

Container Glass Batching (chapter 2 of 15)

In this chapter from the book on "Excellence in Container Glass Manufacturing", we will learn the following:

1. Container glass raw materials and their specifications
2. Glass composition, glass oxides and their impact on glass quality and price
3. Raw materials sourcing, selection and raw materials cost considerations
4. Batching cost calculation
5. Glass composition, batch recipe and controls
6. Types of batching plants, selection and equipments
7. Quality controls in batching plant

Container glass batch making process consisting of following sub-processes:

1. Incoming RM inspection
2. RM unloading / handling
3. Cullet inspection and usage
4. Cullet processing
5. RM storage
6. Batching & transportation

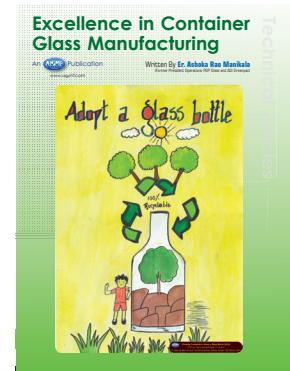
Batching Process is very important process in container glass manufacturing. As the saying—"garbage in - garbage out", the quality of glass produced directly depends upon the input quality of raw materials used. Hence at every stage of batching process, utmost focus on quality is to be maintained to get good quality of glass from melting furnace, for forming. Each raw material is having many variables like physical properties, chemical properties and compositions, and small changes in the raw materials quality can severely impact glass properties, energy required for glass melting and glass

quality etc. Hence it is very important to have very clear specifications for raw materials, good process control, good laboratory analysis and avoid material contaminations.

1.0 Container Glass raw materials and their specifications

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. Also, there is Type IV glass which is having higher alkali in glass with less hydrolytic resistance. This is a general glass having less batch cost. Lead crystal and special aluminosilicate glasses are also used in container glass manufacturing. Special aluminosilicate glass is emerging as very high-performance pharmaceutical glass but cost is very high.

Ninety-five per cent of 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, aluminum 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 coefficient, 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.

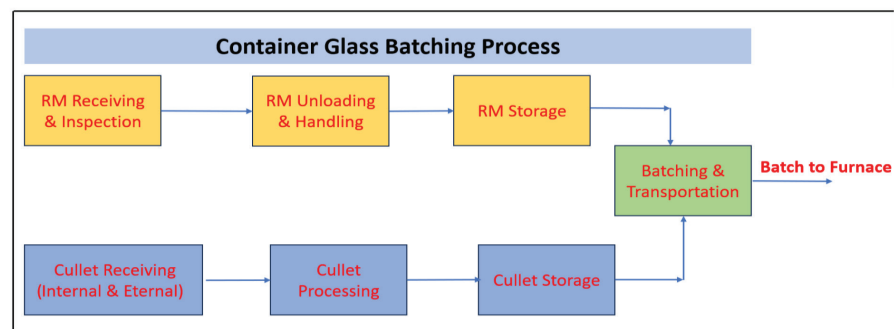


Figure 2.1

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.

Borosilicate glass is a Type of glass that contains silica and boron trioxide as glass formers and sodium oxide as a fluxing agent. It also contains a small amount of alumina and less alkaline solids. The glass formula is:



which usually contains SiO_2 (80.5%), B_2O_3 (13%), Al_2O_3 (0.3%), K_2O (3%) and Na_2O (0.5%)

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 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 a 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.

Its chemical formula is $\text{Na}_2\text{O} \cdot \text{CaO} \cdot 6\text{SiO}_2$

Where soda serves as a flux to lower the temperature at which the silica melts, and the lime acts as a stabilizer for the silica.

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. LEAD CRYSTAL GLASS

Lead crystal glassware and tableware is renowned for its exceptional clarity and brilliance, making it an ideal material for crafting high-end glassware and tableware. Lead glass, also known as crystal, is a Type of glass that has been prized for centuries for its exceptional clarity, brilliance, and luxurious appeal. This unique glass variety contains a significant amount of lead oxide, which enhances its optical properties, making it highly desirable for a wide range of decorative and functional applications. Lead glass has a rich history and has been revered for its beauty and versatility. Its distinct characteristics have made it a popular choice for creating exquisite glassware, chandeliers, jewellery, and decorative ornaments. The allure of lead glass lies in its ability to refract light with unparalleled brilliance, creating a dazzling display that captivates the eye and adds an air of sophistication to any setting.

Lead glass is also known as lead-oxide glass or lead crystal which contains at least 20% lead oxide. Its chemical composition is:



It contains lead oxide instead of calcium oxide as compared to soda-lime glass. The addition of PbO makes the glass brighter and more lustrous.

6. 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, signaling a shift towards materials that can provide enhanced security for high-potency drugs.

The glass industries are striving to develop various glass Types to meet the packaging requirements for various 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.

1.1 Raw materials and batch composition

The decision of raw materials & batch composition requirements is taken based on product requirement, process requirement and cost as shown in Figure 2.2.

We will discuss on each requirement.

Product requirements: Based on the properties of glass required for the product to be packed, the glass composition is decided. For example, for high quality vials, Type I Glass is required and hence borosilicate glass is used. For vodka filling, Type II Glass

temperature, melting temperature, working temperature ranges for container glass forming, annealing temperature etc., are very important which are decided by the glass composition.

Cost / Price: The cost of raw materials, energy cost, melting cost etc., plays an important role in controlling the bottle cost. Glass composition determines the cost of batch, melting energy, annealing energy and forming costs. Hence optimizing the cost is a very important factor. This factor is considered while deciding the batch composition.

2.0 General Compositions of various Types of Glasses (Containers+other Glasses)

Table 2.1

Composition in mass%	SiO ₂	Na ₂ O	K ₂ O	CaO	MgO	Al ₂ O ₃	Fe ₂ O ₃	Diverse
Container Glass								
-Flint	72,6	13,7	0,5	11,0	0,1	1,6	<0,05	0,2 SO ₃ , 0,1 TiO ₂
-Green	72,0	15,1	-	8,4	2,1	1,1	0,4	0,02-0,06 SO ₃ 0,25 Cr ₂ O ₃
-Amber	72,7	13,8	1,0	10,0	-	1,9	0,2	0,05-0,08 SO ₃
Clear Float Glass	71	14	0,8	9	5	1-1,5	0,080	0,2-0,3 SO ₃
Tinted Float Glass	70	14	0,8	9	5	1-1,5	0,3-1,5	0,2-0,3 SO ₃
Display -LCD- glass	58-60	<0,1	<0,1	5-7	0-1	15		± 10 B ₂ O ₃ ± 10 % BaO+SrO
Lighting glass	72,4	17,4	-	5,3	3,7	0,8	-	
Tableware	75,6	13,5	4,1	3,7	2,6	0,4	0,02	
E-Glass'	55,2	0,5	0,5	17,7	4,3	14,8	0,3	0-10 B ₂ O ₃
Insulation wool	64	15,5	1,2	7	3	3,5	0,25	4,5 B ₂ O ₃ ; 0,15 SO ₃
Borosilicate (Pyrex)	80,2	4,5	0,3	0,1	-	2,6	0,07	12,3 B ₂ O ₃
Opal glass	66,9	13,3	2,2	4,8	0,4	6,9	0,08	Up to 6 Fluoride 1,6 BaO
Crystal glass	58,5	1,3	13,1	-	-	-	0,02	25,2 PbO
Lead crystal	54,9	0,2	12,3	-	-	-	0,02	32,0 PbO
Roman glass (first century AD)	70,0	16,5	1,0	7,0	0,6	5,0	-	-

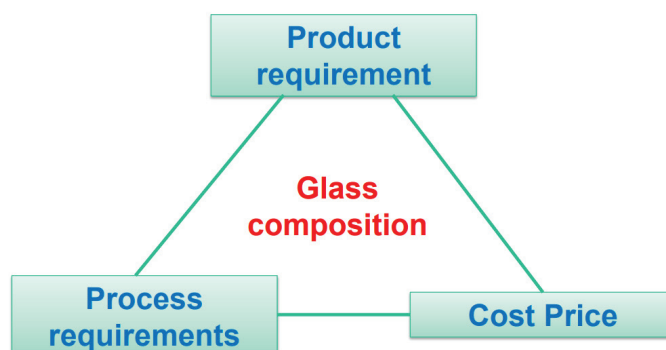


Figure 2.2

is used. For beer filling, Type III Glass is used.

Process requirement: For forming the glass, properties of glass are very important. **Softening**

The container glass Types are shown in Table 2.1

3.0 Container Glass raw materials

The raw materials used in glass are having oxides and based on the function of oxides in glass making, they are classified into following 3 major categories:

a) **Network forming oxides:** It also has other names like glass

former or glass forming oxides. Oxides, which form glasses when melted and fast cooled, are known as glass forming oxides or network forming oxides, because of their ability to build up a continuous three-dimensional random network. They have the ability to rearrange their bonds during crystallisation process. These oxides are SiO_2 , B_2O_3 , P_2O_5 and GeO_2

b) Network modifying oxide:

The role of a modifying oxide is that when such an oxide, for instance sodium oxide, is introduced into a silica glass to produce a sodium silicate glass system, the structure of glass will change. Furthermore, introducing different amount of Na_2O into a glass forming system result in significant modification in the end glass properties. These modifications are commonly observed on the viscosity of the glass, which influences the properties such as thermal expansion coefficient and/or chemical durability. Other alkali and alkali earth metal oxides, such as lithium, potassium or calcium oxides, can take part in the glass structure in a similar manner to fulfil the role of glass modifiers. However, multicomponent glass systems containing mixed alkalis, as a structural (network) modifying oxides, have far more complex changes in many properties. Network modifying oxides –

Na_2O , K_2O , Li_2O , CaO , BaO , MgO , SrO

c) Intermediate oxides–

An intermediate oxide does not form a glass on its own due to the lack of their glass forming characteristics.

