

# Introduction to Container Glass Manufacturing

## (chapter 1 of 15)

### PROCESS OF CONTAINER GLASS MANUFACTURING (FIG. 1.1)

Container glass manufacturing process looks very simple, but in practice it is highly complicated. Good process control and good quality control from receiving raw materials to usage of bottles at customer end is very important as there are many variables in raw materials, process parameters and storage conditions which can impact bottles end performance. Hence, top class quality control in every stage is very important in container glass manufacturing. The investment cost, raw material cost, operation costs and plant output & quality are very important factors, which decides the profitability of the manufacturing facility. It is advisable to thoroughly study all the aspects before setting up glass business as there are many businesses that went into loss due to lack of understanding the market conditions and production requirements.

To set-up container glass industry, following factors/requirements, must be thoroughly reviewed and evaluated:

1. Availability of quality raw materials at nearby places
2. Customer locations
3. Availability of fuel / gas, electricity and water
4. Connectivity by air, sea and road
5. Availability of land
6. Availability of skilled manpower

7. Seismic conditions
8. Local / state / country policies

For example, to set up a 500 TPD container glass Industry, some requirements are:

**Approximate land required:** For factory and warehouses: 20 Acres (40% land reserved for greenery)

**Investment:** INR 750 Cr / USD 90 Million (approximate cost in South East Asia & Middle East and it can vary based on type of equipments, automation levels, glass type)

**Production building size required:** 12,000 Sq. mtr (each floor, 2 floors required)

**Batching plant size required:** 1200 Sq. mtr x 4 floors (25 mtr high)

**Gas / fuel per day:** Natural gas- 100,000 SCM / day

**Electricity:** 110KV / 132KV, 12 MW

**Water:** 300 KL/day

**Major raw materials required / day @ 30% cullet:** Cullet – 150 T (tons), silica sand- 240 T, soda ash –

80 T, lime stone – 50 T, dolomite – 20 T, feldspar-25 T

**Resources availability:** All major raw materials like cullet, silica sand or quartz, lime stone, dolomite and feldspar should be available preferably within 100 kms to have lower transportation cost. Basic RM cost in many cases is low but transport cost may lead to higher cost of RM when delivered to factory. Hence setting-up the Glass plant near main raw material source is advantageous. Fuel or natural gas should also be available at close distance.

**Customer Locations / Delivery:** For reducing transport cost, it is preferred to have 80% of customers within 500 kms or there should be a well-connected shipping arrangement.

**1.0 Container Glass manufacturing process:** Figure

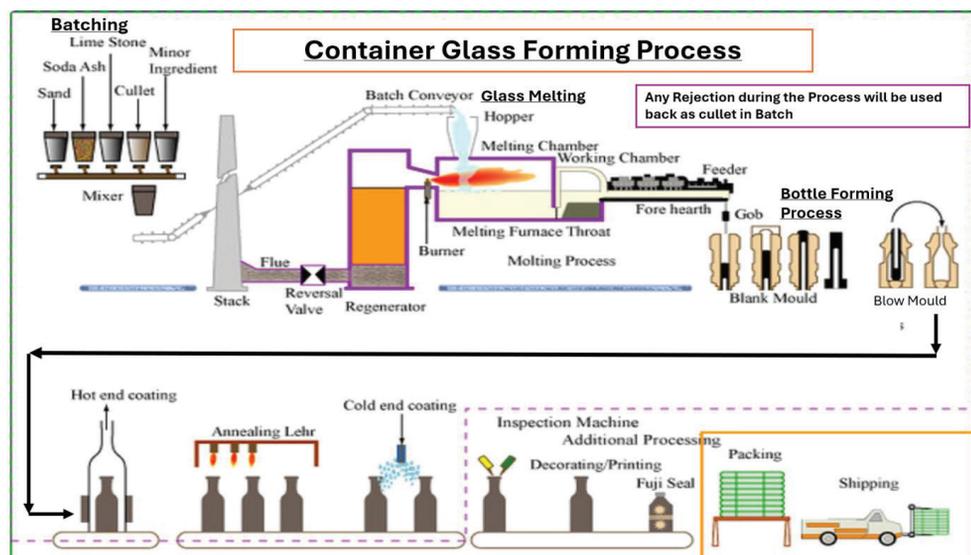
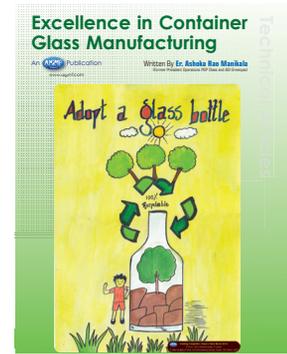


Figure 1.1

**Container Glass Process Flow Diagram**

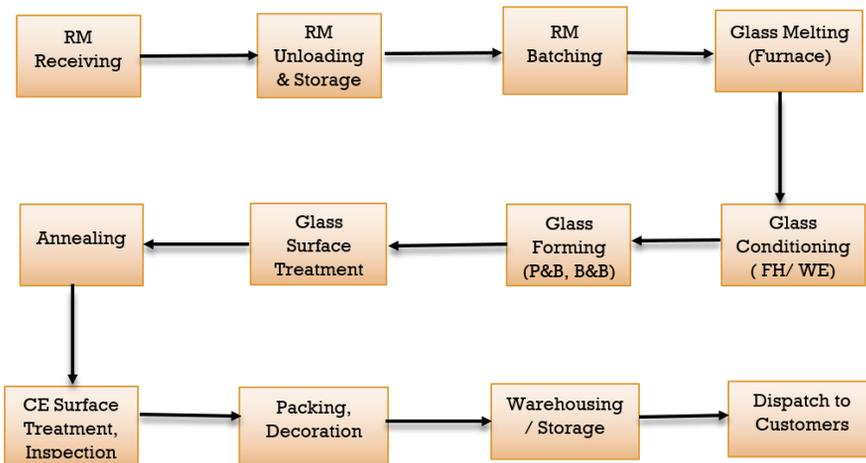


Figure 1.2

1.2 shows the process flow sheet of container glass manufacturing.

