The Future of Glass Forming Technology for the Manufacture of Lightweight Containers

In striving to make lighter weight glass containers available, technologies dictate the final limit of what can be achieved. Through the implementation of developing technologies in forming and related areas, significant advancement in weight reduction may be realised.
WRAP helps individuals, businesses and local authorities to reduce waste and recycle more, making better use of resources and helping to tackle climate change.

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Front cover photography: Bottles at "Hot End," following forming in IS Machine (independent section container forming machine).

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Executive summary

The introduction and use of lightweight containers is critically dependent upon the glass forming technologies available for their manufacture. For many years, ‘blow-blow’ technology was the dominant glass bottle forming process. However, more recently ‘narrow neck press and blow’ (NNPB) has become the dominant technology for the production of lightweight bottles. Superior dimensional control and consistency available from NNPB allows lighter bottles to be produced without compromising fitness for purpose or market appeal. The current NNPB process inevitably has limitations on the minimum bottle weight which can be achieved, this also being critically dependent on bottle design and volume.

The aim of this study, commissioned by WRAP under the GlassRite Beer, Cider and Sprits project, was to review where the future of glass forming technology lies in respect of the production of lightweight containers. The study reviews the historical developments that brought us to the current state of play, and investigates potential technologies for the future. In addition to the technological possibilities, consideration is also given to cultural and market drivers which impact on the development and uptake of new technologies.

The central element of the study was discussions with key players and stakeholders in the sector. A wide range of bodies were consulted, key amongst which were:

- manufacturers of IS machines and related equipment;
- glass manufacturers; and
- glass / material research bodies and universities.

In addition to these key groups, other stakeholders such as glass trade associations, technology service providers and glass consultancies were consulted as appropriate.

Provision of advanced forming technologies is naturally a commercial activity and this influenced the ability of organisations to openly discuss developments. As a consequence, contributions to the project ranged from in-depth discussion of possible new technologies, to provision of more limited statements.

The discussions outlined above were complemented by a focussed review of the very considerable literature available on the subject.

The study gained a good understanding of future possibilities in glass container lightweighting, particularly in the following areas:

- **Process control improvements** - focussing on enhanced control of current technologies;
- **Enabling down-stream technologies** - handling and inspection techniques capable of accommodating ultra-lightweight containers;
- **Strength improvement** - considering coatings / treatments to strengthen glass in order to compensate for glass thinning from lightweighting; and
- **Forming Technologies** - more significant sea changes in the mechanics of forming, the most prominent candidate technology appearing to be single stage forming using a porous plunger.

There exist a number of technological possibilities for further lightweighting of glass containers. These range from incremental improvements in current technologies, through to capital intensive step changes in forming technique. However, the development and uptake of such possibilities is strongly linked with societal demands, and the operational needs of manufacturers themselves. Future possibilities should also be seen in the context that the control of new technologies is increasingly focussed in a small number of organisations, and that these are responding to the needs of increasingly global rather than local glass markets.
Contents

1.0 Introduction ................................................................. 3

2.0 Overview of Development of Automated Container Glass Forming to the Current Time ...... 4

   2.1 Early Mechanised Production................................................................. 4
   2.2 IS Machine..................................................................................................4
   2.3 Forming Processes.......................................................................................5
       2.3.1 Blow and Blow ...........................................................................5
       2.3.2 Press and Blow ............................................................................5
       2.3.3 Narrow Neck Press and Blow (NNPB) .............................................6
   2.4 Mould Temperature Control........................................................................6
   2.5 Machine Timing and Control Systems.........................................................6

3.0 Study Methodology ...............................................................................7

   3.1 General Approach.......................................................................................7
   3.2 Identifying Contacts...................................................................................7
   3.3 Follow up of Key Contacts - Obtaining Information ....................................8

4.0 Study Findings .......................................................................................9

   4.1 Research Bodies........................................................................................9
       4.1.1 International Partners in Glass Research (I.P.G.R.) .................................9
       4.1.2 Technische Universität Bergakademie Freiberg (Institute of Ceramic, Glass and Building Materials).................................10
       4.1.2.1 Lightweighting through Improved Process Stability ..........................11
       4.1.2.2 Single Stage Forming ..................................................................11
       4.1.2.3 Glass Strengthening using Aluminium Tri-Chloride.......................15
   4.2 Glass Container Manufacturers...................................................................17
       4.2.1 Saint Gobain (France / Germany) .....................................................17
       4.2.2 Owens-Illinois (Switzerland) .............................................................17
       4.2.3 Other Container Manufacturers.........................................................18
   4.3 Forming Machine Manufacturers.................................................................18
       4.3.1 Heye-Glass Technology (Ardagh Glass, Germany) ...............................18
       4.3.2 Bottero (Italy)...................................................................................20
       4.3.3 Quantum Engineered Products, Inc (Pennsylvania, USA) ....................21
       4.3.4 Emhart (Switzerland/USA) ...............................................................22
       4.3.5 Sheppee International (UK) ...............................................................23

5.0 Conclusions .......................................................................................24
1.0 Introduction

This study examines glass container forming and related technologies in both the UK and internationally, in order to identify how the next generation lightweight containers might be produced.

The production of lightweight glass containers is currently a subject of considerable interest and activity within the UK food and beverages sector, supported by the WRAP GlassRite projects, and the earlier Containerlite work. In addition, initiatives such as the Courtauld Commitment act as a driver for packaging reduction which in turn creates a requirement for lightweight glass containers. Many of the barriers to lightweighting tackled in the GlassRite projects focus on consumer perception issues, and container fitness for purpose through the supply chain.

However, introduction and use of lightweight containers is critically dependent upon the glass forming technologies available for their manufacture. Currently ‘narrow neck press and blow’ (NNPB) is the dominant technology for the production of lightweight bottles. Inevitably this process has limitations on the minimum bottle weight which can be achieved, this also being critically dependent on bottle design and volume.

Recognising this fact, WRAP commissioned the research discussed herein under the GlassRite Beer, Cider and Spirits project, to assess where the future of glass forming technology lies. The outcome of this work, this report, might be used to advise forward WRAP activities and to inform the wider stakeholder community on current prospects and possibilities.

The report provides historical context to the subject with an overview of previous advances in forming technology, and continues to review more recent and developing technological advances. The report also considers the societal and manufacturing drivers for the uptake of such technologies.

As discussed more fully below, in some of the key areas of interest, barriers exist relating to the release of commercially confidential information. From the inception of this project it was understood that a difficulty would be that state of the art developments are often closely guarded. Where possible GTS have given assurances and established confidentiality agreements to allow access to such information although in some cases this has necessitated the omission of certain information from this report.