However, such oxides are reported to take part in the glass network only in the presence of a glass network forming oxide. Examples of such oxides are aluminum oxide, titanium oxide, and magnesium oxide. Aluminosilicate, aluminoborate and aluminophosphate glasses are good examples where aluminum behaves as an intermediate oxide.

Other raw materials: Based on their purpose in glass making and use, the raw materials are further categorised as following:

- A) Cullet: Cullet is the rejected glass (internal or external), having very close properties as that of the glass obtained from melting the batch. It contains oxides close to the oxides in glass from batch. It acts as catalyst to improve melting as its melting temperature is far below that of batch made from other raw materials.
- B) Fining agents/redox active components – sulphates: Na_2SO_4 , CaSO_4 ; oxides: As_2O_3 , Sb_2O_3 , CeO_2 ; chlorides: NaCl , Nitrates: KNO_3 , NaNO_3 ; carbon
- C) Fluxing agents – CaF_2 , spodumene (lithium raw material), blast furnace slags/calumite
- D) Colouring agents – Fe_2O_3 , Cr_2O_3 , CoO , Mn_2O_3 , Se, $\text{Fe}_3^+/\text{S}_2^{2-}$, rare earth oxides, sulfides, selenides

Sources of Glass oxides and their properties

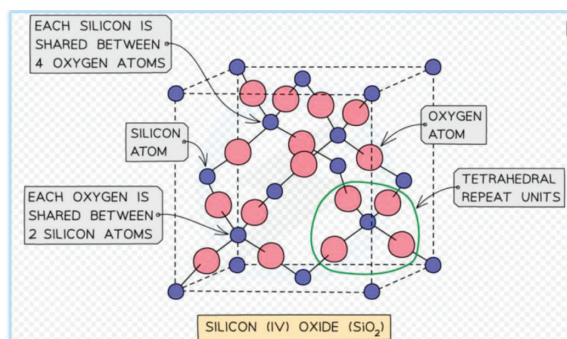
Silica as glass network former.

Silica at high temperatures, liquefies into a very viscous melt that generally impedes crystallization kinetically when it goes below its melting temperature. However, silica melts at 1713°C , and its viscosity at this point is too high to work with any reasonable amount of effort. Temperatures in excess of 2000°C must be attained to work pure silica glasses and these temperatures tend to render such pure silica glasses economically unviable for the majority of glass applications. Hence, to make it easily melt and form containers, modifiers such as soda is used. Natural silica sand or natural quartz stones are the main materials used as network formers for commercial container glass manufacturing.

Other network formers are oxides of boron, phosphorus (P_2O_5), arsenic and germanium. Boric oxide is used in manufacturing borosilicate glass (Type I Glass).

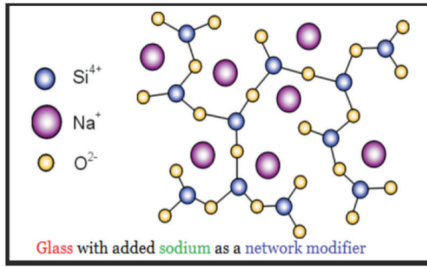
Soda (Na_2O) is a network modifier. Its addition reduces the melting temperature of the silica melt dramatically. Soda (Sodium Oxide) reacts with silica at much lower temperature than melting temperature of silica. In fact, the soda-silica mixture goes into liquid stage at temperature below 1000°C , depending upon amount of soda used.

If soda content is increased in soda-silicate glass, the glass is likely to be chemically attacked by water. Therefore, to produce a useful glass



The materials that form the basic structure of any Glass are called Network Formers. The most common former is silicon dioxide (SiO_2). There are no separate SiO_2 molecules instead they are all linked together to form a Giant network. The silicon and Oxygen atoms are shared between each other as shown in image. Another common network former is Oxide of Boron (B_2O_3). Oxides of Phosphorous, Arsenic and Germanium are also network formers in Glass but they are not used for large volume commercial Glasses.

Figure 2.3



Reaction of Silica with Soda (Glass network modifier):
 $\text{Na}_2\text{CO}_3 + 2\text{SiO}_2 \rightarrow \text{Na}_2\text{O} \cdot 2\text{SiO}_2 + \text{CO}_2 \uparrow \quad T > 790^\circ\text{C}$ (forms with SiO_2 an eutectic melt)
 Other alkali and alkali earth metal oxides, such as lithium, potassium or calcium oxides, can take part in the glass structure in a similar manner to fulfil the role of glass modifiers. To form soda-lime-silicate glass, lime is added into batch and the reaction in Furnace is:
 $2\text{CaO} + (\text{SiO}_2 + \text{Na}_2\text{O} \cdot 2\text{SiO}_2) \rightarrow \text{Na}_2\text{O} \cdot 2\text{CaO} \cdot 3\text{SiO}_2 \quad (>900^\circ\text{C})$
 Eutectic Melt
 Addition of lime increases the resistance of Glass to chemical attack. Lime as modifier stabilizes the glass. MgO and K_2O are also modifiers.

Figure 2.4

now understand how much oxides are going to glass from batch and how much is getting into chimney (atmosphere). The effective oxides remain in the glass from the raw materials is known as yield.

that can be melted easily and formed readily, further modifications to glass composition are necessary.

Other glass modifiers are calcium oxide, used for increasing the chemical resistance of glass; magnesium oxide (MgO), used for durability of glass. Other alternative modifiers are potassium oxide, lithium oxide and zinc oxide. Of these, potassium oxide and lithium oxide act similar to soda as fluxes and zinc oxide act in a similar way to CaO and MgO . An excess of calcium oxide to a silica melt will cause devitrification, however additions of small amounts of lime stabilize the

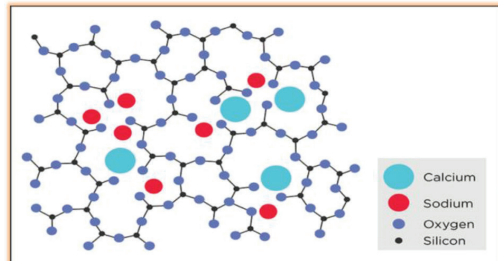
it with the properties it requires for its particular application. Hence intermediate oxides play the role of both former and modifier.

Methodology of glass composition determination

Because the raw materials for glasses are often in carbonate form (for stability reasons) or beneficiated as minerals (compounds containing several oxides), determining the glass composition from raw material batches requires a little mathematics. For the soda- lime silicate (SLS) glass, the raw materials often vary. Let us

Now let us understand the raw materials determination in glass

Silica sand and quartz is "pure" SiO_2 ; its ratio of oxide to total weight is ~100%. Quartz sand is produced from quartz stone, a mineral whose main component is silicon dioxide (SiO_2). Quartz itself is a hard and chemically stable mineral that is usually transparent or translucent and has good corrosion resistance. Silica sand usually refers to a sand-like substance whose main component is silicon dioxide, but it is not necessarily pure quartz. The silicon dioxide component in silica sand may include other silicon minerals besides quartz, such as feldspar, alumina. Therefore, there may be greater variability in the purity and mineral composition of silica



Addition of modifiers other than Soda, imparts different properties in Glass. Addition of CaO increases the resistance of the Glass to chemical attack. Addition of MgO increases durability of glass where as Potassium Oxide & Lithium oxides act similar to Soda, to make Glass melts at lower temperature (Flux). Zinc oxide acts similar way to CaO and MgO .

Figure 2.5

glass melt with respect to water, fixing the problem of water solubility introduced with the soda component.

Intermediate oxides: These are oxides which act partly as network former and partly as network modifier. Hence, they are known as intermediate oxides. Alumina (Al_2O_3), Lead oxide (PbO) are the intermediate oxides used in glass to make it more workable and provide

Requirements - Physical Properties of Raw Materials used in Glass Manufacturing

Table 2.2

Grain Size Conversion Charts and Recommended Sizes for Glass Raw Materials			
U.S. MESH	MICRONS	INCHES	MILLIMETERS
3	6730	0.2650	6.730
4	4760	0.1870	4.760
5	4000	0.1570	4.000
6	3360	0.1320	3.360
7	2830	0.1110	2.830
8	2380	0.0937	2.380
10	2000	0.0787	2.000
12	1680	0.0661	1.680
14	1410	0.0555	1.410
16	1190	0.0469	1.190
18	1000	0.0394	1.000
20	841	0.0331	0.841
25	707	0.0280	0.707
30	595	0.0232	0.595
35	500	0.0197	0.500
40	400	0.0165	0.400
45	354	0.0138	0.354
50	297	0.0117	0.297
60	250	0.0098	0.250
70	210	0.0083	0.210
80	177	0.0070	0.177
100	149	0.0059	0.149
120	125	0.0049	0.125
140	105	0.0041	0.105
170	88	0.0035	0.088
200	74	0.0029	0.074
230	63	0.0024	0.063
270	53	0.0021	0.053
325	44	0.0017	0.044
400	37	0.0015	0.037

Grain Size Distribution Silica Sand	
> 0.84 mm - 0%	
> 0.60 mm - 1% max	
< 0.125 mm - 1% max	
Grain Size Distribution Nepheline Syenite	
> 0.84 mm - 0%	
> 0.50 mm - 3.5% max	
< 0.1 mm - 20% max	
Grain Size Distribution Lime & Dolomite	
> 3.15 mm - 0%	
> 2.0 mm - 10% max	
< 0.1 mm - 20% max	
Grain Size Distribution Soda Ash	
> 1.19 mm - 0%	
> 0.59 mm - 3% max	
< 0.074 mm - 3% max	



Quartz is generally white in color with high % of SiO₂. It is processed by quartz stone crushing. Silica sand is naturally available in land close to sea. This sand may be washed by rain water for many years making it suitable for Glass manufacturing. This naturally available sand requires processing like washing, drying, sieving. The composition of silica sand may vary from mine to mine, location to location.