**1.1 Introduction to Glass:**

Before delving into container glass manufacturing, it is important to understand the general properties of glass, types of glass and its uses.

Glass is an amorphous (non-crystalline) solid. Because it is often transparent and chemically inert, glass has found widespread practical,

technological, and decorative use in window panes, tableware, containers and optics.

**1.1.1 Difference between crystalline and non-crystalline structures (Figure 1.3)**

**a. Arrangement**

Crystalline solids have a regular, repeating three-dimensional arrangement of their atoms, ions, or

molecules. Non-crystalline solids, also known as amorphous solids, have a random arrangement of their atoms.

**b. Physical properties**

Crystalline solids have well-defined edges and faces, and a sharp melting point. Non-crystalline solids have irregular or curved surfaces, and melt over a wide range of temperatures.

**c. Applications**

Crystalline solids are used in lasers, optics, high energy physics, biomedical technology, and light emitting diodes. Non-crystalline solids are used in glasses, amorphous semiconductors and metals, and sol-gel materials.

**d. Examples**

Quartz is a common example of crystalline silica, while glass, silicon carbide, and silicone are examples of non-crystalline silica. Non-crystalline candies, such as hard candies, caramels, toffees, and nougats, are chewy or hard. Crystalline candies, such as fondant and fudge, are smooth, creamy, and easily chewed.

**1.2 Glass classification:** Glass is classified into many types based on applications, market sectors, raw materials used and based on treatment applied on glass.

**1.2.1 Glass classification based on applications:** Refer below details.

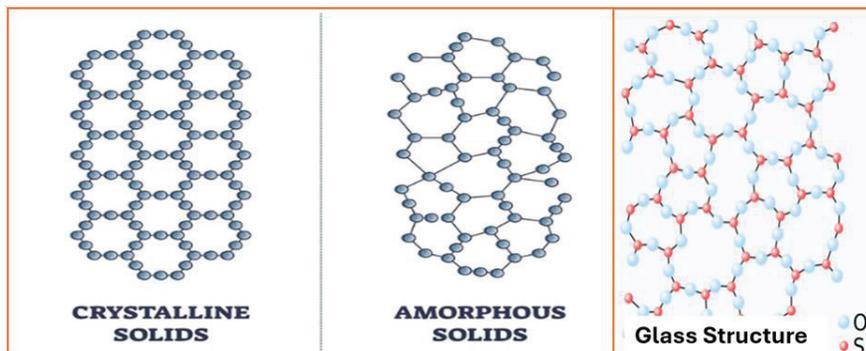


Figure 1.3

**Glass classification based on Applications**

Application	Description
Flat glass	Used for windows, doors, mirrors, and other architectural applications
Automotive glass	Used for windshields, side windows, and rear windows in vehicles
Display glass	Used for screens in televisions, computers and mobile devices
Container glass	Used for containers for food, beverages and pharmaceuticals
Fibre glass	Used for insulation, reinforcement and composite materials
Solar glass	Used for photovoltaic panels to generate electricity from sunlight
Optical glass	Used for lenses, prisms and other optical components in scientific and industrial applications
Safety glass	Used for applications where safety is a concern, such as tempered glass for shower doors or laminated glass for windshields
Decorative glass	Used for artistic and decorative purpose, such as stained glass windows or glass art installations
Medical glass	Used for laboratory equipment, medical devices and implants

### 1.2.2 Glass classification based on market sectors:

Glass Type	Description
Flat glass	Used in buildings (windows and facades) and automotive industries (windcreens, side and rear-side glazing, backlights and sunroofs). Flat glass is also used in solar-energy applications (photovoltaic and solar thermal panels) as well as in urban and domestic furniture, appliances, mirrors and greenhouses; almost all flat glass is made by means of the float process.
Container glass	Used in food, liquor, soft drinks packaging, pharmaceutical applications, cosmetics and perfumery containers (flacons).
Continuous filament glass	Light weight components for flights, automotives, wind turbines, fans etc., for many industrial uses and as insulation material, fiber glass material etc.
Domestic glass	Used for tableware, cookware and decorative items such as drinking glasses bowls, plates, vases and ornaments.
Special glass	Lighting glass, glass tubes, laboratory glassware, glass ceramics, heat-resistant glass, optical and ophthalmic glass, extra thin glass for the electronic industry such as liquid crystal display (LCD) panels, photovoltaic and radiation protection glasses.

### 1.2.3 Glass Types based on

**raw materials used:** Based on raw materials used, glass is usually classified into three main classes:

#### Soda lime glass

- It is obtained from the fusion of a mixture of silica, lime, soda and alumina.
- Soda lime glass cullet too may be used.
- This glass is also termed as Soda-lime- silica glass.
- It is used for glazing doors, windows and making ordinary glass wares.