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2 Bottle Rightweighting - a process of packaging design and production to optimise packaging weight, whilst taking into account the requirements of all stakeholders in the supply chain, including manufacturers, brand owners, fillers, retailers, consumers and the environment.
2.0 Overview of Development of Automated Container Glass Forming to the Current Time

2.1 Early Mechanised Production

The history of the automated production of glass containers spans over 100 years. Prior to this, the manufacture of glass containers was a manually intensive and slow process requiring highly skilled labour. In 1907 the first automated forming process was developed by the American engineer Michael Owens. His patented glass blowing machine allowed the production of some 2,500 bottles per hour and lead to the creation of what is now the multinational glass manufacturer Owens-Illinois.

Working from this basis, a development whereby molten glass was fed into moulds in the form of gobs allowed significant advancements in automation compared to the suction method used on the original Owens machine. In 1912 the Hartford-Fairmont company in Connecticut developed the first glass gob shearing and feeding device and the year after introduced the first plunger feeder. By 1923 further advancements ensured that feeder mechanisms could rapidly supply more consistently sized and weighted gobs, allowing much greater control of the glass manufacturing process.

2.2 IS Machine

In 1922 the Empire Machine Company of Elmira, New York, joined with Hartford-Fairmont to form what is now Emhart Glass. It was around this time that glass-making pioneer Henry W. Ingle joined the company, and in 1924 filed a patent for a glass blowing machine. Over the next three years intensive research and development was carried out by Ingle and his contemporary Algy J Smith. 1927 saw the first commercial operation of this automated system, now universally known as the IS Machine.

It is not certain whether ‘IS’ denotes its inventors, Ingle and Smith, or its main characteristic, individual sections. In this process, forming operations are replicated by using multiple individual sections which each form a container, which can range from a single mould set per a section, known as single gob machine, to the latest IS machines with four mould sets per section, known as quad-gob. The mechanical operation of these sections is synchronised with gob delivery. Due to the flexibility it allows, this approach has been continuously developed and improved up to today and IS Machines are now used for the production of virtually all container glass.

The first IS Machine delivered gobs in succession to 4 pneumatically driven sections. Incremental improvements both in terms of gob delivery and the number of sections used have significantly increased production capacity. In 1940 the first double gob equipment was introduced which allowed the simultaneous delivery of two gobs. In the mid 70’s triple gob systems became available and today quadruple gob machines are increasingly used. The first 6 section machine was introduced to the market in 1954 with 8 section machines arriving in the early 70’s. Up to 20 section machines are increasingly common, with tandem ‘back to back’ IS machines now also being seen. Together, these and other improvements have allowed production speeds upwards of 600 containers per minute.

In 1976 Emhart Glass developed the AIS, Advanced Pneumatic Glass Container Forming with parallel blank and mould opening. This difference compared to previous equipment enabled an improvement in forming speed and a more equal cooling condition. A reduction in wear parts was achieved through an improvement in mould handling. Production flexibility is given by the easy conversion from double to triple gob production resulting in output up to 500 bpm.

In 2000 the Next Generation IS (NIS) was developed by Emhart Glass, the first fully servo-electric machine. The inherent instability of pneumatics and compressed air caused process variation which the NIS solved through use of a ‘closed loop’ control of gob feeding, mechanisms and ware handling which allowed for a faster job change. Reduction in piping had a positive impact on the plunger mechanism performance and mass customization met the demand for production flexibility. Electronics monitor each mechanism leading to higher efficiency by reducing slack time, increasing cycle rates and reducing work-out time by half. Energy consumption has been substantially reduced and noise generated is less than one quarter that of a conventional IS machine. Output of up to 800 bottles per minute can be achieved with a QG12 section machine.

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3 A ‘gob’ is a discrete teardrop shaped slug of glass sheared from a molten glass stream, and matching the desired container weight.
2.3 Forming Processes

Due to its modular operation the IS Machine has proven to be highly adaptable and is capable of being used with varied glass forming processes. There are two basic principles of formation commonly used in manufacture: Blow and Blow (BB) and Press and Blow (PB). In the first forming operation an initial glass preform, known as a parison is produced in a so called ‘blank’ mould. This parison is then rapidly transferred to a second ‘finishing’ mould and blown to form the final container shape. In the BB process, final glass distribution will be affected by the blown glass distribution in the parison which is not completely uniform.

2.3.1 Blow and Blow

In the blow and blow process both the parison and the final product are created by blowing processes using compressed air or other gases. This process is illustrated in Figure 1.

Figure 1 The formation stages in the Blow and Blow Process.

2.3.2 Press and Blow

In the Press and Blow process, the glass gob is pressed to form the parison in the blank mould, using a physical plunger. As in the BB process the parison is transferred to the finishing mould and blown to achieve the final container shape. The use of this process is restricted to wide mouth containers with openings of greater than approximately 35 mm, and is thus most commonly used for jars. This is illustrated in figure 2.

Figure 2 The formation stages in the Press and Blow process.

Source: Images courtesy Food Packaging-Principles and Practice- by Gordon L. Robertson Published 1993 CRC Press
2.3.3 Narrow Neck Press and Blow (NNPB)

The development of the Narrow Neck Press and Blow (NNPB) process has allowed for a significant reduction in the weight of glass bottles. NNPB is similar to PB, however it uses a much narrower plunger which allows the formation of narrow neck bottles. Due to shape considerations it is more difficult to remove heat from the long narrow plungers used; to address this issue dedicated plunger cooling and special heat resistant materials are used to prevent the plunger tip from overheating and sticking to the glass.

As in PB, the plunger and the gob together have the same volume as the blank mould cavity. This enables the glass maker to decide exactly how the glass is distributed in the parison and, hence, be able to control the uniformity of the glass distribution in the finished container more accurately than is possible using the BB process\(^4\).

2.4 Mould Temperature Control

The ability of moulds to remove heat from the molten glass is a primary factor determining the quality and strength of the container produced. With ever increasing speeds of operation, the challenge of controlling mould cooling becomes greater.

Advances in cooling have been made by modifying the materials and design of the individual moulds used. Initial developments involved the use of different mould materials and coatings to improve the durability and heat transfer characteristics. Originally, two part solid moulds with no specialised mechanism for heat extraction were used. Simple air cooling methods developed into more advanced techniques involving incorporation of cooling channels in the mould body. This eventually led to the creation of the VertiFlow\(^\text{®}\) mould cooling system which uses software to direct the internal mould cooling to achieve a constant mould temperature. This development almost doubled production speed and enhanced the quality and strength of the final product.

2.5 Machine Timing and Control Systems

Whilst the fundamental principles of IS machine operation have remained largely unchanged, the systems used to control the synchronisation and actuation of the machine mechanics have advanced significantly. Early IS machines used a simple rotating drum mechanism to provide the timing and synchronisation of pneumatically controlled actuators. In the 1970s electronic timing systems were introduced, offering the advantage of a greater level of control over pneumatic and hydraulic actuators and improved machine adaptability, with easier modification of timing.

Throughout the 1990s pneumatic and hydraulic mechanisms were increasingly replaced with servo-electric actuators which offered a new level of control. By 2000, with the introduction of the Emhart NIS (Next Generation IS Machine) systems were available with complete servo-electric control. By using actuators which can be accelerated or decelerated as required, the new system offered significant advantages, both in terms of production control and reduced equipment wear, and the capability to use interlocks to prevent collisions between machine parts.

