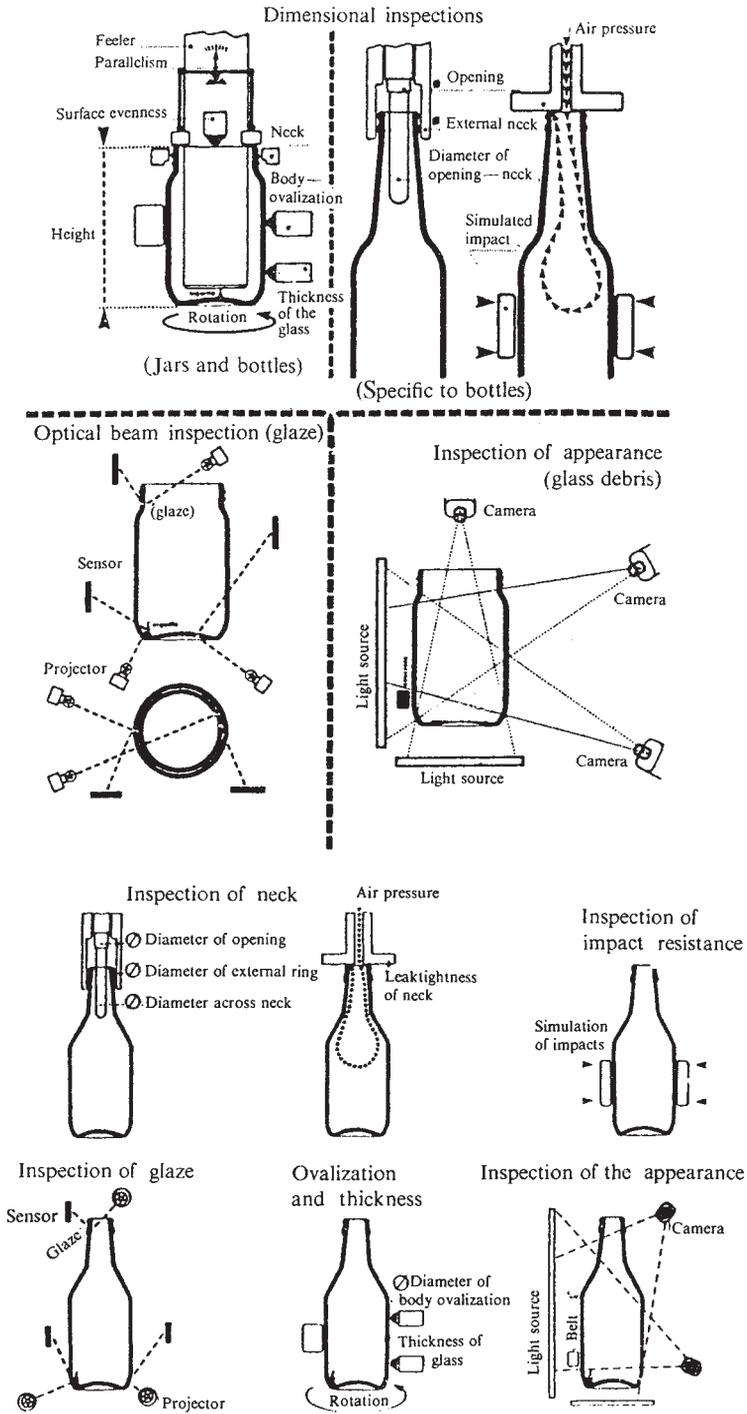


Fig. 6.7 Principles of production line inspections. (Reproduced with permission from John Wiley & Sons.)

6.4 CLOSURE SELECTION

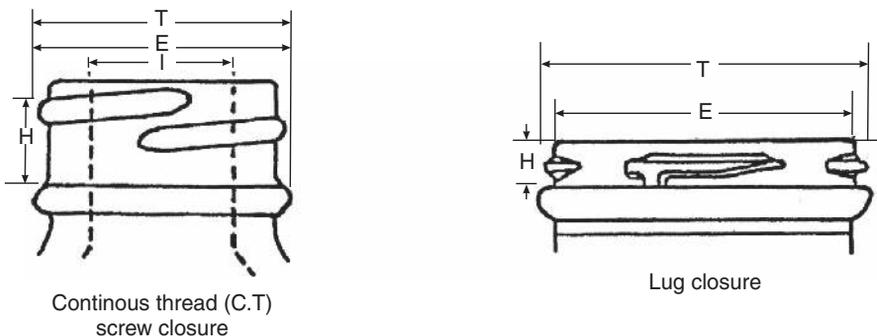
Closures for glass packaging containers are usually metal or plastic, though cork is still widely used for wine and spirits. Effecting a seal is achieved either by a tight fitting plug, a screw threaded cap applied with torque in one of several ways or a metal cap applied with pressure and edge crimping. Hermetic, or airtight, sealing can be achieved by heat sealing, by conduction or induction, 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 that 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 was, therefore, called the *finish*.