#### Lead Glass

- It is obtained from the fusion of a mixture of silica, lead and potash.
- Powdered glass / cullet, too may be added.
- This glass is also termed as Lead crystal glass.
- Lead glass has highly shining appearance.
- It is not affected by temperature.
- Cut glass work, electric bulbs and optical glass are made from it.

#### Borosilicate glass (Type I Glass)

- It is obtained from the fusion of a mixture of silica, borax, lime, and

feldspar.

- Borosilicate glass cullet too may be added.
- This glass withstands high temperature.
- Laboratory equipment and kitchen utensils are made out of it.

**1.2.4 Glass types based on treatments** Certain treatments make glass suitable for various applications. The types of glass based on certain treatments are:

- 1. Normal annealed glass:** Most glasses are normal annealed glass and they break with impact. Normal sheet glasses, container glasses are annealed after forming.
- 2. Tempered glass:** Tempered glass is a type of glass that is heated to a high temperature and then rapidly cooled. The process makes the glass stronger than regular glass and resistant to impact. Tempered glass is used in car windows, shower doors, and other applications where safety is paramount.
- 3. Laminated glass:** Laminated glass is made by sandwiching a layer of polyvinyl butyral (PVB) between two or more layers

of glass. The PVB layer acts as an adhesive and helps to hold the glass together in case of breakage. Laminated glass is used in car windshields, skylights, and other applications where safety is critical. Bulletproof glass is also made from laminated glass of many layers.

- 4. Insulated glass:** Insulated glass is made by sandwiching two or more panes of glass with a spacer between them. The spacer creates a gap between the glass panes, which is filled with air or gas. The insulating effect of the spacer reduces heat loss, making insulated glass an energy-efficient option. Insulated glass is used in windows and doors in homes and buildings.
- 5. Low-E glass:** Low-E (low emissivity) glass is a type of glass that has a thin metallic coating on one side. The coating helps to reflect heat and light, making it an energy-efficient option. Low-E glass is used in windows and doors in homes and buildings.
- 6. Mirrored glass:** Mirrored glass is made by coating one side of the glass with a reflective material such as aluminium. Mirrored glass is used in mirrors, decorative items, and security applications.

7. **Tinted glass:** Tinted glass is made by adding a color to the glass during the manufacturing process. Tinted glass is used in windows, doors, and other applications to reduce glare and heat gain.

8. **Wired glass:** Wired glass is a type of glass that has a wire mesh embedded in it. The wire mesh helps to hold the glass together in case of breakage, making it a popular option for fire-rated doors and windows. Wired glass is also used in skylights, greenhouses, and other applications where safety is critical.

9. **Type II glass:** This is the container glass type treated internally to increase chemical resistance of glass.

### 1.3 Glass uses

The glass is one of the early discoveries of man. It was made out of molten sand, and since then, it has become indispensable. There are no alternatives to it in some cases. Its applications to man include:

1. **Containers / Bottles:** Glass bottles are used for filling various products like jam, beer, liquor, beverages, chemicals, pharmaceuticals etc.



2. **Kitchenware:** Glass is used in kitchen as containers, plates, in microwaves and tumblers.



3. **Building materials:** Sheet glass is used in buildings, structures, bridges.



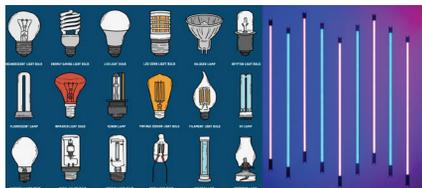
4. **Eyeglasses and lenses:** Glass is used in manufacturing eye lenses, camera lenses, microscopes and binoculars.



5. **Electronic screens, TVs:** Glass used in LCDs, LCD screens for display, laptops, computers.



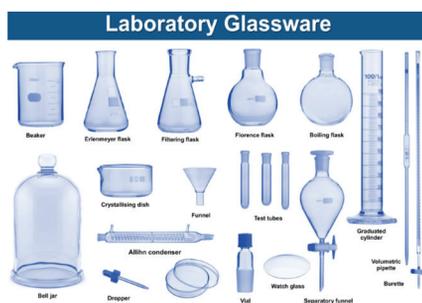
6. **Lights and bulbs:** Glass is used for making bulbs, tube lights.



7. **Automobiles, aeroplanes:** Glass is used in wind shields of vehicles, window glasses and also in aeroplanes.



8. **Laboratory appliances:** Glass made from borosilicate glass is



used for laboratory appliances like beakers, burettes, pipettes and funnels etc.

9. **Reinforced fibreglass material:** Glass is used as fibre glass to make many components like boat bodies, ship parts, wind power turbine blades & components, aeroplane bodies.



10. **Solar panels:** Glass is used widely in solar panels and market demand for solar panels is increasing now a days.



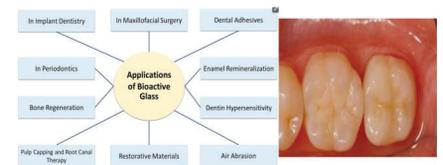
11. **Insulation material:** Insulating material uses fiber glass and it finds wide applications in building constructions, industrial pipes and vessels insulation.



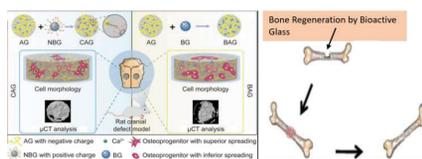
12. **Communication optic cables:** Fibre optic cables use glass core and glass cladding.