\(^4\) Food Packaging—Principles and Practice—by Gordon L. Robertson Published 1993 CRC Press
3.0 Study Methodology

This section addresses the methodology used during this study, explaining the overall approach and the nature of the responses received from different bodies.

3.1 General Approach

Whilst some time and resource was devoted to an initial desktop literature review, this proved less fruitful than had originally been anticipated. The review uncovered numerous technical documents and research papers but with little or no information directly pertinent to this study. That is, most published information was out of date or without suitable industrial application. A more focussed search produced a similar result, and it was concluded that the specific objectives of this study greatly restricted what could be achieved through a straight forward literature review. As discussed below, there are several factors which limit the relevance of information available in the public domain. As such it was decided to re-consider the role of published literature in the study.

The information that this work aims to reveal (new forming technologies or forthcoming significant improvements to existing techniques) represents a significant commercial advantage to those in the industry and by and large will not be published in advance of commercial exploitation in order not to pass the advantage gained to competitors.

Academic institutions and specific research bodies, while less driven by commercial aspirations do not in general have the resources to independently replicate container forming operations to any meaningful level. This is primarily due to the tremendous costs involved in operating a glass furnace and complex equipment currently used in glass container manufacture. Therefore without access to specialised equipment through industrial partnerships the potential for significant real-world improvement and associated published papers is limited within such organisations.

For these reasons, the focus has been on direct contact with stakeholders in the different sectors of the glass industry across the world, to seek to understand what advancements are currently being developed. As technologies were identified through this approach, a supporting focussed literature review was conducted, seeking to better understand the background, technical details and/or to see if claims could be substantiated.

3.2 Identifying Contacts

In order to identify those involved in the development of new technologies, organisations in various groups of the glass industry were contacted by phone and/or email. While many of the initial contacts were known to Glass Technology Services and/or the British Glass Manufacturers' Confederation, in general the most useful contacts were identified through a series of referrals. In most cases multiple approaches through different referrals were required before the relevant contact was identified.

To offer a global view, representatives of Glass Federations and Trade Organisations across Europe and Asia were contacted. This facilitated later discussions by providing specific named contacts at certain companies and institutes. Such organisations approached included: Bundesverband Glasindustrie (Germany), Greek Glass Federation, Polish Manufacturers Federation and ASEAN Glass Federation (South East Asia).

Research bodies and Universities known to be involved with development of new glass technologies were approached to identify relevant research activities. As the most relevant developments in container forming technology are undertaken through industrial partnerships, these approaches largely led back to commercial contacts. Contact with the Managing Director of the Research Association of the German Glass Industry, HVG (Germany) Dr. Ulrich Roger proved to be invaluable, identifying specific contacts at a number of institutes and companies in Germany, Switzerland and Italy. These contacts were extremely helpful and provided some valuable unpublished information.
Follow up of Key Contacts - Obtaining Information

Once an appropriate contact was identified and approached, either information could be provided immediately or in many cases there was extended dialogue over several weeks, due to reservations related to commercial confidentiality.

It was found that the detail of information provided depended largely on the nature of the organisation contacted. For this reason the findings in this report are broken down by stakeholder type: research bodies, glass container manufacturers, and machine manufacturers. Other stakeholders which do not fall into the above categories were also contacted but did not provide information warranting a report section. To widen the search for relevant information, contact was also made with companies which support the glass industry such as glass consultancies, suppliers of mould equipment and machine maintenance providers. While some developments were identified, these all appeared to be incremental improvements rather than novel or new technologies. Flat glass manufacturers were also approached to identify any relevant technologies that might be applied to container glass such as coatings, surface treatments etc. This, however, did not identify any unique developments.

Where possible, in the following discussion, estimates of the cost of implementing the technologies and the expected deliverable weight reductions are provided. In the majority, however, this was not possible either because the technologies involved were still in early stages of development, developments were incremental in nature (e.g. process control improvements) and not aimed specifically at lightweighting, or because contributors were unable to share information as it was commercially sensitive.
4.0 Study Findings

The following sections consider the outcome of discussions with the different key stakeholder groups.

4.1 Research Bodies

As indicated previously, the considerable cost of equipment and resources required for container glass forming represents a sizable barrier to independent research and limits the potential for specific industry-relevant advancements. Detailed in this section are two research bodies which have been able to develop significant advancements which do have direct industrial application to lightweighting.

4.1.1 International Partners in Glass Research (I.P.G.R.)

IPGR is an international research group based in Switzerland which was set up as a forum for independent glass research projects. IPGR was founded in 1984 as a consortium between four well-known manufacturers of glass containers ACI (Australia), Portion (Canada), Yamamura (Japan) and Brockway (USA) and the manufacturer of container forming equipment, Emhart. Within a year Wiegand-Glas (Germany) and Rockware Glass (now Ardagh Glass) also joined. In recent years Sisecam, Vetropack, Vidrala and Gallo have joined.

The initial aim of IPGR was to strengthen glass so that lighter and stronger glass packaging would be available to consumers worldwide. As a result a polymer coating technology was developed which allowed for the production of lightweight containers. Within the first five years IPGR had the ambitious goal to improve glass containers strength by a factor of ten and over this period much basic research was carried out. Whilst several promising technologies were advanced the initial ambition was not realised.

Discussions with IPGR researchers provided detail of a significant development in the production of lightweight glass which is currently available but has yet to be widely adopted, namely the strengthening of glass using UV-cured epoxy based coatings. Figure 3 below illustrates this work.

Figure 3 Left: Graph shows two 100ml soft drink bottles Red: original weight without coating Blue: lighted weighted bottle with epoxy coating. Right: examples of epoxy coated bottles.

This work suggests that in all cases strength in the lightweighted bottle can be maintained or even increased through the use of epoxy coatings.

Published research suggests that the following three mechanisms may contribute to the increase in strength seen in the coated bottles. The coating:

- protects the external surface of glass containers from surface damage which reduces strength;
- penetrates into certain types of pre-existing defects in the glass inhibiting propagation at the crack tip; and,

5 R. Hand and co 2001-2003
results in strengthening due to compressive stress in the glass surface (thermal expansion of coating differs from that of the glass).

Whilst this technology has, for several years, been licensed for commercial use by Wiegand-Glas in Germany, under the name of PCT Polymer Coating Technology, it has apparently seen limited use, and is currently primarily used as a method of colouring glass. Throughout the course of this study references were made to this process by various stakeholders in the glass container industry. It is not certain why this has not been widely adopted but in the course of this study four possible explanations were offered:

- in more than one discussion it was suggested that the coating proved unpopular because it dramatically changed the appearance and feel of the glass and thus may affect the perceived quality of the product;
- concerns related to recycling of the coated glass were also raised; this however is somewhat in conflict with claims by Wiegand-Glas that it is recyclable. With a reported thickness of the 0.005mm it is not certain that this would have a significant impact on cullet quality;
- it was more generally suggested that coatings of this type were not successful because of their relatively high cost (0.7–2 ¢/bottle); and
- the fact that whilst they increased the burst pressure, impact strength did not improve.