Figure 2.6

sand. Its true purity varies depending on the site from where it is mined.

High Quartz contains +99% SiO₂

The chemical composition of silica sand determines its quality and suitability for Glass applications. High-purity silica sand typically contains 96–99% silicon dioxide (SiO₂). However, minor impurities can influence its properties. Common impurities include:

Iron Oxides (Fe₂O₃): Affects color and transparency.

Aluminum Oxide (Al₂O₃): Impacts thermal resistance.

Calcium Oxide (CaO): Alters the sand's reactivity.

Magnesium Oxide (MgO): Affects structural stability.

Potassium Oxide (K₂O) and Sodium Oxide (Na₂O): Influence melting and fusion properties.

The other impurities which are found in natural sand are chromium (Cr₂O₃) titanium (TiO₂) and volatile compound (LOI).

Soda ash is sodium carbonate (Na₂CO₃); when heated, it transforms into Na₂O and CO₂. Its oxide to total weight ratio is 0.585. Only 58.5% Na₂O is going into glass and balance is going to chimney as CO₂. General composition of soda ash is shown in Figure 2.7.

Limestone is calcium carbonate (CaCO₃) and releases CO₂ on decomposition like soda ash as shown in Figure 2.8. There are 0.56 units of lime per unit of limestone.

Soda feldspar/albite: Feldspars and other feldspathic materials such as nepheline syenite are mostly used in the glass and ceramic industries. Feldspar consists essentially of aluminum silicates combined with varying percentages

of potassium, sodium, and calcium, and it is the most abundant mineral of the igneous rocks. The two Types of feldspar are soda feldspar (7% or higher Na₂O) and potash feldspar (8% or higher K₂O). Feldspar-silica mixtures can occur naturally,

such as in sand deposits, or can be obtained from flotation of mined and crushed rock.

The glass industry prefers to use orthoclase (potassium feldspar) mainly because it tends to make the melt transparent, while albite (sodium feldspar) tends to melt the clear glass. Anorthite (calcium feldspar), although it contains twice as much alumina as sodium and potassium feldspar and also contains lime, another important component of glass, is not preferred in glassmaking because it is more heat-resistant and has a high melting point. Feldspar acts as a melting agent, lowering the melting temperature of quartz and helping to control the viscosity of the glass, thereby reducing production costs.

Soda Feldspar (Na₂O-Al₂O₃-6SiO₂), also known as albite, is a mineral which contributes both soda and alumina to glass. It contains 11.8% Na₂O, 19.4% Al₂O₃ and 68.7% SiO₂ per unit of soda feldspar.

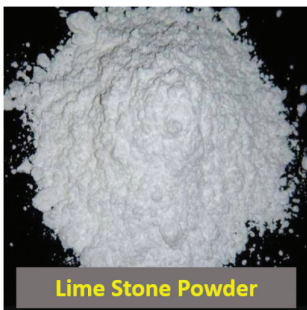
Figure 2.9 shows different Types of feldspar and their properties.

Without going into deeper understanding of other raw materials, let us look at the reaction/decomposition of RM (and their yield into glass)



Na₂CO₃ → Na₂O + CO₂ ↑ (Reaction in Glass Furnace at Temperature above 900 Deg C)
 100kg 58.5kg + 41.5kg ↑
 Purity: Sodium Carbonate (Na₂CO₃) – 99.5%, Na₂O – 58.5%
 Bulk Density: 951–1250 kg/m³

Figure 2.7



Decomposition of Calcium Carbonate (Lime Stone)
 CaCO₃ → CaO + CO₂ ↑ Molecular weight of CaCO₃ 100, CaO is 56 and CO₂ is 48
 Molecular weight is sum of individual atomic weights multiplied by the number of atoms of each elements in it. In this case, atomic weight of Ca, C and O are 40, 12 and 16 respectively. Hence Molecular weight of CaCO₃ is 40+12+(3x16) =100. Molecular weight of CaO is 40+16 =56 and that of CO₂ is 12+(2x16) = 44 . As CO₂ is Gas, it will leave the furnace as Gas, leaving CaO into Glass. Hence lime stone will give only 56% as CaO to the Glass.

Figure 2.8

- a) Potassium Carbonate: It releases potassium nitrate into glass.
($K_2CO_3 \implies K_2O + CO_2$)
- b) Dolomite: It is a combination of calcium and magnesium carbonate composition and is an extremely useful mineral in the glass industry because CaO and MgO act as network modifiers in the glass manufacturing process. Dolomite influence glass transition temperature, density, rigidity, durability, and dimension stability. Dolomite powder for glass industry requires high-grade dolomite with as little iron and silica as possible.
 $CaCO_3 \cdot MgCO_3 \implies CaO + MgO + 2CO_2$
- c) Sodium Sulphate
- d) Calcium Sulphate
- e) Sodium Borate
- f) Sodium Hydroxide (Caustic Soda)
- g) Sodium Nitrate
- h) Furnace Slag
- i) Black Soda
- j) Potassium Nitrate
- k) Potassium Carbonate

SiO₂ forms an excellent glass but has a high melting temperature (>2000°C).

- Fluxes are added to reduce the melting temperature to below 1600°C. Common fluxes: alkali oxides (usually Na₂O or K₂O), PbO.
- PbO is very good at dissolving impurities (e.g. refractory particles) but is toxic.
- Addition of alkali oxides causes degradation of many properties, especially chemical resistance. This degradation can be reduced by using property modifiers e.g. alkaline earth oxides, transition metal oxides, alumina. These oxides cause a small increase in processing temperatures, but improve glass properties.
- Colorants are added to control the colour of the glass. They are usually, oxides of 3d transition metals or 4f rare earths.
- Gold and silver can also produce colours by formation of colloids in glasses.
- Iron oxides (impurities in sands) are often unintentional colorants.
- Decolorants can be added to counteract the effect of other colorants.
- Fining agents are added to remove bubbles from the melt. They include As₂O₅, Sb₂O₃, NaCl,

CaF₂, NaF, Na₃AlF₆ and some sulphates. They are added in very small amounts (< 1 wt %)

Batch composition and yield calculation

Now, one could have understood how much each raw material will give oxides into glass. With this knowledge, it will be now easy to calculate the glass oxides and yield. It should be noted that moisture content in each raw material should not be considered in deciding batch composition calculation and yield calculation as water is not going to give any oxides into glass, instead it will evaporate in furnace or while transporting the batch. Proper control of moisture is very important as this will increase the raw material cost, energy cost and RM transport cost.


Table 2.3 shows an example of batch recipe for one glass manufacturing plant. We learn how to calculate the glass composition and yield.

Table 2.3

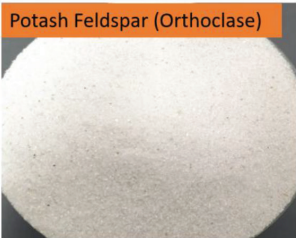
Raw Material	Weight Kgs.
Silica sand	1000
Soda ash	300
Lime stone	240
Feldspar	100
Sodium Sulphate	12
Dolomite	90
Cullet	900

Container Glass raw materials-Summary


- Most commercial glasses use SiO₂ as the network former.



Soda Feldspar (Albite)



Potash Feldspar (Orthoclase)



Nepheline Syenite

Nepheline syenite (silicate, naturally occurring blend of albite, microcline and nepheline) is a feldspatic mineral mined in Canada and Norway. Nepheline syenite is used within the glass batch to promote faster melting at lower temperatures whilst at the same time decreasing viscosity. Its addition therefore helps to reduce overall energy consumption. Nepheline syenite increases the chemical resistance and stability of the finished glass.

Feldspar	Formula	Theoretical Chemical Composition				
		K ₂ O	Na ₂ O	CaO	Al ₂ O ₃	SiO ₂
Orthoclase- Potash	K ₂ O.Al ₂ O ₃ .6SiO ₂	16.9	-	-	18.4	64.7
Albite- Soda	Na ₂ O. Al ₂ O ₃ .6SiO ₂		11.8		19.4	
Anorthite- Calcium	CaO. Al ₂ O ₃ .2SiO ₂			20.1	36.62	
Nepheline Syenite	Combination of Minerals	6.5	4.2	2.2	21.5	61.3

Figure 2.9

Now let us understand how to calculate the glass composition and yield.

First, one should have complete chemical composition analysis of each raw materials and keep in excel format.