Four key dimensions determine the *finish* shown in Fig. 6.8. Industry-wide standards for these dimensions have been agreed upon. The contour of glass threads can be round, V-shaped, or a combination of both. Closures, both metal and plastic with symmetrical threads, will fit the appropriate containers.

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 the 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:

- (i) Normal seal.
- (ii) Vacuum seal.
- (iii) Pressure seal.



- I Diameter at smallest opening inside finish
- T Thread diameter measured across the threads
- E Thread root diameter
- H Top of finish to top of bead or to intersection with bottle shoulder on beadless designs

Fig. 6.8 Standard finish nomenclature. (Courtesy of The Packaging Society.)

6.4.1 Normal Seals

Normal seals are used for non-vacuum/non-pressure filled products. They comprise composite closures of plastic/aluminium foil for products, such as coffee, milk powders and other powdered and granular products and for mustards, milk and yoghurts.

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

Crimped aluminium foil seals used, for example on milk bottles, 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 pasteurisation and retort sterilisation and diameter 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 twisted crown
- metal closures rolled onto the thread of the glass
- roll-on pilfer proof (ROPP)
- preformed plastic screwed into position with or without a tamper evident 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

With moves to remove or reduce the amounts of salt and preservatives in food the thermal processing of glass packaged foods is becoming more important.

Glass containers are ideal for use as measuring containers (see EU Directive 75/107/EC) as they do not deform or change in volume under elevated temperature conditions (a problem that can adversely affect some types of plastic containers).

Glass containers lend themselves to in-bottle sterilisation and pasteurisation 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 products filled at 85°C and then cooled will require a minimum headspace of 5%, whilst a cold filled product requiring sterilisation at 121°C will require a 6% minimum head space. In all cases, recommendations of the closure supplier should be obtained before preparing the design brief. It should be noted that the thermal shock resistance when being cooled down is only half of that when being warmed 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 service requirements rarely exceed 5 bar. It is capable of withstanding internal vacuum conditions and filling of thick concentrates, with steam-flushing of the head space to produce the initial vacuum requirements for the closure seal.

Resealability. Preformed metal, rolled on metal and preformed plastic closures can be readily applied to the neck finish of 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 screening, printing with ceramic inks, 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.

When plastic sleeving the container, it is essential to test the sleeving film under in-bottle pasteurisation temperatures to ensure that no secondary movement of the sleeve occurs. Care should be also taken not to exceed the stretch limits of the film by ensuring that the maximum and minimum diameters of the area to be sleeved do not fall outside the stretch of the 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 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, using techniques such as high speed video, and instrumented 'dummy' container techniques, i.e. to estimate import loads, can lead to improvements in performance by eliminating stress points.

Broken bottles can be reconstructed and thereby demonstrate the type of impact that 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 interrelationship can be subjected to computer modelling 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, pasteurisation and sterilisation)

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 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 recognised 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 container 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 that meets the requirements of branding, manufacture, filling and distribution under recommended good manufacturing practices and procedures.

The brand manager/packaging technologist can 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 the following:

- type and density of the product
- carbonated level, if required, in the product
- closure type/neck specification required
- quantity to be filled
- type of filling process (hot-fill/cooled, hot-fill pasteurised, ambient-fill/sterilised 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 635 mm or 25 inches per second)
- what pallet size is to be used in the distribution of the filled stock?
- is the depalletiser 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 used for distribution to the filling line and the

handling systems. Wherever possible, the body size of the container should ensure an optimum fit within the pallet footprint, 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 and tension strapped packs can be accommodated together with live bed deliveries. This creates a highly efficient delivery system with minimal stockholding 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. The emotional connection between consumer and brand is highly valued by food and drink consumers. Add this to 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 the needs of automatic filling lines and bulk distribution being very 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 double, triple, even quadruple gob (NNPB) machines and have capacity to weight ratios down to 0.5. A *full circle* design process starts with the creation of a range of radical design options and a common sense view on the likely costs and implications of each concept. This ensures that all the design options are fully explored and the best 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, it ensures that the pack is as active as possible at the point of sale, in use, and in communicating the brands value and market 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, 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 the exact replication of the design into the glass container. 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 and ensures that the design is satisfactory in all respects.

6.9 PACKING – DUE DILIGENCE IN THE USE OF GLASS CONTAINERS

Receipt of deliveries. Glass containers are usually delivered in bulk on shrink wrapped pallets. A check should be made for holes in the pallet shroud and broken glass on the pallet. Any pallets damaged in these ways should be rejected. The advice note should be signed for 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 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. Further information regarding the packaging of glass containers for their safe transport and delivery to the customer has been published by British Glass (1998).