13. **Medical & dental applications:** Bio-active glass is used in dental applications, medical applications



for bone and other parts for regeneration.



Glass finds its use in many areas and its demand is increasing. In this book we will discuss mainly about container glass manufacturing process.

**1.4 Types of container glass:** Again, the container glass can be classified based on raw materials used, glass specification, sectors for which glass is used and glass colours.

**1.4.1 There are basically 3 types of glass used for container glass manufacturing, based on raw materials**

They are:

1. Soda-lime-silica glass
2. Borosilicate glass
3. Lead glass

**Soda-lime-silica glass:** Soda lime silica glass is the most common glass used for making container glass, sheet / flat glass, bulbs & tubing with slight changes in composition for each of them. Approximately more than 90% of glass produced are soda- lime-silica glass.

**Borosilicate glass:** This is known as Type I glass. It is mainly used for pharmaceutical applications (vials), laboratory purposes where high temperature and high resistance to chemical attack is required.

**Lead glass:** This glass is typically used for table ware or lead crystal glass, produced using traditional hand working methods. The composition provides wide working range and gives sparkling appearance to the finished product.

**1.4.2 Container glass Types based on specification / surface properties**

Container glass means all type of glass bottles and jars used for beverages e.g. juices, soft drinks, carbonated drinks, pharmaceutical, cosmetics, perfumes and foods. Glass containers are mostly intended to come into direct contact with the inside content. Therefore, they must comply with their respective specifications for identity and surface hydrolytic resistance. Container glass is generally classified as Type I, II and III glass.

In addition to the above glass Types, there is also Type 4 Glass which contains higher alkali content & has lower hydrolytic resistance. Other notable categories include lead crystal and special alumino silicate glasses. Special aluminosilicate glass is emerging as very high-performance pharmaceutical glass.

Glass used for container glass is either soda- lime-silica glass or borosilicate glass (neutral). Soda-lime-silica glass has a moderate hydrolytic resistance due to the chemical composition of the glass itself; it is classified as Type III. Suitable treatment of the inner surface of Type III soda-lime-silica glass containers will raise the hydrolytic resistance from moderate to a high level, changing the classification of the glass to Type II. Borosilicate glass contains significant amounts of boric oxide, aluminium oxide, alkali and/or alkali earth oxides. Borosilicate glass has a high hydrolytic resistance and high thermal shock resistance due to chemical composition of the glass itself; it is classified as Type I. Now let us study in details, each type of container Glass and their applications.

### 1. Type I Glass

Type I borosilicate glass is the gold standard in pharmaceutical packaging, primarily due to its exceptional material properties. Characterized by its low thermal expansion co-efficient, this glass type exhibits remarkable stability under temperature fluctuations. This

stability is crucial in environments where drugs are exposed to varying temperatures, ensuring that the integrity of the glass remains intact. Also, its high resistance to chemical attack, makes it an ideal candidate for storing a wide array of pharmaceutical products. Whether the contents are acidic, neutral, or slightly basic, Type I borosilicate glass ensures minimal interaction, preserving the purity and efficacy of the medication. Its use in vials, ampoules, and containers for injectable drugs is widespread, as these applications demand the highest level of chemical inertness to prevent any potential drug-container interactions. The ability of Type I borosilicate glass to maintain the chemical composition of medications unaltered is invaluable for pharmaceutical companies.

### 2. Type II Glass

Type II glass offers an excellent balance of affordability and safety. As a treated form of soda-lime glass, it undergoes a surface treatment process known as de-alkalization. This process significantly reduces the glass's alkali content on inside surface of the glass, enhancing its chemical resistance compared to untreated soda-lime glass. Although it doesn't reach the heights of chemical resistance seen in Type I glass, Type II glass still offers sufficient protection for less sensitive pharmaceutical preparations. It is an excellent choice for oral medication bottles and containers where the risk of chemical interaction is moderate. The cost-effectiveness of Type II glass also makes it a popular option, particularly in scenarios where the stringent requirements for Type I glass are not necessary. This Type of glass is often used in situations where budget considerations are as crucial as the packaging's protective properties, providing a practical solution for a wide array of pharmaceutical applications. Type II glass is also used

for packing of high-end beverages, liquors, chemicals and water bottles. The process of making Type II glass is explained in detail in separate chapter.

### 3. Type III Glass

Type III regular soda-lime glass is a widely utilized material in the pharmaceutical industry, particularly for non-critical applications. While less resistant to chemical attacks than Type I or II glasses, its composition is perfectly suited for packaging products where strong chemical resistance is not a primary concern. This makes it an ideal choice for non-aqueous products like tablets, capsules, and powders. The affordability of Type III glass is one of its most appealing attributes, offering a cost-effective solution for large-scale packaging needs. Its application is most common in products where the interaction between the medication and its container is less likely to compromise the medication's effectiveness.

### 4. Type IV Glass

Type IV glass is a category of general-purpose soda-lime glass used in the pharmaceutical industry. This Type of glass is not as chemically resistant as Types I or II, and it's typically used for packaging products where the contents do not directly interact with the glass or are not highly sensitive to the container material.

The primary advantage of Type IV glass is its flexibility and cost-effectiveness, making it suitable for a wide range of non-parenteral products such as oral liquids, topical creams, and ointments. While Type IV glass does not offer the same level of protection against leaching as borosilicate or treated soda-lime glasses, it is still a viable option for many pharmaceutical applications. Its use is generally preferred in scenarios where the risk of chemical interaction is minimal, and the primary requirement is a practical, economical packaging solution.