Another technology developed at IPGR is the provision of permanent blank mould lubrication which, by eliminating the need for blank mould lubrication via periodic manual ‘swabbing’, can lead to greater stability of wall thickness and thereby process and product control. IPGR’s technology is claimed to offer certain benefits over competitive products in terms of toxicity. The coating process, however, is not absolutely applicable to the BB process. In addition, in discussions with Prof. Heinz Houben of IPGR, he indicated that he felt there was strong competition for this technology such as the currently available swab-less mould coating technology sold by CERTEK Ceramic Technologies (Prospect, Connecticut, USA).

Further discussions with Prof. Houben confirmed accounts that IPGR is no longer strictly focussed on research related to physical strength of glass and is concerned with other issues which will more generally enhance the position of glass within the container market. For example, one area of current research deals with increasing the efficiency of the hot end coating process.

4.1.2 Technische Universität Bergakademie Freiberg (Institute of Ceramic, Glass and Building Materials)

Discussions with Prof. Heiko Hessenkemper, professor of glass and enamel at the Institute of Ceramics, Technische Universität Bergakademie Freiberg, Germany proved very useful in identifying significant process improvements and potential new technologies relevant to this study.

Prof. Hessenkemper is a leading figure in applied glass research, and heads a facility within the Department of Glass and Enamel Technology which appears to be unique in terms of its capabilities. The research laboratory includes a fully operational glass furnace with the capability to produce one tonne of glass per day. The department (numbering >24 researchers) works on a number of research projects directly applicable to issues faced by the glass manufacturing industry. Because the funding mechanism of this research group involves public funding, the majority of developments are available to European interests for relatively small licensing fees. Outside of the EU there is potential for exclusivity, however, the licensing fees can be significant.

GTS held detailed discussions with Prof. Hessenkemper. In these he highlighted developing technologies which have the potential to bring thinner and thereby lighter glass containers to market. Professor Hessenkemper believes that focussed research can lead to major advancements in forming technology but expressed frustration that in the current climate there can be considerable resistance from glass manufacturers to invest money to actively pursue or adapt new forming and associated technologies. In these discussions GTS became aware of certain advancements underway at many of the major glass manufacturers. While most of these are discussed in

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6 http://www.ipgr.com/index.php?id=466
8 Clem McKown, Elf Atochem from report on Coatings on Glass Technology Roadmap Workshop Jan 18-19 2000 prepared by Sandia National Laboratories, Albuquerque, New Mexico, USA
9 http://www.ipgr.com/index.php?id=468
the following sections, due to confidentiality concerns it is not possible to indicate which organisations are involved with each project.

Prof. Hessenkemper indicated that significantly improved capability is possible through full exploitation of existing process and production control technologies. By way of example Hessenkemper cites the Altajir Glass Bottle Factory (Jebel Ali, Dubai, and U.A.E.). Due to the unique market forces in the U.A.E. there have been no barriers to investment and this has lead to significant advantages, with secure return on current development investments. Through full exploitation of current technologies and optimised production conditions Altajir are able to produce light weight containers at a cost which is competitive in European and Global markets despite transport considerations.

According to Hessenkemper, even through moderate investment of the order of several hundred thousand pounds, significant improvements in lightweighting capability can be achieved with quick pay back in terms of reduced use of raw materials, energy and transport costs. Hessenkemper estimates that 40-50% of the total cost of delivering a glass bottle is directly related to glass weight, suggesting that investments in weight reduction can pay for themselves in relatively short time frames.

Through discussions with the industry Prof. Hessenkemper has outlined a number of improvements which he believes could almost immediately, individually or together, deliver lighter weight glass containers. These improvements, detailed in the following sections, can be broken down into two categories:

- improved process stabilisation; and,
- increased strength.

Once these improvements have been implemented, Hessenkemper claims that Single Stage Forming will be feasible and that this would represent a sea change, with the potential to deliver major advancement in container weight reduction. Compared to current BB, PB and NNPB technologies single stage forming comprises:

- combined press and blow forming in a single mould using a porous plunger to deliver the blow glass; and,
- use of modified glass compositions, “Short Glass”, which has a short forming temperature range which quickly sets and holds its shape.

The above bulleted technologies are discussed in more detail below.

4.1.2.1 Lightweighting through Improved Process Stability

Prof. Hessenkemper suggests that considerable improvements in process stability are possible. He spoke of a current high level of variability in the production of glass containers and that it is not uncommon for a 30-50% variation in thickness to be seen around the circumference of a bottle, equating to unnecessary glass, as the strength of the bottle will largely be dictated by strength at the thinnest location.

It is claimed that this situation can be significantly improved through the use of new technologies which allow a greater level of stability in glass production. Hessenkemper suggests that if thickness variation across a bottle could be reduced to around 10-20%, this could on average allow a 10% reduction in glass weight without design change, and in turn increase profit by approximately 5% of total turnover. The following examples of new technologies under the general heading of improved process stability are described in the following sections:

- closed-loop feedback between on-line hot end inspection equipment and temperature control systems;
- advanced gob conditioning; and,
- furnace stabilisation through improvements in batch processing and feed back control.

Closed-Loop Feedback between On-Line Hot End Inspection Equipment and Temperature Control Systems

Hessenkemper has been involved with developments which are underway to use a currently available hot end inspection system to enable closed-loop control to actively control glass forming through differential mould cooling. This work has been done using an On-Line Hot-End Inspection System produced by OTTO Vision Technology (Jena, Germany) as seen in figure 4 below.
According to Hessenkemper the system has the ability to, in real-time, provide as many as 70 independent geometric measurements of hot bottles to a precision of greater than 0.01mm. The company claims that this system can analyse 600 bottles a minute using up to 8 high resolution cameras along with advanced image processing techniques to assess quality characteristics within a millisecond. As this system is based on visible light it does not suffer from the sensitivity limitations experienced when inspecting lightweight glass using near infra red radiation (NIR), as discussed further below. Whilst not specifically discussed, it would appear that information from other systems based on visible light could also be used. One such system produced by JLI Vision A/S (Søborg, Denmark) uses two cameras, oriented at 90 degrees to each other, to analyse backlight images of a bottle. It is claimed that this gives excellent coverage and provides detailed information on glass distribution, allowing measurement of glass thickness around the bottle to an accuracy of 0.01mm, at least for amber and green glasses. As well as glass distribution, this system is designed to detect glass defects such as inclusions, fractures and bubbles.

Trials are underway using the OTTO Vision system to provide information to correct dimensional problems through automatic feedback to support differential cooling of individual moulds. This approach is said to correct dimensional variance largely independent of the specific cause. If these claims are correct, the increased level of control provided by such a system should make it possible to produce consistently stronger, lighter weight containers.