Depalletisation. A record should be made of the sequence and time of use of each pallet and the product batch code. Plastic sheeting should 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 from dropping onto the next layer of glass. Breakages must be recorded and clean-up equipment provided to prevent any further contamination.

Cleaning operation. It is as follows:

- *air rinse.* The glass must be temperature-conditioned to prevent condensation forming on the inside, which could 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 65°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 as 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, including an instruction 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 the 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.

Pasteurisation/sterilisation. It is necessary to ensure that cooling water in the pasteuriser or sterilisation retort does not exceed a differential of more than 40°C (104°C) 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 correctly aligned should be used to remove water from closures to further minimise the risk of rusting.

Labelling. Where self-adhesive labels are used, all traces of condensate must be eliminated to obtain optimum conditions for label application. The adhesive must not be changed without informing the glass supplier, since this could affect the specification of adhesive/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 plastic shrink-wrapping 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 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 United Kingdom, the British Retail Consortium (BRC) and The Institute of Packaging (IOP) have cooperated in the publication of a Technical Standard and Protocol (BRC/IOP, 2008), which can be integrated with their ISO 9000 procedures.

The BRC is a trade association representing around 90% of the retail trade in the United Kingdom and the IOP is the professional membership body, established in 1947, for the packaging industry. The IOP is now 'IOP: The Packaging Society' and part of IOM3. It 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

Suitably designed glass containers can be reused for food use. However, there is only one well established household example in the United Kingdom – 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 drinks 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 the place of virgin raw materials, to manufacture new glass containers reduces:

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

The basic facts are that every 1000 tonnes of recycled glass (cullet) used to make new glass saves 345 000 kwh of energy, 314 000 tonnes of carbon dioxide, 1200 tonnes of raw material, whilst at the same time reducing the weight of glass waste by 1000 tonnes. In addition, these savings can be repeated again and again without any loss in the quality of the glass, (King, 2008).

In order to recycle glass, it must first be recovered. In the United Kingdom, there are a number of collection systems currently in operation; glass is either collected by Local Authorities at the kerb-side where it is either separated from other materials at that point or is sent to a materials recovery facility (MRF), where it is separated from other recyclables. Traditionally, glass was, and is, also brought by consumers to bring banks. In 2007, over 1.4 million tonnes was recovered. By the end of 2008, the United Kingdom, under the EU Packaging and Packaging Waste Directive, had to achieve a recycling rate of 60% of glass packaging. Despite the fact that there is enough recycled glass in the waste stream to supply the glass container industry, the quality of material being returned for recycling via Local Authority Kerbside systems, is of such a low quality that it is only suitable for use as aggregate in road building and repair where it is classified as recyclate but does not result in the environmental benefits associated with its use in a glass furnace. The increase in Local Authority collections, whilst being positive in terms of increasing the overall amount of glass recycled, has been at the demise of Bring Banks.

British Glass has stated that the proportion of recovered glass that can be added to the raw material input to the glass furnace is up to 60% for clear and amber glass and up to 90% for green glass.

6.10.3 Reduction – light weighting

Improvements in process control and fault detection technologies, now widely used and relied upon by container manufacturers, have helped the progress towards reducing typical container weight. The removal of weight is obviously beneficial in terms of environmental impact and in reducing fuel and raw material costs in manufacture. The counter balance to weight reduction is to ensure the safe use of the container post-production. All containers leaving the factory must be completely fit for purpose; hence, weight reduction will always be controlled to ensure safety in distribution and use.

Most food containers, including jam and preserve jars, pickles and sauce bottles have seen more than 50% of their pre-1990s weight removed and a similar container in 2008 could be as much as 60% lighter. Even wine and spirits bottles have begun to move over to NNPB production, allowing better glass distribution, more even wall thickness, and lighter weights, though some traditional brands still maintain the heavier bottles for top of the range products as manufacturers claim that weight is equated with quality by many consumers.

In recent years, the environmental (green) lobby has highlighted the need for light-weighting, even major retailers are now being forced, through governmental pressure, to demand lighter containers with lower carbon footprints and reduced environmental impact. This has resulted in several initiatives that have focussed on light-weighting in the industry in order to enable it to compete with other packaging formats that are beginning to displace glass in some of its traditional markets on supermarket shelves. It is hoped that through continued good practice and further light-weighting of glass containers that the trend to other light-weight containers can be reversed.

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. Printing pressure-sensitive plastic labels using adhesives that are as clear, or transparent, as glass can be used to give a *no label* effect. Precision in manufacturing and the 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.

Developments include the use of metallic, thermochromic, photochromic 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. Laser coding on the glass container is also possible for certain designs of container.

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