Because of its versatility, Type IV glass is the leading choice for less critical pharmaceutical packaging needs.

### 5. Aluminosilicate Glass

Aluminosilicate glass is emerging as a high-performance contender in pharmaceutical packaging. Characterised by its exceptional strength and durability, this Type of glass is particularly suited for medications that demand an extra layer of protection. Its robust nature makes it an ideal choice for prefilled syringes, cartridges, and other containers where the risk of breakage must be minimized. The increasing demand for more resilient packaging solutions in the pharmaceutical industry has put aluminosilicate glass in the spotlight, signalling a shift towards materials that can provide enhanced security for high-potency drugs.

#### 1.4.3 Container glass classification based on segments

- 1. Perfumery bottles:** These bottles are generally Type III bottles but with high clarity & good surface finish. These bottles are decorated by coating & printing.
- 2. Pharmaceutical:** These bottles can be from any Type of soda lime, borax and aluminosilicate glass depending upon the inside glass surface alkali resistance requirement for the particular pharmaceutical products to be filled.
- 3. Liquor:** Generally, Type III bottles are used however in certain cases where the taste and properties are main concerns, Type I and Type II glass bottles are also used.
- 4. Carbonated drinks:** Carbonated drinks are generally Type III bottles.
- 5. Food:** Type III Glass is used in

majority cases for food packaging but for certain application, speciality or Type II glass is also used.

- 6. Chemical:** As the bottles are used for laboratory chemicals packaging, any small deviation in quality can be a concern. Hence Type II glass is generally used.
- 7. Specialty bottles:** These are for special applications like perfume, liquor, food and water filling where high quality of glass surface and glass clarity is required. Bottles are generally Type III flint glass having low iron content in glass. In special cases, Type II treatment is applied to bottles.
- 8. Water bottles:** Type III soda lime glass is generally used but for alkaline water or high-quality water, Type II treated glass is used.

#### 1.4.4 Container glass classification based on glass colour:

The bottles are classified into five categories. In this category, flint or super flint, amber and green (including light green and champagne green) can be made directly from furnace and others are by adding coloured glass frits into glass in forehearth or by coating the colours on flint bottles in decoration plants.

- 1. Flint and super flint:** In market, 60% of bottles are flint or super flint bottles. They are generally used in all market segments.
- 2. Amber:** Its main use is in pharmaceutical and beer filling but in few cases it used for liquor, food and perfume filling.
- 3. Green:** Used for carbonated drinks, liquor and wine segments.
- 4. Coloured bottles:** Used for high end filling requirements for liquor, water, perfume and wine filling.

**5. Coated bottles:** Mainly used for filling perfumes and high-end liquor, water bottles.

### 1.5 Embracing the future of container glass

The glass industries are striving to develop various glass types to meet the packaging requirements for many applications. From the highly resistant Type I glass to the economical Type IV glass, each type serves a specific purpose, ensuring that products are stored and delivered in the safest and most effective manner possible. The evolution of glass technology for packaging requirements continues, promising even more advanced and secure solutions in the future.

### 1.6 Glass raw materials and oxides

Over 90% of container glass produced are from soda-lime-silica glass. So, in this book, we will study about soda-lime-silica glass. We will look at general composition of borosilicate Type I glass and lead glass.

#### 1.6.1 Major raw materials used in container glass manufacturing are:

**a. Pure silica ( $\text{SiO}_2$ , fused quartz)** represents 70-74% weight of modern glass. In ancient times, glassworkers prepared recipes with more than 90% of pure silica, but because this substance

has a melting point of about 2000 degrees centigrade ( $3600^\circ\text{F}$ ) chemist found a way to lower that temperature by introducing various additives into the mix, most notably sodium carbonate. One of the most interesting features of pure silica glass is its ability to block UV radiation, which modern 70-72% silica glass can't do.

- b. Sodium carbonate ( $\text{Na}_2\text{CO}_3$ ) (soda ash)** represents important ingredient of modern glass that adds both positive and negative features. It successfully lowers the melting point of silica to more manageable  $1200^\circ\text{C}$  but it also makes the glass water soluble.
- c.** To prevent glass from being water soluble and to increase its chemical structure, **lime (calcium oxide,  $\text{CaO}$ ), magnesium oxide ( $\text{MgO}$ ) and aluminum oxide ( $\text{Al}_2\text{O}_3$ )** are added. Glass enriched with lime represents over 90% of the glass that is used today.
- d.** Addition of **lead oxide, barium and lanthanum oxide** can increase glass refractive index, making it more reflecting and suitable for optical purposes (eyeglasses and lenses). **Thorium oxide** served a similar role in the past, but it was phased out from manufacture because of its radioactivity.

- e. Sodium sulphate, sodium chloride, or antimony oxide** can be added to prevent the creation of air bubbles in the glass mixture. These are for refining the glass during melting.
- f.** Cerium (IV) oxide is responsible for absorbing UV radiation.
- g.** Boron oxide (Borax) is one of the main ingredients in so called Pyrex glass. Its ability to strengthen the structure of glass and protect it from thermal expansion, cracking and thermal shock makes it perfect for production of many kitchen cookware, optical component, Type I vials bottles and reagent bottles.