Next enter the batch recipe details in Excel and then calculate the theoretical oxides going inside as shown in Table 2.4. The glass composition can be easily

found by making an Excel file and incorporating formulas, which will give the composition once the raw material's oxide value and weight of each RM as per batch recipes entered. As the cullet is generally having close composition as that of virgin glass from batch, yield is not calculated with cullet as 100% cullet used is converted into glass in furnace.

4.0 Batch cost calculation

There are two ways of calculating the cost. One is cost per ton of batch or cost per ton of glass (Table 2.5).

Cost per ton of glass is straight forward to calculate. Decide the recipe and then calculate the cost of each RM by multiplying weight and rate. Add the cost of all the raw materials. By dividing the cost of all raw materials with total batch weight, cost/ton of batch will be calculated. In the example below, calculated the batch cost/ton of batch and also batch cost/ton of glass in Indian Rupees. Same thing can be calculated by changing price in your local currency.

Batch Optimisation: In the above example, we have considered only the virgin batch cost of 5 raw materials and cullet cost is not added. The cost can be worked-out considering the cullet cost and that of all other materials used like colouring agents. By changing the raw materials without changing the desired glass oxides, one can optimise the batch recipe for achieving lowest cost per ton of glass. It is always advisable to workout

Table 2.4

Glass Batch Calculation									
Raw Material Composition as % (Oxides into Glass)									
RM	SiO ₂	Na ₂ O	CaO	K ₂ O	Al ₂ O ₃	MgO	Fe ₂ O ₃		
Sand	98.8	0.22	0.01		0.77	0.02	0.04		
Soda		58.5					0.002		
Lime stone	0.94		56.5		0.31	0.12	0.18		
Feldspar	66.5	9.4			1	17.8	0.3		
Dolomite	1.2		30.41			21.8	0.25		
Sod.Sulphate	0	43.6	0	0	0	0	0.07		
Batch Calculation: Oxides going into Glass (Kgs): (Weight x % of Oxide in RM/100)									
RM	Weight Kgs	SiO ₂	Na ₂ O	CaO	K ₂ O	Al ₂ O ₃	MgO	Fe ₂ O ₃	Total Glass Oxide Kgs
Sand	1000.00	988.00	2.20	0.10	0.00	7.70	0.20	0.40	998.60
Soda	325.00	0.00	190.13	0.00	0.00	0.00	0.00	0.01	190.13
Lime Stone	220.00	2.07	0.00	124.30	0.00	0.68	0.26	0.40	127.71
Feldspar	100.00	66.50	9.40	0.00	1.00	17.80	0.00	0.30	95.00
Dolomite	94.00	1.13	0.00	28.59	0.00	0.00	20.49	0.24	50.44
Sod. Sulphate	12.00	0.00	5.23	0.00	0.00	0.00	0.00	0.01	5.24
									0.00
Total	1751.00	1057.70	206.96	152.99	1.00	26.18	20.96	1.35	1467.12
Glass Comp		72.09	14.11	10.43	0.07	1.78	1.43	0.09	
									83.79 Yield

batch cost per ton of glass and not batch cost per ton of batch. Please note that the yield value of each raw materials will be different and hence the cost per ton of batch is not giving the exact impact of recipe on glass cost.

5.0 Batching plant operation

Now let us delve into batch plant operation.

1. **Incoming RM Inspection:** As explained earlier, most of the raw materials used in container glass manufacturing are minerals and there will be many variations in physical & chemical properties of each lot of RM received. This is mainly because the minerals while mining will have lot of variations in properties with

respect to depth, site and climate conditions. Also, there can be contamination issues in RM while processing RM, packing and transportation. Hence every glass industry should have very clear specifications for each raw materials mentioning acceptable limits for physical and chemical parameters. As small changes in properties of RM will have impact on cost, melting and glass quality, good inspection of all RMs is necessary. Every lot to be checked physically and also checked for composition in laboratory before accepting for use.

2. **RM Unloading / Handling:** Unloading and handling of raw materials is also important activity

Table 2.5

Batch Cost Determination - Cost per Ton of Batch				Batch Cost Determination - Cost per Ton of Glass				
RM	Weight as per Recipe Kgs	Rate/ Kg INR	Total Cost INR	RM	Weight as per Recipe Kgs	Rate/ Kg INR	Total Cost INR	Total Glass Oxide Kgs
Sand	1000.00	3	3000	Sand	1000.00	3	3000	998.6
Soda	325.00	45	14625	Soda	325.00	45	14625	190.1
Lime stone	220.00	5	1100	Lime stone	220.00	5	1100	127.7
Feldspar	100.00	4	400	Feldspar	100.00	4	400	95.0
Dolomite	94.00	6	564	Dolomite	94.00	6	564	50.4
Sod.Sulphate	12.00	35	420	Sod.Sulphate	12.00	35	420	5.2
Total	1751.00		20109	Total			20109	1467.1
Batch Wt.in Ton	1.75			Glass Wt.in Ton				1.4671
Batch Cost INR / Kg			11.48	Batch Cost/ Kg of Glass				13.71
Batch Cost INR / Ton			11484	Batch Cost/ Ton of Glass				13707

as it will have direct impact on cost and quality. If unloading is taking very long, then the truck or container to be detained for longer period and the vendor will definitely charge or consider the cost of RM. Also, if not unloaded properly, contamination issues, loss of material, environmental issues may crop up. Hence good procedure for unloading and handling is required. As the inhalation of dust from raw materials can lead to some diseases to unloading/ handling crew, every precaution to unload safely without dust creation should be taken. Also, automation for unloading of RMs to be incorporated for safety, quick unloading and for avoiding mix-up. Housekeeping in batching plant is very essential and proper cleaning of handling equipments after every change in raw materials is necessary to avoid mix-up and contamination.

5.1 CULLET PROCESSING & USAGE

For general public, “cullet” is typically an unfamiliar word but in glass industry, it is used commonly on daily basis. It is believed that the first use of this word started in the year 1817, perhaps from French word cueillette, meaning act of gathering (Latin word collecta).

Cullet refers to crushed or broken glass that is used in the production of new glass products. It is typically composed of glass that has been rejected or discarded, often due to damage or breakage, and is generally of the same composition as the mineral mixture used in glassmaking. The inclusion of cullet in the glass batch is beneficial because it melts early in the furnace, helping to bring the mineral particles together and

accelerating the reactions necessary for glass formation.

Cullet has been an integral part of glassmaking for many years due to its role in improving the efficiency of the melting process. The use of cullet in glass production is also a form of recycling, as it involves reusing waste glass to create new glass products. This practice helps reduce the need for raw materials and can lower energy consumption in the glassmaking process. The use of recycled glass (cullet) in the manufacturing process has major advantages. Cullet reduces the consumption of natural raw materials such as sand or synthetic materials such as sodium carbonate. By replacing raw materials, it reduces CO₂ emissions on two levels: by lowering the energy required for melting and by decreasing the use of raw materials whose melting emits carbon dioxide.

Today, cullet is the main raw material for glassmakers. Its incorporation rate in the furnaces has increased considerably in recent years. This rate could technically reach up to 95% for certain colors. Today it is mainly the availability of cullet that limits this integration. There are many difficulties in collection of cullet due to various reasons. Collection of cullet requires a lot of effort and dedication.

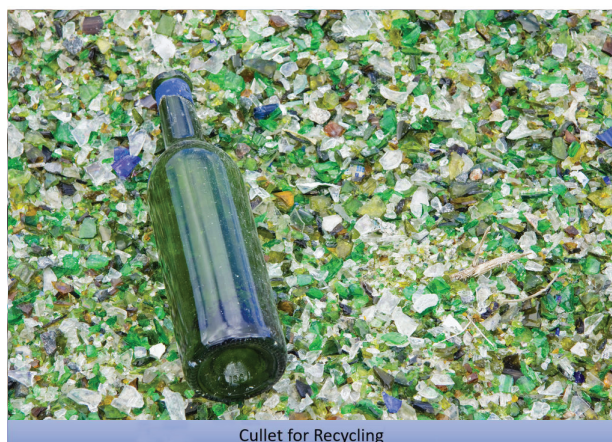
Despite the benefits, recycling glass and using cullet can be challenging. One of the main difficulties is separating glass from other waste materials and sorting it by color, as different colors of glass must be processed separately to maintain the quality of the final product. Nevertheless, cullet remains a crucial component in glass manufacturing, with usage rates varying significantly by country, ranging from 35 to 95 per cent in new glass production. Figure 2.10 shows the typical cullet received from market.

CULLET PREPARATION

Within the intricate realm of glass production, the process of preparing cullet for use in glass manufacturing takes center stage as a critical phase that weaves together sustainability, quality, and innovation. This crucial step acts as the gateway to transforming discarded glass into useful cullet to form new glass products, championing both environmental consciousness and manufacturing excellence.

Collecting and preparing Cullet:

The journey of cullet begins with the collection of recycled glass, often sourced from used glass bottles and the remnants of previous glass production. This raw material, once collected, undergoes a meticulous preparation process. Initially, the



Cullet for Recycling

The cullet received from market contains caps, labels, mud and impurities along with different colored glasses. This cullet can be used after proper processing & sorting. The process includes crushing, washing, sorting as explained in this article. It is difficult to do the sorting manually and hence many Glass manufacturers use automatic cullet sorting systems to have a good quality of cullet.