The cost of the OTTO Vision system is between £50,000 and £100,000 depending on configuration, with additional cost for systems using more than 3 cameras. The cost of the JLI Vision system is approximately £60,000. While Hessenkemper did not give a specific cost to the feedback control system, he said there were no issues related to licensing as the software being used was developed at a university.
**Advanced Gob Conditioning**

The temperature distribution within the gob at the time of delivery to the mould significantly influences the regularity of temperature within the parison and hence the ability to have well distributed and consistent glass thickness in the final formed containers. With triple or quadruple gob systems there are increased challenges in ensuring regularity across all gobs due to influences of neighbouring gobs and other configuration-dependant variations.

To have the best chance of consistent, controllable manufacture, which would allow thinner containers to be produced, there would be advantage in having greater control of the condition of the gob. According to Prof. Hessenkemper this is attainable using a system which would use multiple jets e.g. flame, air, water emulsifier to ‘trim’ local gob temperature immediately prior to delivery into the mould. A schematic of the system principle is shown in figure 5 below.

**Figure 5** Diagram illustrating a system to allow improved control of gob temperature upon delivery to the mould.

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Work in this area has been carried out in partnership with WALTEC Maschinen GmbH (Steinberg, Germany). WALTEC is a leading manufacturer of automatic, electronically controlled feeder, pressing and spinning machines, as well as handling systems and fire polishing machines for the glass industry. The experience that WALTEC has with equipment for the processing of glass tableware, says Hessenkemper, could be adapted to create such an advanced gob conditioning system.

Hessenkemper indicated that the greatest opportunity for affecting the gob temperature distribution lies at the point when it is drawn and sheared and that the cost of implementation would ultimately depend on the gob configuration (single, double, triple etc.) and not the number of sections. Due to the fact that this technique is still at the development stage, Hessenkemper was unable to give a clear estimate of the expenditure which would be required to realise this system. He stated, however, that there was no reason to expect that this cost would be excessive as there was not a need for any completely new systems. That is, current systems for control of IS machines could be adapted to allow this facility, using the gas, air and water supplies readily available in a glass making environment.

Compensating for different gob delivery times, the time from shearing to entering the mould, the system would allow rapid adjustment of parameters and independent conditioning of gobs supplied to individual sections. This level of control could allow further improvement through the use of closed loop feed-back control using near-infrared gob monitoring equipment or other data sources. This could eventually include the On-Line Hot End vision system previously highlighted.
**Furnace Stabilisation**

Prof. Hessenkemper suggested that furnace stabilisation through improvements in batch processing and increased feedback control could lead to better control of forming and increased ability to lightweight. For example, the use of improved grinding and mixing of raw materials to ensure homogeneity of the batch along with advanced image-based feedback control to optimise mixing in the furnace might be used to improve glass temperature and composition homogeneity. Increased furnace stability, and consistency of glass composition and temperature in turn results in better control of the forming step, and thereby the potential to make consistently thinner glass. EIRICH Technologies (Germany) echo the idea that perhaps the greatest potential for significant improvement in glass forming might come through advanced feedback and control systems. This is made more feasible with recent advancements in vision systems such as that illustrated in figure 6, which can offer real-time furnace operation feedback.

**Figure 6** Visual furnace monitoring system (Software & Technologie Glas GmbH Cottbus).

The images shown above look towards the furnace batch feeder and dog house. Burner and exhaust ports can be seen in the sidewalls, and glass disturbance from the bath bubblers, used to hold back unmelted batch, are visible as a dotted line in the foreground. Dark spots in the top right hand image represent unmelted batch.

**4.1.2.2 Single Stage Forming**

Prof. Hessenkemper asserts that through a combination of gob conditioning and hot end inspection feedback control, it is possible to use a single mould process to make containers with a significantly reduced wall thickness (compared to the typical two stage process of using a blank mould followed by a finishing mould).

If it were possible to use a single mould to form bottles at speeds currently attained by the two stage process, this would represent a considerable advantage in terms of lightweighting. Using a single mould process there is potential to produce significantly stronger glass by limiting mould contact and thereby avoiding defects which can occur in two stage operations. By effecting an increase in the overall strength, this technology would allow the production of thinner glass containers without reducing performance.

In a two stage forming processes, the cooling and pre-forming operations of the parison in the blank mould provide an intermediate stage between the gob and the final formed container during which it is possible to positively influence the glass temperature distribution. If this step is removed, forming using a single stage process depends more directly on the temperature distribution of the gob. For this reason, previously detailed
advancements in gob conditioning were stated by Hessenkemper as a pre-condition for single stage forming. The single stage forming approach is illustrated in figure 7.

**Figure 7** Combined single stage press and blow formation process using a porous plunger.

The use of a porous plunger material allows greater control of formation by allowing press and blow operations to be carried out within the same mould. The use of this technique also has the potential to allow greater uniformity of glass thickness than may be possible using a standard blow process, again supporting the manufacture of thinner lighter bottles.

From searching available patents it would appear that some development in this direction had been made as early as 1979 by Olivotto Vetromeccanica S.a.s.\textsuperscript{11}. GTS is not aware of any current use of this technology and the likely cost and time frame to implement is unknown. However, such a move would likely require significant engineering works and capital investment within existing container plants.

Along with a change to single step forming, it is also possible to gain advantage through the use of modified glass compositions. Compared to a standard two stage process a single mould operation would allow less time to extract heat from the glass. For this reason it might be expected that there would be difficulty in being able to solidify enough of the glass to maintain a stable form on exit from the machine, within the time available for forming. In typical two stage forming the stability of the parison is very transient; only enough heat is extracted to allow the very outer shell of glass to solidify for transfer to the finishing mould. Upon removal from the blank mould the parison shell quickly softens as it is reheated by the hotter glass within the parison. This effect allows the glass to be fluid enough to be blown once it arrives in the blow/finishing mould. This issue says Hessenkemper, may be addressed by using “short glass” compositions. “Short glass” shows changes in viscosity over a narrower temperature range and hence can be made to solidify more rapidly. As this development requires only a change in the proportion of raw materials used, its adoption is not expected to require capital expenditure.

### 4.1.2.3 Glass Strengthening using Aluminium Tri-Chloride

Theoretically, glass can be made which is stronger than steel, and so strong that an articulated lorry could be suspended by a single fibre\textsuperscript{12}. In practice, manufactured glass is less than 1% of its maximum theoretical strength, in part due to weaknesses introduced by surface damage. A technology which would allow glass to resist damage-induced weakness could potentially allow the production of bottles which are significantly thinner yet robust. Figure 8 shows the strength characteristics of different types of glass.


\textsuperscript{12} (Glass International September 2007).
**Figure 8** Shows that only perfect glass fibres approach the theoretical maximum strength of glass and how damage present in glass reduces its strength by orders of magnitude.

Prof. Hessenkemper has developed a post-forming treatment using hot aluminium tri-chloride (AlCl₃) deposition to significantly increase glass strength by improving resistance to surface damage. This technology bears some similarity to IPGR’s use of cured epoxy coatings. Figure 9 shows the increase in tensile strength resulting from deposition of AlCl₃.