### 1.6.2 Glass oxides and their properties (Fig. 1.4)

#### 1.6.3 Oxides are classified into following categories:

- **Network forming oxides** –  $\text{SiO}_2$ ,  $\text{B}_2\text{O}_3$ ,  $\text{P}_2\text{O}_5$ ,  $\text{GeO}_2$  – Non-oxide components: fluorides, halides, chalcogenides ( $\text{As}_2\text{S}_3$ ,  $\text{GeS}_2$ )
- **Network modifying oxides** –  $\text{Na}_2\text{O}$ ,  $\text{K}_2\text{O}$ ,  $\text{Li}_2\text{O}$ ,  $\text{CaO}$ ,  $\text{BaO}$ ,  $\text{MgO}$ ,  $\text{SrO}$
- **Intermediate oxides** –  $\text{Al}_2\text{O}_3$ ,  $\text{PbO}$ ,  $\text{ZnO}$ ,  $\text{ZrO}_2$
- **Fining agents/redox active components – sulphates:**  $\text{Na}_2\text{SO}_4$ ,  $\text{CaSO}_4$  – Oxides:  $\text{As}_2\text{O}_3$ ,  $\text{Sb}_2\text{O}_3$ ,  $\text{CeO}_2$  – Chlorides:  $\text{NaCl}$  – Nitrates:  $\text{KNO}_3$ ,  $\text{NaNO}_3$  – Carbon
- **Fluxing agents** –  $\text{CaF}_2$ , spodumene (lithium raw material), blast furnace slags/calamite
- **Colouring agents** –  $\text{Fe}_2\text{O}_3$ ,  $\text{Cr}_2\text{O}_3$ ,  $\text{CoO}$ ,  $\text{Mn}_2\text{O}_3$ ,  $\text{Se}$ ,  $\text{Fe}_3^+$ / $\text{S}_2^-$ , rare earth oxides, sulfides, selenides

The glass is not a single compound. It

Major raw materials and % of oxides in them			Oxides in glass	
Raw material	Oxides	(%)	Oxides range min (%)	Oxides range max (%)
Quartz sand (Silica)	$\text{SiO}_2$	Min 98	71	73
Soda ash	$\text{Na}_2\text{O}$	Min 53	12	14.5
Lime stone	$\text{CaO}$	Min 50	9.25	10.75
Dolomite	$\text{MgO}$	Min 18	0.9	2.50
Feldspars	$\text{SiO}_2$	Min 65	1.20	1.90
(Silica+ Alumina+ Potash)	$\text{Al}_2\text{O}_3$	Min 15	0.00	1.50
	$\text{K}_2\text{O}$	Min 50		

Pictorial Representation of Function of Oxides in Glass

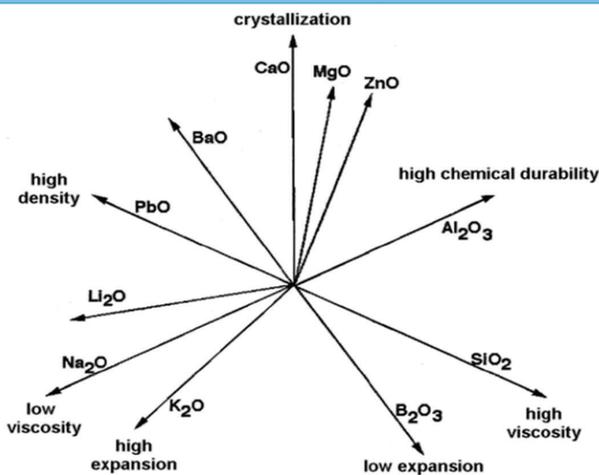


Figure 1.4

is therefore very difficult to give any particular chemical formula for it. But with reasonable accuracy, it may generally be expressed as follows –  $aX_2O.bYO.6SiO_2$

Where, a and b are numbers of molecules,

X = an atom of an alkali metal such as Na, K, etc.

Y = an atom of a bivalent metal such as Ca, Pb, etc.

### 1.7 History of Container Glass Manufacturing

Glass is one of the oldest materials dating back to 3500 BC. Egyptians manufactured the first hollow glass container in 1500 BC, and the invention of the blowpipe in the first century BC was considered a technological revolution. The true revolution, however, was the automatic bottle blowing machine invented in the USA by Michael Joseph Owens at the beginning of the 20<sup>th</sup> century. Owens was a mechanical genius who began to work on various inventions that would earn him 49 patents. His efforts eliminated child labor in the glass industry. The most important invention was the automatic bottle blowing machine (Fig. 1.5), consisting of 9000 separate

parts and developed from 1895-1904. He also later helped produce continuous flat sheet glass. His name has been associated with multiple companies, including Libbey-Owens-Ford, Owens-Illinois and Owens Corning. Its ability to manufacture 30,000 containers per day, made glass container production possible

on an industrial scale. His machines could produce glass bottles at a rate of 240 per minute, and reduce labor costs by 80%.

The technology continued to be improved over time, and in 1924, the first Individual Section (IS) machine was developed by Hartford-Empire company (Now Bucher Emhart) enabling each section to produce one or more containers independently. This IS machine was developed by glass-making pioneer Henry W. Ingle of Hartford-Empire company and emerged as a game-changer. Unlike its predecessors, this machine featured a stationary working table, with molds performing automatic opening and closing actions.