Figure 2.10

collected glass is sorted, ensuring that it meets the specific criteria required for the desired glass product. The sorted glass then undergoes rigorous cleaning to eliminate any impurities or foreign substances that could compromise the integrity of the final glass product. This thorough cleaning process not only guarantees the quality of the glass but also aligns with sustainability goals by maximizing the usability of recycled materials.

The importance of sorting and cleaning: The sorting and cleaning of cullet plays an important role in ensuring that the resulting glass maintains the highest standards of quality. The precision of this process directly impacts the properties of the glass, from its transparency and color consistency to its durability. By meticulously sorting the cullet, manufacturers can select pieces that match the specific requirements of their intended glass product, enhancing uniformity and performance. Moreover, the intensive cleaning of cullet eliminates contaminants, creating a clean canvas for the glass-making process. This focus on quality not only satisfies customer expectations but also upholds the industry's commitment to sustainable practices, as higher-quality cullet optimizes resource usage.

Challenges and considerations in handling cullet: While the benefits of using cullet in glass production are undeniable, this practice does come with unique challenges. One significant challenge revolves around the removal of contaminants from the collected glass. These contaminants can range from non-glass materials to residues from previous contents in glass bottles. Effectively identifying and eliminating these contaminants requires sophisticated technology and meticulous attention to

detail. Additionally, ensuring the consistency of cullet quality can be a consideration. Variations in cullet characteristics, such as size and composition, can impact the final glass product. Addressing these challenges involves a combination of advanced sorting and cleaning techniques, as well as a commitment to continuous improvement. As we delve into the intricacies of cullet preparation, it becomes evident that this process is a cornerstone of sustainable glass manufacturing. It is a testament to the industry's dedication to innovation and eco-conscious practices. By meticulously collecting, sorting, and cleaning cullet, manufacturers not only enhance the quality of their glass products but also contribute to the preservation of natural resources and the reduction of waste. It is a harmonious blend of craftsmanship and environmental responsibility, paving the way for a brighter, greener, and more resource-efficient future. Hence cullet processing is an important activity in glass manufacturing and understanding it well will help industries to get good quality of their glass products, save energy & reduce natural raw materials usage.

Recycling is gaining very high importance now a days. What was already the norm in advanced countries a long time ago, is now on the agenda in all countries around the world. However, there are still big differences in the quality of the collection systems. In some countries the raw material glass is collected and sorted according to color; sometimes, however, it is collected completely mixed. The proportion of foreign substances (metals, ceramics, waste in general, etc.) also differs from country to country.

Stages in Cullet processing:

1. Receiving & storage of cullet

2. Cullet sorting

3. Processed cullet storage

4. Processed cullet usage

1. Receiving & storage of Cullet

It is a very important activity in container glass manufacturing facility. Proper inspection of cullet while receiving & storage in designated locations according to Type, grade, size, source etc., will largely help to process the cullet for final use. If all the incoming cullet is stored together, then sorting load will be extremely high & maintaining quality of glass will be a herculean task.

Cullet is classified into two categories based on source namely internal and external cullet. These two categories should be processed and stored separately. Based on glass properties, external cullet can be classified as flint, amber, green, mixed, sheet glass etc., and they have to be again stored separately before & after processing for better control of glass quality. One dedicated staff may be given full responsibility of cullet receiving, processing & storage as it is an important activity. With good sorting quality, cullet up to 95% can be used in batch for glass melting.

Inspection of cullet while receiving & unloading is extremely important. While unloading the external cullet, check the quality at different stages of unloading as there is every chance of contamination at different areas of truck (top, middle, bottom or at front & backside of truck). Any suspected quality of cullet (especially for metals, stones, ceramics, porcelain, micro-oven glasses) should be stored separately and then sorted properly to avoid such contaminants going to glass furnace. Regular training & advise to vendors to supply cullet as per the specification will largely reduce the load on sorting process.

2. Cullet sorting

Earlier cullet sorting used to be a laborious & tedious process but, thanks to innovative technologies, which is helping glass industries to sort the cullet with high quality & speed. Manual sorting is exceedingly difficult and slow process. As the glass industries are expanding and increasing their capacities, manual sorting of cullet is becoming difficult and hence they are moving to automatic cullet sorting.

a) **Manual sorting:** Figure 2.11 shows the flowchart of general manual sorting system adopted.

In manual sorting, controlling the sorting quality is difficult due to various constraints with labor, speed of sorting, thickness of cullet on belt conveyor etc. Along the conveyor, powerful magnets can be installed to remove ferrous material and eddy current separator can be independently installed to remove non-ferrous items like aluminum caps. Sorters need to be positioned along the manual sorting belt conveyors and there are chances of some accidents if adequate safety precautions are not taken. All the conveyors should have emergency pull chord system to immediately stop the belt conveyor in case of emergency and the sorters should have good seating & walking arrangements along the belt conveyors to avoid any accidents (to avoid fall).

b) **Automatic Cullet sorting system**

As the glass quality requirement is becoming stringent day by day, cullet sorting quality should be extremely high because it

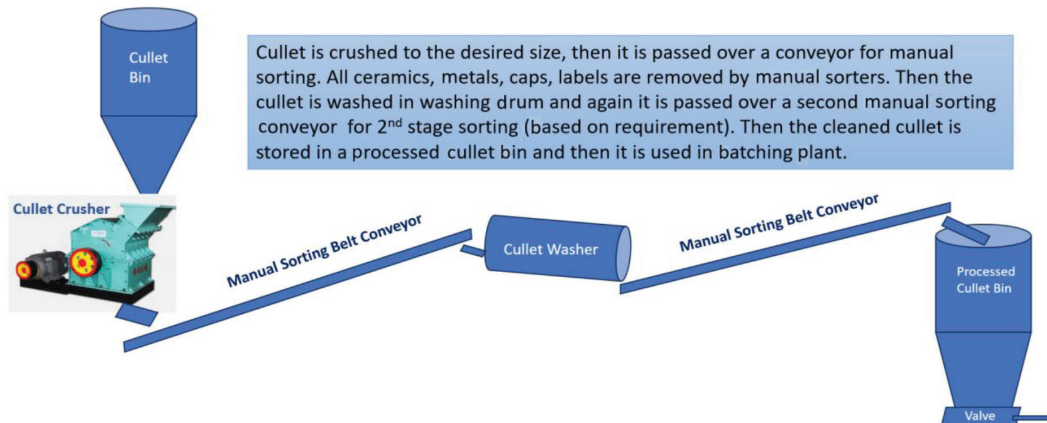


Figure 2.11

has direct bearing on melted glass. It can be achieved only by auto cullet sorting system. Auto cullet sorting system consists of screening the cullet for coarse and fines, crushing bigger size cullet, drying of cullet, organic matter removal, metal separation, color and CSP sorting (sorting flint, amber and green separately) as shown in process map in Figure 2.12. There are many reputed suppliers of cullet sorting system like M/s BINDER+CO AG Austria, M/s REDWAVE Austria, M/s ZIPPE GmbH Germany etc., who can design & supply as per plant requirement.

Necessity of sorting / processing of Cullet

Cullet is sorted and processed for following reasons:

1. Cullet is one of the major ingredients for producing glass. Without cullet (minimum of 10%), glass melting will be exceedingly difficult, and it will lead to many melting problems.

Cullet acts as a catalyst for melting. Hence minimum amount of cullet in batch is necessary for melting Glass.

2. Proper sizing of cullet for use in batch is very important. It is recommended to use 6mm to 15mm size of cullet for satisfactory results in terms of melting, energy saving and glass quality.
3. Un-sorted or poorly sorted cullet may lead to many problems. Following are a few of them:
 - a) Damage to furnace & furnace equipments:
 - If there are lot of contaminants like ferrous materials & aluminum caps,

Process Map of Container Glass Cullet Auto Sorting

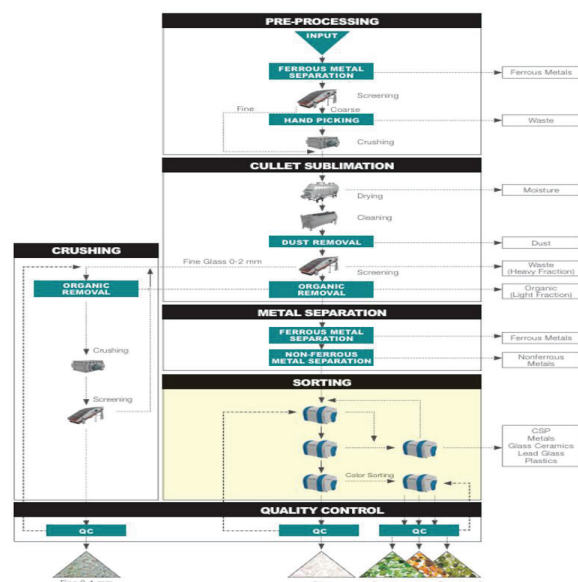


Figure 2.12

the same can settle at the bottom of the melter and create downward drilling of bottom tiles. This will make the refractory to corrode quickly and glass can leak from melter bottom.