**Figure 9** Strengthening of glass fibres using AlCl₃

The patent filed by Hessenkemper claims the surface modification resulting from AlCl₃ treatment, which is responsible for the strengthening effect, is stabilised. This prevents reverse sodium diffusion from the bulk glass, which would reverse the strengthening effect, even at high temperatures such as those seen during flame reprocessing¹³. This technology has already been developed for use with glass tableware and flat glass allowing thinner glass to be used in both applications without significantly reducing the glass strength of the finished product.

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¹³ patent (WO/2004/096724) ALKALINE GLASSES WITH MODIFIED SURFACES AND METHOD FOR PRODUCING SAME; HESSENKEMPER, Heiko
It is understood that there have been trials at a major manufacturer with the aim of using this technology for the production of glass containers. Whilst initial results were variable, Prof. Hessenkemper is confident that within several months processes can be optimised so this technology can be used to allow thinner glass containers to be introduced to market. Commercial confidentiality requirements of the glass manufacturer mean it is not possible for specific trial results to be discussed here. However, in a 2006 article published by Hessenkemper it is indicated that for most manufacturing processes this technology represents a low cost improvement in on-line processing which can be implemented just after the forming process. It was indicated that costs for realising the technology, at least outside of Europe, are largely dependant on negotiation and agreement of licensing fees allowing exclusive use for the markets concerned. As previously indicated, due to partial governmental funding of the research, such licensing fees are nominal for interests within Europe. Hessenkemper estimated that in order to add the strengthening treatment in a container line as an on-line process the equipment costs would be of the order £10,000 to £30,000. Treatment reagent costs were said to be inconsequential, with a few Euros worth of AlCl3 claimed to be enough to treat approximately 5,000 tonnes of glass containers.

4.2 Glass Container Manufacturers

Several glass manufacturers were contacted to determine if they were developing or were aware of any relevant new technologies, or indeed were developing any of the technologies already highlighted, due to these often being developed in partnership with container manufacturers both in Europe and the US.

4.2.1 Saint Gobain (France / Germany)

The Technical Director (France), indicated that he was confident that by using existing technologies St. Gobain could already produce bottles which are perhaps lighter than are currently required by their customers. He believes that currently there may not be enough of a pull from the market to justify the expenditure necessary to produce significantly lighter weight glass containers. Two issues of relevance were highlighted:

- increased glass bottle weight may allow differentiation from light plastic containers by consumers, which might be perceived positively or negatively; and
- regardless of the true strength of an ultra lightweight glass container, potential consumer perceptions that a lightweight glass bottle is weaker may influence complaint levels.

The Sustainable Development Manager provided a further statement, quoted below:

“Lightweighting is clearly one of the means of reducing the overall environmental impact of one-way glass packaging though in practice recycling is clearly the most effective and accessible. Saint-Gobain is active both with external machine suppliers and our own development teams to improve the forming process and although this is generally not specifically aimed at “extreme” lightweighting, every development that enables to improve the regularity with which we achieve a given glass distribution will contribute to further steps in this direction when necessary. No single miracle technology that would enable a step change in minimum container weight is to our knowledge conceivable in the foreseeable future, but this would not be necessary to gain for example 10 to 15 % on the current lightest weight containers (e.g. 300g 75cl wine bottles) in a fairly short time frame of 1 - 2 years, including time for market feedback on initial production. The developments concern for example process control, in particular feedback from infra-red imaging of bottles and moulds, and corresponding mould cooling regulation systems. The upstream glass temperature homogeneity in the forehearth and through to the feeder mechanism is also known to be essential to obtain even and consistent wall thicknesses, and progress in mathematical modelling has and will have a positive impact on this. However it is to be stressed that technology - neither in production, inspection or downstream handling - is not the real barrier to making extreme lightweight bottles. We are approaching the physical limits of the material even with current NNPB and “advanced” BB technologies, but also for market acceptability for the main product types packed in glass packaging.”

Nicholas Harris, Sustainable Development Manager, Saint-Gobain Packaging

It is notable that the above statement alludes to many of the process control enhancements discussed earlier in this report, as being key to forward improvements in container weight.

4.2.2 Owens-Illinois (Switzerland)

O-I are currently the largest global container manufacturer and are also a key manufacturer of glass forming equipment with considerable internal R&D capabilities. O-I were approached during the study regarding their
current and anticipated developments and also their views on the way forming technologies are moving. The Vice President of O-I Europe indicated that OI are involved with a number of advances relevant to lightweighting. However, for confidential reasons an overall statement on activities were provided.

"O-I is a major manufacturer of glass container forming equipment who invests significant R&D funding into developing leading edge technologies and processes for glass container production. Innovation in glass packaging continues to be a driving theme for O-I, including differentiation through container lightweighting. O-I believes the greatest opportunity for lightweighting glass containers exists in collaborative efforts between glass customers and glass suppliers to create container designs that optimize weight reduction opportunities while meeting the demands of the marketers. O-I continues to work with customers individually to provide a sustainable package that meets the objectives requested. Longer term projects, continue to be a part of the O-I portfolio of projects and are being advanced, but O-I will further reduce glass weight on individual projects that are part of the value we provide our customers".

4.2.3 Other Container Manufacturers

Several other container manufacturers were contacted; the following have confirmed that they are not pursuing new technologies related to lightweighting and that any reductions in weight would be carried out through optimisation of using current technologies:

- Vetropack;
- Allied Glass;
- Beaton Clark; and
- Quinn Glass.

One reason stated for this position was the lack of demand for lightweight containers, particularly in mainland Europe due to the returnable-dominated market. Additionally, issues were raised relating to line handling or inspection capabilities and factory performance concerns if producing lighter weight containers.

4.3 Forming Machine Manufacturers

This section deals with contacts whose main area of interest is the development and sale of equipment used in the manufacture of glass.

Whilst representing significant advances, many of the technologies described by these contacts may not in the strictest sense be "new". There are a number of reasons for this:

- As evidenced with the glass manufacturers, novel technologies represent commercial advantage and there is often therefore a natural reluctance to discuss these. Similarly in the competitive market of machine manufacture there is extreme reluctance to release information about technologies which are not yet in market.
- The greatest motivation is to publicise currently available technologies.
- In many cases, development by the machine manufacturers may be less speculative or far reaching, but instead represent ideas which can quickly be turned into saleable products or incremental improvements based on customer demand.

4.3.1 Heye-Glass Technology (Ardagh Glass, Germany)

Heye-Glass are currently owned and operated by Ardagh Glass. Due to their history as a global supplier of machines, until recently their developments were better publicised than they are currently. Commercial confidentiality restrictions prevented a clear understanding of current developments being gained, however information on historical advancements may give an indication of the current direction of their research.
Conversations with the Division Manager of Product Development, Dr Michael Kellner, proved useful in gaining perspective on lightweighting technology at Heye International GmbH. It was indicated that within European operations, the drive for lightweight containers is now much less that it once was, with the largest markets dominated by returnable markets. Relatively speaking, he said there is greater demand for lightweight bottles in certain markets in which Heye have operations (Americas, Africa and Australia). Kellner feels that even in these markets the approach is to effect lighter containers through incremental improvement of lightweighting technologies rather than a step change.