By 1930, advancements such as changing the plunger to a blow head resulted in the Press-and-Blow method for manufacturing large-mouth bottles. In the 1960s, German glassworks like HEYE Glass further refined the process. It evolved to

support single, double, and triple gob delivery, with the IS machine adopting both Blow-and-Blow (B&B) (for small-necked bottles) and Press-and-Blow (P&B) (for large-necked bottles) methods. The IS style machines used ‘blow and blow’ or ‘press and blow’ techniques that are still applied today. Using these processes, a specific amount of melted glass or a ‘gob’— falls in a blank mold where it is either blown or pressed with a plunger in first stage and then it is (Parison) is deposited into a finish mold where blowing is completed. Over the time, subsequent innovations led to the creation of variations like the Automatic Milk Bottle Machine, Automatic Press-and-Blow Machine, Lynch Bottle Machine, and Roirant Bottle Machine. These machines shared a common feature - the mould rotation with the working table.

Nowadays, forming machines can have single machines up to 12 individual sections or 24 section tandem machine (12x2, tandem machine) each producing one to six containers simultaneously. This means that one to six gobs of melted glass fall in one to six moulds present in each section, which occur in parallel in each section. Depending on the container’s size and shape, the production speed can be as fast as 800 containers per minute.

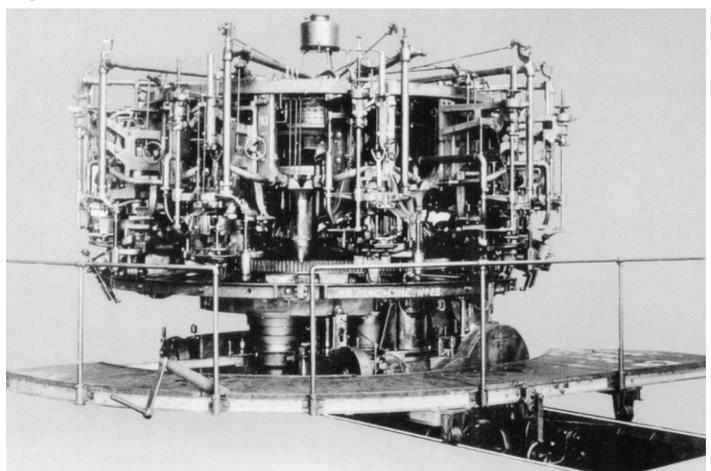


Figure 1.5

### 1.7.1 Figure 1.6 shows the IS machine of 1925 and present

**1.8 Container glass manufacturing:** Glass Manufacturing involves inspection of RMs, storage & batching, melting & conditioning, forming, annealing and inspection.

Once the RMs are tested and accepted, they are stored in batch house silos. Then, as per the recipe, the batch is prepared and fed to melting furnace continuously where the batch is melted at around 1560°C. The molten glass is then refined and conditioned. The conditioned glass in the form of gob is fed to IS Machine where it is formed into bottle by B&B or P&B process. The formed bottle is then passed into an annealing lehr for removing internal stresses. Before the bottle enters the annealing lehr, if required hot end coating, internal Type II treatments are applied. After the annealing bottle is passed through cold end coating process if required. Then the bottle is passed for inspection and packing. If required, the packed bottle is subjected to decoration as per customer requirement or as it is, it is sent to customers.

### 1.9 Glass forming techniques

Container glass is formed in two stages namely blank side (stage 1) and blow side (stage 2). Bottles are two Types- narrow neck bottles and jars. Generally narrow neck bottles, having neck bore up to 28mm are produced using B&B process and bigger mouth diameter bottles (jars) are formed by P&B process (Fig. 1.7).

P&B bottles will have more uniform thickness compared to B&B process as pressing in first stage make the parison (1<sup>st</sup> stage bottle) wall thickness more uniform compared to blowing in B&B process. There is a latest process known as NNPB (Narrow Neck

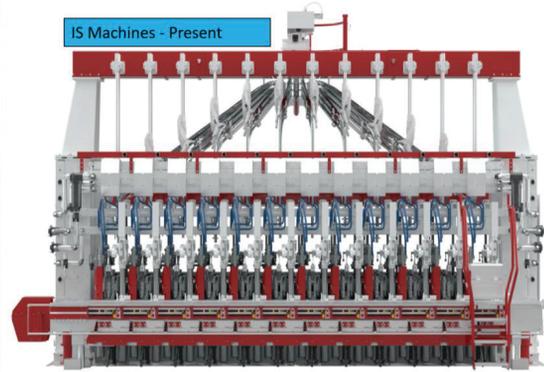


Figure 1.6

Press & Blow), where in 1<sup>st</sup> stage the narrow neck bottles are pressed and then blown in 2<sup>nd</sup> stage (Fig. 1.8).

There are many advantages of NNPB process, which is explained in container glass forming chapter.

Container glass like tumblers and table wares are produced by manual or auto press machine (Fig. 1.9).

**1.10 Challenges in container glass industry:** Challenges can be classified into two categories, internal and external. Both the challenges need to be addressed quickly & reviewed regularly as these challenges can make the organisation to fail or succeed.

**Internal challenges:** There are five main internal organizational challenges

**a. Skill & manpower:** Container glass making needs lot of skill along with common sense. There are many unknown variables in process which can impact the glass & bottle quality. If the process owners are not able to closely monitor the parameters & quickly act in case of variations, the impact of this on production may continue for few hours to some days. As furnace is heart of glass manufacturing, what is getting inside it, how it is operating and what is coming out of furnace has direct bearing on container glass quality. Similarly, each forming

machine engineers and operators should very well know the skills to form defective free bottles. Many container glass industry suffer because of non-availability of skilled manpower for furnace & IS machine operations. Equally the instrumentation team and IS maintenance team should possess good skills to perform perfect job changes quickly and attend to breakdowns immediately with proper solution.