- The ferrous and non-ferrous metals can form a metal layer at the bottom of the melter and as the time passes, it can have a metal layer of many millimeters of thickness. If there are bottom boosting electrodes, then it can create sparking of electrodes and electrodes may be damaged very quickly making the electrodes ineffective or lead to glass leak from electrode areas at the bottom. This kind of leakage will be very difficult to control and there can be a major accident due to glass leakage.
- Due to metal contaminants present in cullet, the furnace life will be seriously impacted due to rapid corrosion of melter bottom tiles.

b) Poor glass quality:

- If cullet is not sorted properly & has lot of impurities, the glass color can vary frequently resulting in customer complaints. This is extremely critical for cosmetic glass production.
- Final glass may have lot of stones, glass knots and forming defects. This can lead to higher rejections, lower production efficiency and increased customer complaints.
- Frequent yellow lines in glass because of reaction of glass with contaminants (ferrous and non-ferrous metals).

- Bubbles, seeds may increase suddenly due to reaction of contaminants with glass.

c) Increased melting energy:

- Increase in iron level in glass will lower the heat transfer rate in melter and forehearth. Hence melting energy or SFC (specific fuel consumption) for melting and forehearth energy consumption will increase.
- More bubbles and seeds in glass due to high contaminants in cullet may necessitate increase of melter temperature which will lead to increase in energy consumption.

3. Processed Cullet storage

It is very important that the processed cullet is stored properly in batching plant. It is recommended to have separate cullet bins / silos for internal and external cullet with independent weighing and feeding units for better control of glass quality. Also, for different types of cullet (flint, amber, green), separate silos / bins are to be used. As the cullet is highly abrasive material, storage bins / silos to be designed by experts to minimize wear & tear and avoid contamination of cullet from storage silos.

During transportation of cullet from processing to storage and then storage to melting, enough powerful magnets need to be fixed on conveyor belts and cullet chutes to remove any left-over ferrous contaminants.

4. Processed Cullet usage: During the batching, cullet is generally not mixed in mixer as cullet is highly abrasive and can damage the mixer blades quickly. Hence cullet is spread over the batch uniformly by proper cullet feeding system. During conveying and feeding of

cullet powerful hanging magnets may be used to catch the ferrous contaminants present in cullet. It is recommended to daily collect the cullet sample from cullet feeding system and check the quality for sorting & contamination. Accordingly corrective actions to be taken in sorting. There are systems to pre-heat cullet using furnace waste heat to save energy. M/s ZIPPE GmbH Germany and few others can design and supply these systems. However, in India, this system is not installed due to low return on investment.

Advantages of using Cullet

When it comes to the ecological footprint of glass manufacturing, the adoption of cullet serves as a game-changer, yielding an impressive array of environmental benefits that outshine the conventional reliance on virgin raw materials. Let us embark on a journey through the eco-conscious realm of cullet, unearthing its profound contributions to reducing raw material extraction, conserving energy, and mitigating carbon emissions.

Reduction in raw material extraction:

One of the most glaring advantages of incorporating cullet into the glass-making process is the substantial reduction in the need for primary raw materials such as sand, soda ash, and limestone. These materials are traditionally mined, a process that extracts a significant toll on the environment. By substituting a portion of these virgin materials with recycled glass, we are diminishing the pressure on fragile ecosystems, preserving pristine sand dunes, and minimizing the ecological disturbances caused by mining operations. This reduction in raw material extraction is a triumph for the environment, as it directly curbs habitat disruption and soil degradation while easing the strain on natural resources.

Energy savings during the melting process:

The allure of cullet extends beyond material conservation, delving into the realm of energy efficiency. When recycled glass is introduced into the melting furnace, its lower melting point imparts a profound energy-saving effect. The furnace does not need to reach the same temperatures as it would when processing solely virgin materials, resulting in reduced energy consumption. This translates into fewer fossil fuels burned, fewer emissions spewed into the atmosphere, and a tangible step towards a greener future. It is a virtuous cycle where every shard of cullet becomes a catalyst for energy conservation, aligning industry practices with sustainable aspirations. It is established in glass industry that every 10% increase in cullet usage will result into 3% reduction in specific fuel consumption. Also, by increasing the cullet usage, glass draw can be increased by 2 to 3% for every 10% increase in cullet.

Decreased carbon emissions due to reduced energy consumption:

The connection between energy use and carbon emissions is a fundamental pillar of environmental responsibility. As the energy demands decrease, so do the carbon emissions. By leveraging cullet in glass manufacturing, we are ushering in a paradigm where reduced energy requirements equate to a significant reduction in carbon footprints. The virtuous synergy of cullet's lower melting point and the resultant energy savings culminate in a measurable decrease in greenhouse gas emissions. This not only contributes to cleaner air but also aligns with international efforts to

combat climate change, positioning cullet as a frontline ally in the battle for a sustainable planet. It is estimated that every ton of glass cullet saves about 300 kg of CO₂, thanks to reduced fuel consumption and the absence of carbonate raw material decomposition in the purified material.

5.2 COLOURING AGENTS

Glass colours can be obtained either from furnace or individual forehearth (Colouring forehearth). The colour from furnace will be for mass production in all lines whereas colour from colour forehearth will be for a particular line. Colour forehearth is described separately in glass conditioning chapter.

Furnace Glass colours from batch composition:

From furnace we can produce basically 3 types of glass-flint, amber or green (dark, light). Commercial green container glass is coloured by additions of approximately 0.25 wt% chromium oxide (Cr₂O₃) and 0.35 wt% iron oxide (Fe₂O₃) and amber (brown) is essentially coloured by 0.5wt% iron oxide in a reduced

state. Both chromium and iron oxide are relatively strong colouring oxides in container glass. Therefore, flint (clear) container glass must only have trace additions of chromium and iron to avoid visible colour; a slight green/yellow colour is generally masked by adding a decolouriser. However, the addition of decolouriser can result in loss of light transmission and result in a grey appearance in the flint glass. Commercial flint container glass generally has no more than 0.5wt% of green glass added as cullet.

Figures 2.13. a & b show images of impact of addition of metal oxides into flint Glass (in colour FH) or into RM batch

6.0 Batching systems: Batching plants require to provide consistent batch without weight variations with proper sequence of operation. It has 2 sections namely silo seeding & storage of raw materials and batching. The first section is for receiving the raw materials and storing; and the second section is making glass batch as per recipe.

Silo feeding: Once the raw material

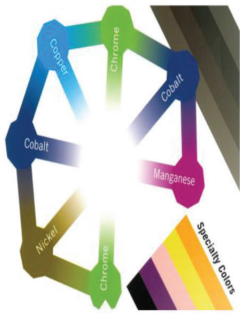
Glass Colours can be obtained in 3 ways. A) By addition of rare earth metal ions B) By colloidal particles formed in the glass C) By particles which are coloured themselves.



The colour effect is affected by base Glass composition or by the level of oxidation of Glass. Also by mixing different oxides, different Glass colors

Figure 2.13.a

Colour Metal Oxides



Glass colours can be obtained by adding oxides of metals in furnace or in colouring forehearth. Basically flint, Amber and Green (Dark, Light) colours for mass production are produced by adding colourants into the furnace batch and the entire Glass coming out of furnace to all the forming machines will have same colour. Other colours like Black, Red, Antiquity Blue etc. are produced by adding colourants in coloured forehearth whereby only these lines can produce the required colours. The picture shows the oxides of metals to get the desired colour.

Colorant	Color
Iron oxides	greens, browns
Manganese oxides	deep amber, amethyst, decolorizer
Cobalt oxide	deep blue
Gold chloride	ruby red
Selenium compounds	reds
Carbon oxides	amber/brown
Mix of manganese, cobalt, iron	black
Antimony oxides	white
Uranium oxides	yellow green (glows!)
Sulfur compounds	amber/brown
Copper compounds	light blue, red
Tin compounds	white
Lead with antimony	yellow

and should be closely monitored by the operators. The sequence of operations are generally done as follows:

1. Weighing of all the RMs as per recipe with weight corrections for moisture & losses, if any.

is inspected and accepted for use, it has to be stored for further usage in batching plant. The process of unloading and storing in respective RM silos is known as silo feeding. There are generally 3 unloading bays- 1st for silica sand / quartz, 2nd for all other RM like soda ash, feldspar, dolomite and lime stone, 3rd for cullet. Fine chemicals are manually loaded in many companies using hoists or lifts as the daily quantity requirement is very less. Earlier days, bucket elevators were used for unloading of most of the raw materials but now pneumatic conveying is introduced for many RMs provided the moisture in it is very less. Pneumatic conveying is advantageous to prevent dust in batching plant and avoid manual labour for unloading. It is very convenient and faster.

to requirements. This will help in controlling the glass quality. For main raw materials except soda ash and fine chemicals, it is always advisable to use 3 stage magnetic separators to remove free iron and fine dust. This will help to reduce iron in glass as well as improve melting & save melting energy. While feeding RMs into silos, wherever possible, install hanging magnets or pipe magnets to catch iron (magnetic) contaminants. Contaminants can come from external source (with RM) or from internal sources. Hence it is important to catch these contaminants where ever possible till it goes inside the furnace.