In the 1980s and 1990s Heye-Glass led developments in forming technology which allowed significant advancements in container lightweighting, examples of which are shown in table 1.

<table>
<thead>
<tr>
<th>Article</th>
<th>Original Weight</th>
<th>Reduced Weight</th>
<th>Percentage Reduction</th>
<th>Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Packaging Glass, 325ml</td>
<td>220g</td>
<td>120g</td>
<td>45%</td>
<td>1988</td>
</tr>
<tr>
<td>Spirit Bottle Rectangular, 70cl</td>
<td>600g</td>
<td>350g</td>
<td>42%</td>
<td>1991</td>
</tr>
<tr>
<td>Mulled-Wine Bottle, 1l</td>
<td>650g</td>
<td>380g</td>
<td>42%</td>
<td>1997</td>
</tr>
</tbody>
</table>

It was indicated that the lightweight process requires a long parison reheating time which means that a lightweight process on the IS machine must be seen as a compromise, because the necessary function times are not optimal for one blank mould serving one blow mould. For this reason the so named H1-2 process was developed alongside the development of NNPB on existing IS-machines. This lead to the development of a new production machine, the Heye 1-2 machine. In this case the developed function times for a lightweight process were chosen as a basis for the new type of machine.

Significant advances were also claimed to have been made through the development of an advanced process control system. This incorporated a sensor coil into the blank mould plunger mechanism allowing the position of the plunger to be measured, giving an indication of mould fill level. The information obtained was used to maintain a constant gob weight and blank mould fill through feedback to the gob weight control system. It is understood that this technology is commonly used in the NNPB process.

Figure 10 shows a strategy provided by Heye-Glass for reducing glass thickness through a combination of improvements in the forming technology, coatings and glass strengthening technologies previously described.

This figure suggests that through a combination of technologies, container wall thicknesses considerably thinner than those currently seen in market might be realisable.
Figure 10 Predicted reduction in glass container thickness possible through combined technologies.

4.3.2 Bottero (Italy)

As a global supplier of specialised glass manufacturing equipment, BOTTERO S.P.A. (Cuneo, Italy) believes itself to be well positioned to deliver new and customised equipment; activities including machine design, control systems and final testing are carried out in house.

The Company Director Nino Boglione indicated that Bottero has being working on improvements in machine control that have the potential to produce consistently thinner bottles. He pointed to one specific technology, ‘Forming Pack’, that they have developed and are working to advance:

“What we have done is develop an electronic control for the compressed air, specifically for the glass makers. This product allows the forming specialist to have the right pressure at the right time during the forming process. A glass container must be as light as possible but strong enough to resist the internal pressure as well as the handling from the glassworks, to the filling line, to the supermarket shelf and finally to the shopping bag of the final user. In order to be strong enough the container must have a minimum wall thickness. In most cases this wall thickness will be higher than necessary in certain areas in order for it to be within the limits where the glass tends to be less. Improving the uniformity of the distribution allows glass weight reduction, and that is what the Forming Pack helps doing. Another source of breakage is the presence of marked seems where the different parts of the moulding components join together, and that is another improvement offered by the Forming Pack.”

Nino Boglione, Company Director
The Forming Pack system developed at Bottero (figure 11) provides more precise control of the air pressure used in blowing. It is claimed that fine modulation of pressures during the forming cycle allows:

- improvement in Glass Distribution through a strong reduction of the ‘settle wave’\(^\text{14}\), better glass distribution on difficult shoulders / thick bottoms and constant diameter on long necks; and,
- reduction of product defects including an important reduction in seams due to mould equipment junctions, reduction of neck checks (defects around the bottle closure), and improved quality of surface embossing.

By allowing a greater consistency of glass thickness and reduced glass defects through this technology it may be possible to produce thinner stronger bottles.

As well as providing better control of the blowing process Bottero claims that this technology can be used to optimise the control of IS machines and related operations which are pneumatically actuated, to quote, “converting a simple pneumatic mechanism into a servo proportional driven mechanism, where an improved control of the movement can be achieved through a better consistency of performances and a high flexibility in pressure management. Multi-step movements and optimised motion profiles are now easily accessible results at affordable costs through the new Bottero Proportional Valve Block.”

With significant growth of container manufacturing in developing countries, such “retro-fit” technologies may have the potential to significantly impact on the weight of bottles produced in an ever expanding global market. In an article Glass International\(^\text{15}\) Liu Jian Ping from the China National Association of the Glass Industry (CNAGI) said that “CNAGI members are very interested in lightweight, so they can use the same amount of raw material to make more (product) but we need foreign partners to help us produce them.” Despite the ever growing demands Ping stated doubts that any new plants will be built. He explains: “to establish a new glass container plant here (one) needs a permit from Government, and to get the permit the plant must be energy-efficient to meet very tight emissions limits.” Because of pressure to use existing plants, there is a great demand for technologies which can be used to upgrade existing equipment.

4.3.3 Quantum Engineered Products, Inc (Pennsylvania, USA)

Quantum Engineered Products (QEP) is a US company specialising in glass container forming technology.

QEP indicated that their new TFA System (Total Forming Analysis) is to be launched in October 2008 at the Glasstec conference and exhibition. This is a system for providing real time control of Narrow Neck Press and

\(^{14}\) The ‘settle wave’ is an undesirable thickening of the glass distribution approximately half way down the bottle side wall, and is particularly prevalent in the blow-blow process.

\(^{15}\) Glass International (June 2007) Liu Jian Ping
Blow (NNPB) IS Machines, involving feedback from a large number of machine sensors. Such technology may support enhanced process control necessary for further lightweighting.

Additionally a technology which has been available for some years, Quantum’s ABB/A Process (Advanced Blow & Blow with AFCON®), can potentially produce stronger bottles by minimising defects related to plunger contact and mould debris, by use of an enhanced blow-blow process. The technology, which came to market after NNPB, uses vacuum assistance of standard blow-blow forming to give enhanced mould loading, enabled by the system’s ‘AFCON’ Air Flow Controller.

It was suggested that on its own the technology cannot be used to produce lightweight containers. However, when used along with other improved control systems and design optimisation, significant advancements in lightweighting could be possible. Examples are cited where a 24% reduction in container weight over conventional blow-blow technology was achieved\(^\text{16}\). Quantum has recently received a contract with a major glass manufacturer to install over 100 new lines using this process. However, this is within markets where lightweighting is not a primary concern and so far adoption has been related to advantages such as increased strength and reduction of defects.

A company representative indicated that their system engineering is comparatively minimal compared to other systems for making lightweight containers in NNPB, with only the AFCONs, actuating valves, and vacuum manifold representing added costs items. It was indicated that uptake of the technology over NNPB and conventional BB processes was currently quite limited.