**b. Machines:** As the glass furnace expected life is around 12 to 14 years now a days, all the machines should operate to the best optimum levels. Proper selection of machines, planning of stand-by equipments, good layout, good maintenance practices will help the machines & equipments to perform to the desired levels continuously and give best performance. As the glass manufacturing equipments are expensive and sensitive to operation, good knowledge of selection of equipments, identification of services (inspection, training, online support, online condition monitoring) and proper installation etc., are very important.

**c. Material:** Glass industry uses many materials like raw materials, refractories, moulds, packing

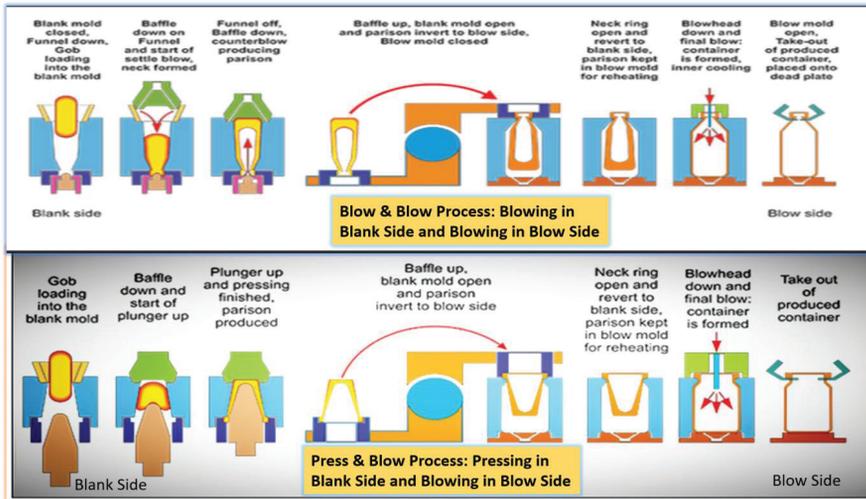


Figure 1.7

material, lubricants, fuels etc. and the availability, cost & quality should be closely monitored. The sum of batch cost, energy cost, packing cost and mould cost will be approximately 70% of the total manufacturing cost, hence good monitoring is very essential. Regular reviews of cost, availability, alternatives and consumption should be performed, to avoid any surprises. Good budget preparation and monitoring system will definitely help to control the challenges.

- d. Methods:** Due to existence of many process variables in manufacturing, good systems to control each process is essential in glass manufacturing to continuously improve the performance and maintain good profit. Hence good & effective GMP, ISO / IMS, HR, SHE and housekeeping systems should be implemented in high spirit. Management should ensure that these systems are implemented properly and reviewed regularly.
- e. Environment:** For container glass production, glass has to be melted at very high temperature (approximately 1570°C) and hot glass required to blow the bottle, hence

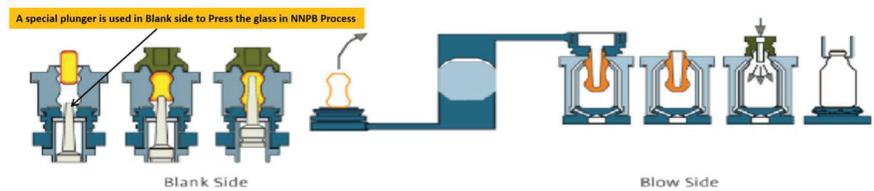


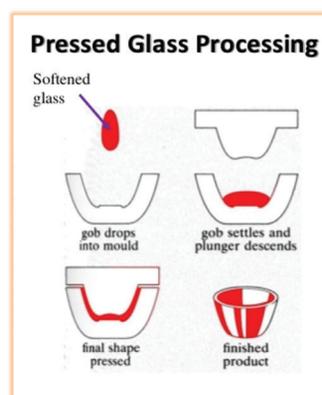
Figure 1.8

the working environment is hot. As lot of compressed air is required for container glass blowing in IS machines, there exists lot of noise. Also, batching involves fine minerals, hence dust too is an issue. All these factors make the operating environment very challenging. Every action is required to make sure that there are sufficient dust, heat and noise prevention systems installed, so that operating team can work efficiently. In many companies, these challenges remain for very long resulting in high manpower attrition & accidents.

- Government policies and regulations
- Competition from alternative materials
- Energy cost
- Manpower cost
- Investment cost and economical plant capacity
- Competition from manufacturers within the country and outside
- Innovations
- Sustainability

### How to use this book

This book consists of various chapters explaining the container glass manufacturing processes including important trouble shooting charts. This will be a good reference book for everyone involved in glass manufacturing. Additionally, there



In Pressing operation, required quantity (Weight) of glass is poured into Mould and then it is pressed to form the article as shown in this image. Gob forming & Pressing process can be manual or fully automatic. Mostly Mass Manufacturing of Tumblers, Cups and Drinking Glasses are manufactured using Automatic Press Machines and other items like Dish Plates, Jugs etc. are made by Manual Operation.

Figure 1.9

are chapters on energy conservation, manufacturing excellence and safety. These are currently gaining importance and are very useful for improving the overall performance ■