Batching system: In batching, weighing of RMs as per the recipe and then releasing & mixing sequence is very important. It is done automatically

2. Once all the weighing is completed release RMs to running empty mixer in following order- release sand/ quartz first and when it is almost done, release soda ash. Once soda ash is completely released, then release other RMs like lime stone, dolomite, feldspar and fine chemicals (done directly into mixer manually or in auto as releasing it on conveyor with other RMs may have some spillage of it, resulting in loss of fine chemicals which is very less in quantity). It is important that silica / quartz grains get soda ash coating to enable it to melt in furnace quickly and effective, as explained in melting reaction

In silo feeding, there are bucket elevators, vibro-feeders, belt conveyors, diverters, shuttle conveyors etc., as shown in Figure 2.14. There can be few silos for silica and quartz storage for storage of the same from different quality / sources so that they can be used according

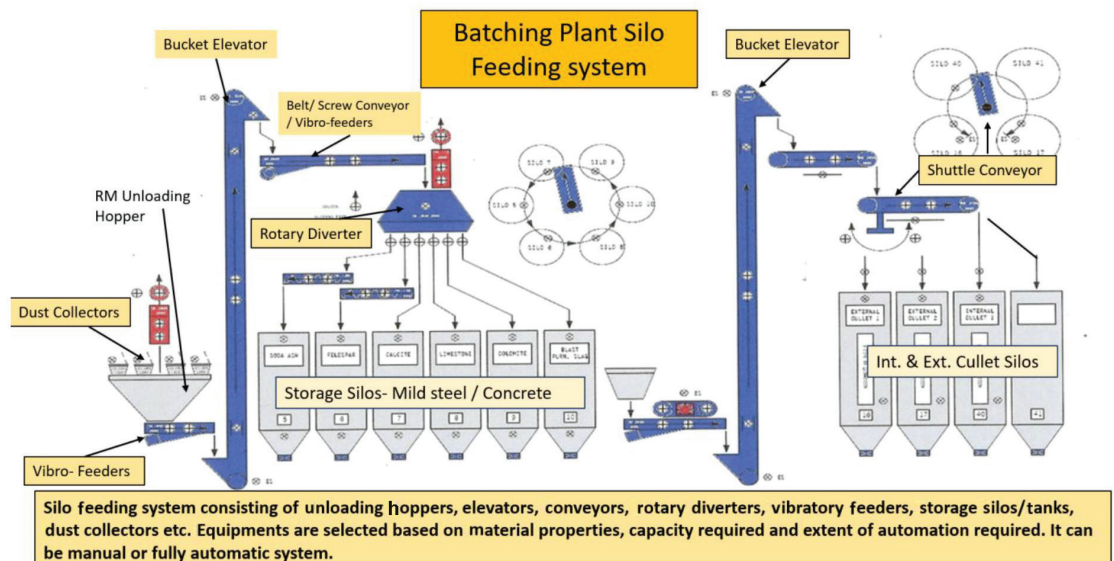


Figure 2.14

process. Simultaneously cullet weighing should be working separately and ready for release into batch after the mixer. (Cullet is not mixed in mixer as it can damage the mixer and hence cullet is dropped on batch after the mixer).

3. Mixing generally takes 5 minutes to mix the entire RMs. For initial 3 minutes, dry mixing and after this 2 minutes, wet mixing by adding water to maintain 2 to 3% total moisture in batch (considering moisture in RMs+ addition of water to get 2 to 3% moisture in batch). During mixing, the weighing of all the RMs will start as per the recipe and weight for next mixing cycle.
4. Once batch is mixed completely, it is released on to the surge hopper and then to batch conveyor. On this batch in conveyor, the cullet should be dropped such that it is completely released by the time the entire mixed batch is moved. The cullet should be spread over the batch such that it is uniformly mixed with batch while moving forward into hoppers, conveyors and day bin of furnace.
5. Once the batch from mixer is released completely, the mixer gate is closed and it then sends signal to system to release RMs again in sequence as above. So, the batch mixing is continued as per requirement in auto mode.
6. Generally, the mixing operation stops in auto mode, when the day bin level near furnace doghouse is reached full. Again, when the day bin

level drops to low level, the batching plant starts automatically. The operation of batch house in majority of companies work on auto mode with level sensors installed in dog house day bin. If there are two doghouse for one furnace, diverters are installed to divert batch to required silos, depending on silo levels.

7. In many manufacturing facilities, single batching plant supplies batch to many furnaces in auto mode. The recipe can be different or same for different furnaces. However, care should be taken to ensure that the batch shouldn't get mixed or contaminated when different recipe is used for different furnaces (especially when the same batching plant is used for different glass colors- flint, amber & green). When different recipe is used, separate mixer and batch conveying systems are used for each furnace to avoid mix-up or contamination of batch.

The auto batching diagram is shown in Figure 2.15.

The batching plant can be as big as 2000 TPD capacity depending upon the requirement of the plant

considering future expansion plans. M/s ZIPPE and M/s EME are the leading designers and suppliers of batching plants in the world and also there are other suppliers like M/s Eliar Turkey and M/s Glass Service s.r.l. Italy.

Important considerations in batching plant design & operation:

The accurate and reliable weighing, dosing and movement of raw materials used in glass production is critical to final glass quality. Like, how food recipe and preparation is important for human beings, the batch recipe and preparation is important to get good and consistent glass quality from furnace. Following are some of the procedures and of pre-requisites for good batching operation:

Design

- a) Weighing accuracy should be good and should have high repeatability/ reproductivity.
- b) For major RMs, the weighing tolerance can be +/- 100 gms. But for fine chemicals it can be +/- 1gm.
- c) The weighing system should have good auto-correction. Ex.: If in first batch 100 gms. of extra material is fed, then in

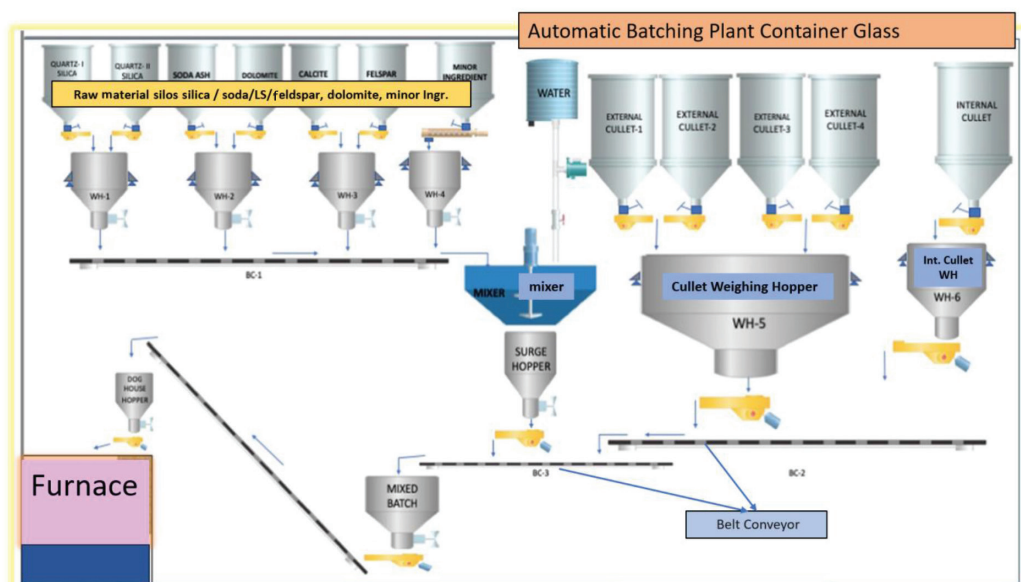


Figure 2.15

2nd batch, 100 gms. should be automatically reduced. This is for all RMs. In weighing hopper, after gate closing, if any material is left, it should be automatically corrected in new batch.

- d) All the equipments should operate very reliably especially gate opening and closing, diverters functioning, online moisture measurement etc.
- e) Weighing controls should be very effective. They should work on auto control feeds with weighing such that during start of weighing, the feeding to weigh hopper is at higher rate and when it is going to reach close to the set parameter, the feed rate should be slow so that the accurate weighing is achieved.
- f) Mixer performance should be excellent. Homogeneity of batch is very important to control to get desired glass quality and hence mixer should be very reliable and give required homogeneity of batch.
- g) Batch transport design is important to avoid spillage and batch segregation.
- h) All the weighing parameters to

be captured by SCADA or good control systems so that all the batch details can be monitored and data can be retrieved, as & when required.

- i) Design of silos, equipments should be of high standard to reduce contamination, wear and tear, breakdowns and glass quality problems (batch segregation, contamination, poor homogeneity), as wear and tear is high due to abrasive nature of RMs, provision of rings at 1 meter spacing is recommended, as shown in Figure 2.16.

Operation of Batching Plant: Good operational controls are necessary to get good quality batch from batching plant. Following are the important operation disciplines required in batching plant.

- a) Raw materials should be properly checked before unloading and storage. Good & clear SOPs for RM inspection, unloading and storage should be in place and practiced religiously.
- b) When common equipments like hoppers, elevators and conveyors are used for loading & unloading

of different raw materials, ensure good cleaning procedure, before using it for other materials. This is essential for avoiding mix-up of materials. Also have good interlock & automatic systems for silo feeding of raw materials to avoid mix-up. It is very common error in batching plants where operators many times make mistake in unloading resulting in mix-up, leading to loss of productivity, time and quality.