4.3.4 Emhart (Switzerland/USA)

Emhart Glass is a major international supplier of equipment, controls and parts to glass container industry. The company works in the fields of glass container forming, glass conditioning, gob forming, ware handling, cold end inspection and refractories. The company's machines and systems are prevalent in the global container industry.

Stephen Pinkerton (VP Research & Development, USA) provided a statement on their activities:

"Emhart Glass is working to develop new processes and products aimed toward automation and increased container strength. Products that allow for higher production speeds and reduced defects will be introduced over the coming years facilitating further automation in the glass container industry. In addition, investments in process development will yield both stronger and lighter containers within the next five years."

Steven Pinkerton, Vice President RD&E of Emhart Glass

Current publicity would appear to indicate a move to simplify manufacture, with processes being “toughened” to allow use of potentially less skilled workforces whilst still producing a consistent high quality product with high line efficiencies. Publicity states “now that the technology has moved forward many things are possible”..., “in years to come the NIS will be self-controlled and will be able to react to situations during production”. In this context Emhart’s new SIS (Standard IS Machine) line package integrates the functionality of the feeder, gob distributor, IS machine, flex pusher and ware transfer into a single unit. Adaptability of this new “all-in-one” unit may be more limited. For this reason there may be less potential to optimise or improve production to allow thinner and lighter glass containers to be produced.

Recent developments focussed on technology to improve consistency in the forming process which is the prerequisite for further lightweighting. Products currently available or planned for commercial release in the near future include:

- Advanced cooling systems such as Vertiflow®, InVertiflow® on blank side Vertiflow® and auxiliary cooling on mold side.
- Individual cavity control of cooling.
- Automatic temperature measurement of individual mold cavity and plungers.
- Closed loop plunger process with full stroke sensors linked to proportional valves for plunger cooling and plunger motion.
- Parallel mold open close to minimize variation in temperature profiles of the glass.

\(^\text{16} 'Solving Problems', Glass International, May/June 2003\)
Servo controlled mechanisms to improve motion, alignment and mold life. Reduction in wear and damage to the molds increasing productivity on lightweight containers.

Following a recent multimillion Euro investment Emhart have a research centre which has its own 40 tons per day furnace complete with production line to enable research into new technologies which include lightweighting. Current projects supporting lightweighting are focused on:

- Fully automatic gob formation and delivery systems.
- Closed loop temperature optimization and control for the whole forming process.
- Advanced modelling technologies to model container shapes and forming times to minimise weight.

Research work is already well developed in this important area and lightweighting of existing containers by as much as 30-40% is thought to be technically feasible.

4.3.5 Sheppee International (UK)

Sheppee International (UK) is a company with a specialism in the downstream handling of formed containers, including lehr loaders and cross conveyors, ware transfer units, drives and control systems.

In discussions with Sheppee International (UK), (SIUK), the issues of bottle inspection, and the downstream handling of lightweight bottles were raised.

With respect to the latter point, it was indicated that using funding from BERR, Sheppee is currently developing a new line-handling system to eliminate problems related to the handling of ultra-lightweight glass containers whilst allowing processing speeds up to 1,000 bottles per minute; it was indicated that lightweight containers are extremely susceptible to instability where ever their is a change in momentum or direction, with impacts on line efficiency and breakage rates.

In 2002 Sheppee International launched their HST transfer unit capable of transferring 500+ bottles per minute (bpm). HST is a flexible transfer unit claimed to exhibit significant container stability when transporting from (IS) machine conveyor to cross conveyor; a feature of this unit was the smooth deceleration and control from pick up at the machine conveyor to release on the cross conveyor. This transfer could smoothly reduce the container spacing from pick up at 4.5" and decelerate down to 2.8" without any sudden speed changes. An IS machine foreman at Allied Glass Containers Ltd. with direct experience of the HST system was contacted. He said that when installed it dramatically reduced incidence of breakages and ware falling and that in his opinion could likely help overcome problems which would be expected in the handling of light weight containers.

In recent years Sheppee International has noted the use of transfer systems for ultra light weight containers with speeds of 450 - 500bpm becoming the norm. In consequence the company has developed the new transfer unit, the VFT transfer, that has proved successful in cold trials, capable of running at speeds in excess of 1000bpm.
5.0 Conclusions

Through a comprehensive survey of literature and stakeholders in the glass manufacturing sector it has been possible to provide considerable insight into the status quo and future of technologies for the production and handling of lightweight containers. Findings are set in the context of commercial confidentiality and what is publically available.

Many of the technological possibilities focus around the subject of improved process control of current technologies, including furnace stabilisation, continuous mould lubrication, advanced gob conditioning, compressed air management and significant use of feedback and monitoring loops to allow fine and continuous optimisation of processes. It is evident that many of these technologies can be retrofitted in current glass factories, and one key manufacturer indicated they felt improvements of 10-15% over current best in class might be achieved in a relatively short timescale using this incremental approach.

A more radical change of forming process, which it is believed would further the production of lightweight containers, is ‘single stage forming’ wherein the press and blow processes are combined in a single mould, utilising the solidification properties of ‘short glass’.

A second area of activity which complements the production of thinner and lighter containers is the strengthening of glass through the use of surface treatments and coatings. Such approaches may allow lighter bottles to be produced than is possible within the current constraints of glass strength.

Complementing technologies for the production of lighter bottles, work is also taking place within the sector considering the development of ‘gentler’ bottle handling systems, suitable for light and ultralight glass containers.

The above technical possibilities for the production of lighter weight bottles must be set in the context of the market demand of such containers, and also the trend in manufacturing approach.

It became apparent through the course of the study that within certain markets some stakeholders feel that there is not sufficient market demand at the current time to justify significant investment in advancing this area of technology, and that developments are more likely to be along an incremental rather than radical path.

Compared to the UK, much of the rest of Europe continues to make considerably greater use of heavier returnable bottles. For this reason there is apparently not the same drive to produce lightweight single trip (use) containers.

In the US and the developing world the situation is different. The main manufacturing pressure is to reduce the cost of production, whilst maintaining quality. As such technology and research is focussed on these objectives and not lightweighting per-se.

Whilst lightweighting has the potential to provide cost savings through reduced raw material, energy and transport costs, in today’s global market there are increasing pressures to move glass manufacture to locations with lower labour and energy costs. Some of the technologies identified in this study were primarily developed to simplify forming or make the process more forgiving and less skill intensive. Such ‘toughened’ processes may prove less adaptable for the production of lightweight containers, although with further development this may be possible.

Currently the dominant pressure appears to be for increased production efficiencies and reduced costs. These would seem to drive current technological advances in several of today’s global markets, with lightweighting efforts where present being incremental in nature.

In the future, as waste reduction and environmental issues continue to gain prominence, along with a move to more carbon constrained economies, it is anticipated that there will be increased pressure to advance the production of light weight glass containers with greater uptake of new technologies.