- c) Regular calibration of weighing system is required. In every shift, calibration of each weighing hopper once, is recommended.
- d) Batching sequence should be followed as per SOPs. Silica sand mixing with soda first should be ensured.
- e) Cleaning of mixers, silos, hoppers, equipments, magnets to be done regularly to avoid contamination and breakdowns.
- f) Timely maintenance of all equipments is very essential. Mixer and elevators should be given top importance as any breakdown in these equipments may disrupt production due to more time required for repair. Condition monitoring of critical equipments is recommended.

g) All the dust collectors should work effectively and there should not be dust in plant. Batching plant equipments can frequently fail if dust is too much.

h) Environment should be clean and no rain water should enter the building. There should be

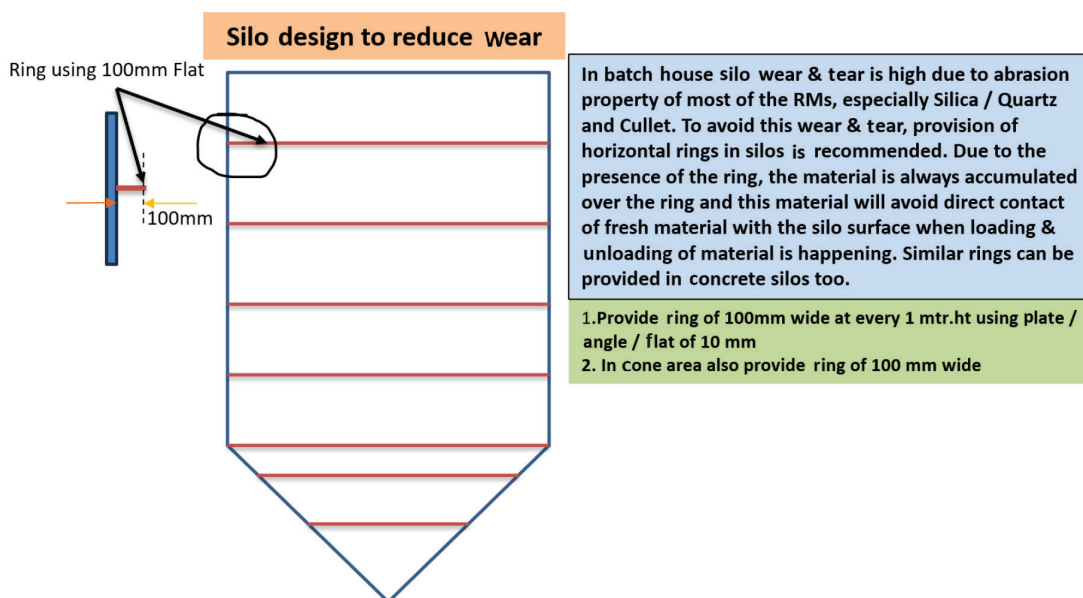


Figure 2.16

good ventilation system and good covering of batching plant to avoid entry of wind & rain. Top class housekeeping is required for smooth operation of the batching plant.

7.0 Quality controls in batch house

As batch house is responsible for quality of glass in terms of achieving desired physical & chemical properties of glass for producing good container bottles, it is very important that quality is maintained in every batching processes. Glass properties like density, glass colour, seeds & blisters, annealing temperature etc., are having direct relationship with glass recipe. Following controls are required in batching operation to get good quality of glass.

1. All incoming materials need to be checked thoroughly for physical and chemical properties and materials meeting the specifications only to be accepted for use in batch, as there are many variables in raw materials, deviations in any of the properties can impact glass quality. Few examples are-
 - a) Silica sand chemical analysis
2. Cullet sorting should be very good and contaminations should be below the limits. In few

is okay and meeting the specification, however the grain size is above specification. In this case, glass melting will be impacted, stones can appear in glass and bottle quality can be a major problem in all production lines.

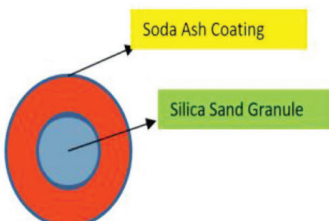
- b) Lime stone chemical analysis is okay but it has very high fine material. If this is used in batch, lot of dust can fly everywhere, batch segregation may happen and dust can go to regenerator & chimney. Glass composition also can be impacted due to loss of material in every stage of batching operation due to high fine dust in lime stone.
- c) Cullet physically looks okay but has high porcelain or microwave waste glass. These impurities are difficult to sort and if it is accepted to use, can result in glass knot, bubbles, blisters issues in glass.

organisations, cullet up to 95% is used. Hence cullet quality has direct bearing on quality of glass coming out of furnace. Enough eddy current separators, magnets need to be used to catch contaminants effectively.

3. During unloading care should be taken to avoid mix-up and contamination. Proper unloading procedure, cleaning procedure need to be strictly followed to eliminate these issues. If any mix-up or contamination incident occurs, it will take a few days to clear the glass and the entire production may have to be scrapped. Also, such scrapped glass (internal cullet) if used back in batch house, can create issue in glass again as the specification of the recycled cullet may be totally different and make it difficult to control the glass composition.
4. While making batch, operation should be watched carefully. Any malfunction in equipments, gate opening, sequence of RM releasing into mixer, errors in weighing and improper mixing can lead to melting & glass issues. To rectify the problem, if not noticed quickly, will take

Batching Ideas

1. It is very important to get good mixing so that batch homogeneity is excellent which will lead to energy saving in melting, good & consistent Glass quality.
2. Soda ash coating on silica sand granules will accelerate melting leading to lower seed count, lower SFC.
3. Proper distribution of cullet with batch is important to get good quality of Glass.
4. 6 to 12 mm cullet size helps in good melting.
5. Optimum moisture in batch is very important for melting / furnace operation. 2-3% moisture recommended.
6. Batch transportation is to be designed properly. Iron particles removal, batch segregation aspects to be evaluated.



Batch mixing sequence is very important to get very good Glass quality, improved melting and reduce SFC & seed count. The sand / quartz to be released first followed by soda and both should be mixed first for few seconds to get good soda ash coating on sand / quartz granules. The coating of soda on silica will accelerate dissolution of silica into glass and this will be achieved at lower temperature compared to uncoated granules without soda or coated with other materials. Once the dissolution of silica improves with soda coating at lower temperature. The melting becomes easy, melting energy requirement reduces, seed count improves.

Figure 2.17

few days to clear the glass in the furnace. Proper checklist should be prepared and monitored to avoid such issues. One example of such cases is that in one of the installations, the jack bolt above the load cell got loose in sand weigh hopper and bolt was touching the bottom frame of load cell mounting while sand filling for batching. This resulted in wrong weighing as one of the load cells had obstruction but the control system was showing the recipe weight correctly in panel. Since it was not noticed immediately, after 24 hours, the glass density became abnormal due to high silica in glass and entire production was scrapped till the problem got rectified.

5. Batching plant operators and furnace operators should have proper communication and provide quick feedback to each other to make small changes in operations, in case some abnormalities are observed. The feedback related to moisture in

batch, batch segregation, cullet segregation, seeds, bubbles, glass colour, melting issues may be immediately communicated to batch house team for finding if there are any abnormalities.

6. Batching plant & laboratory should have quick & proper communication channels. Any issue in batching will reflect in glass properties and hence to maintain consistent quality, getting the report from chemical lab & analysing to make corrections is an important task by batching team.

7. Batching operators should get regular bottle sample from production floor and look at glass quality like stone, bubbles, blisters, glass knots etc., and act quickly to rectify the problems, if it is related to batch or batching process. Also, should have good communication with quality/QA departments regarding defects related to glass (cordy glass, seeds, blisters, colour).

8. Control on internal cullet quality is important as there can be many possibilities of local contamination from various areas of operation. Sometimes along with rejected cullet, foreign materials are mixed if GMP is not followed and there are instances like moulds, iron pieces and packing materials getting mixed with internal cullet due to negligence by IS Machine operators, sorters and other maintenance people. Also, the internal cullet crushing quality need to be checked regularly. Install sufficient magnets in internal cullet conveyors, to catch any ferrous materials mixed accidentally, with cullet.

9. Figure 2.17 shows some important points to be noted in batching plant.

We have now understood importance of batching process in detail. Here we have a small root cause analysis chart (Figure 2.18) to act quickly, if similar glass problem occurs in your factory ■

Batching plant problems, root cause and remedy chart (related to batch only)

Sl. No.	Problem	Root Cause	Remedy
1	Increased stone in glass	1. Contamination in cullet Intl. or Ext. 2. Grain size high- silica, quartz and dolomite	1. Check cullet sorting 2. Check grain size of RMs 3. Check intl. cullet quality
2	Glass density decreased suddenly	1. Sand feeding high 2. Change in RMs quality 3. Weighing abnormality	1. Check sand scale 2. Check glass oxides by lab analysis 3. Check all weighing scales
3	Glass density increased suddenly	1. Soda feeding high 2. Weighing abnormality 3. Change in RMs quality	1. Check soda scale 2. Check all weighing scales 3. Check Glass oxides by lab analysis
4	Yellow lines in Glass	1. Contamination in cullet 2. Contamination in RMs	1. Check free iron in cullet 2. Check contamination in RMs
5	Increase in seeds and blisters	1. High contamination 2. Mixing abnormalities 3. Weighing abnormalities	1. Check RMs and batch 2. Check mixing 3. Check weighing scales
6	Increase in iron content in batch	1. Iron content high in RMs 2. Increase in iron contamination in cullet 3. Magnets not catching iron 4. Equipment parts missing and entered furnace (Especially from dog house silo or batch charger)	1. Check RMs quality & functioning of magnetic separators 2. Check cullet 3. Check magnets 4. Check equipments
7	Cordy Glass & bottles breaking in thermal shock	1. Abnormal batch change 2. Mixing issue 3. Segregation	1. Check changes made / weighing accuracy 2. Check homogeneity / mixer 3. Check batch transport / silo for segregation

Figure 2.18