

Glass and Cement

Unit 05

Topic Name - Glass

(subtopics - Definition, Composition, General characteristics, Raw Materials used in the manufacturing of glass, Colouring materials of Glass, types of Glass, Manufacturing of Glass and industrial applications of Glass.

Definition of glass : Due to the complexity and variability of glass, it is difficult to give its definition. Ordinary glass is the mixture of silica (SiO_2) i.e., sodium silicate calcium silicates. It is non-crystalline super cooled material. **Thorpe** gave the definition of glass as follows :

"Glass is a transparent or translucent super cooled liquid mixture of metallic silicates in which the presence of an alkali metal is necessary."

Composition of Glass

Glass is a mixture not a compound and it is not a true solid. Hence, it does not have any definite chemical composition. Due to its variability in composition and its amorphous nature it does not have any definite melting point. It does not have any definite chemical formula. It may be represented by the following possible general formula :



where, R = Alkali metal like Na and K etc.

M = Any divalent metal like Ca and Pb etc.

x and y are the number of molecules.

Example : The formula of glass may be written in following way :

- (i) Potash lime glass ($K_2O \cdot CaO \cdot 6SiO_2$)
- (ii) Potash lead glass ($K_2O \cdot PbO \cdot 6SiO_2$)
- (iii) Soda lime glass ($Na_2O \cdot CaO \cdot 6SiO_2$)

Example : The composition of glass used in electric bulb may be given as :

SiO_2 – 72.4%, Al_2O_3 – 0.8%, Fe_2O_3 – 0.4 %

CaO – 5.3%, MgO – 3.7%, Na_2O – 17.4%

General Characteristics of Glass

Glass is having the following characteristics :

- (i) It is a brittle transparent or translucent, amorphous and super cooled liquid mixture of metallic silicates. It is hard in solid state.
- (ii) It melts on heating.
- (iii) It is very hard and it can be polished.
- (iv) It is not affected by air and water.
- (v) It is non-conductor of heat and electricity.
- (vi) It does not have any definite melting point.
- (vii) Its compressive strength is more.
- (viii) Generally, it is not affected by acids and bases.
- (ix) It dissolves in hydrofluoric acid (HF) and forms SiF_4 compound.
- (x) Its coefficient of expansion is high.
- (xi) Its can be moulded in various shapes by melting.

Raw Materials Used in the Manufacture of Glass

The following raw materials are used in the manufacture of glass :

(1) Acidic oxides : The use of acidic oxides depends upon the quality of glass. Some of the important acidic oxides are as follows:

(a) Silica (SiO_2) : The sand used in the manufacture of glass should be in the form of pure quartz. It should not have organic impurities and iron oxides. The size of particles of sand should be proper.

(b) Boron trioxide (B_2O_3) : It is used in the form of boric acid (H_3BO_3) or borex ($\text{Na}_2\text{B}_4\text{O}_7 \cdot 10\text{H}_2\text{O}$).

It is used to reduce the coefficient of expansion of glass. Specially it is used in the manufacture of pyrex glass.

(c) Phosphorus pentaoxide (P_2O_5) : It is used in the form of calcium phosphate [$\text{Ca}_3(\text{PO}_4)_2$]. It is used in the manufacture of opalescent glass.

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(2) **Basic oxides :** The following basic oxides are used in the manufacture of glass :

(a) **Lead oxide :** It is used in the form of lead tetra oxide or litharge (PbO).

(b) **Calcium oxide (CaO) :** It is in the form of lime stone or CaCO_3 .

(c) **Sodium oxide (Na_2O) :** It is used in the form of sodium hydroxide (NaOH) or sodium carbonate (Na_2CO_3) or sodium nitrate (NaNO_3) or sodium sulphate (Na_2SO_4). It may be used in the mixture of the above compounds.

(d) **Potassium oxide (K_2O) :** It is used in the form of potassium carbonate (K_2CO_3) or potassium nitrate (KNO_3).

(e) **Barium oxide (BaO) :** It is used in the form of BaCO_3 .

(f) **Lithium oxide (Li_2O) :** It is used in the form of Li_2CO_3 .

(g) **Cullets :** The broken pieces of glass are called 'cullets'. They are used to increase the feasibility of glass and it reduces the melting point of glass.

Colouring Materials of Glass

Colouring Materials of Glass

At the time of manufacture of glass to impart the desired colour to the glass some colouring compounds are mixed in the glass. To obtain the glass of various colours, various colouring compounds are mixed in it. The compounds may be mixed in the solid or molten state. Some colouring compounds may be given in the following table :

S.No.	Name of the compound/substance used	Colour of Glass
1.	Ferric oxide (Fe_2O_3)	Red-brown
2.	Ferrous oxide (FeO)	Green
3.	Manganese oxide (MnO_2)	Black or Violet
4.	Carbon (C)	Amber like colour
5.	Cupric oxide (CuO)	Blue
6.	Sulphur (S)	Brown
7.	Tin oxide (SnO_2)	Milky white
8.	Cadmium sulphide (CdS)	Yellow
9.	Potassium-di-chormate ($\text{K}_2\text{Cr}_2\text{O}_7$)	Green yellow
10.	Sodium chromate (Na_2CrO_4)	Green
11.	Copper sulphate ($\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$)	Peacock blue
12.	Gold chloride	Ruby red
13.	Selenium oxide (SeO_2)	Orange red
14.	Nickel oxide (NiO)	Black
15.	Cobalt oxide (CoO)	Black
16.	Selenium (Se)	Red

Classification and Composition of Different Types of Glass

Glass is of the following types :

(1) **Soft glass :** It is also called soda glass. It is the mixture of sodium silicate (Na_2SiO_3) and calcium silicate (CaSiO_3). Its approximate percentage of composition is : Na_2O – 13 to 15%, CaO – 13 to 14%, SiO_2 – 70 to 73%. Its formula is $\text{Na}_2\text{O} \cdot \text{CaO} \cdot 6\text{SiO}_2$. It melts easily hence it is called soft glass. It consists of 2% Al_2O_3 as an impurity.

It is used in the manufacture of window panes, bottles and electric bulbs etc. It softens on heating at 600°C temperature.

(2) **Hard glass :** It is also called potash lime-glass. It is the mixture of potassium and calcium silicates. It is manufactured by heating the mixture of K_2CO_3 and CaCO_3 with silica at about 1200°C to 1300°C . Comparatively it melts at high temperature hence it is called hard glass. Its formula is $\text{K}_2\text{O} \cdot \text{CaO} \cdot 6\text{SiO}_2$. It is unaffected by water and acid. It is costlier as compared to soda glass. It is used in the manufacture of laboratory instruments. It softens on heating at about 800°C temperature.

(3) **Flint glass :** It is also called potash lead glass. It is manufactured by heating the mixture of Na_2CO_3 , K_2CO_3 , PbCO_3 , H_3BO_3 and silica. Its formula is $\text{K}_2\text{O} \cdot \text{PbO} \cdot 6\text{SiO}_2$. Its refractive index is more. It consists of SiO_2 – 45%, Na_2O – 4%, K_2O – 4%, CaO – 3% and PbO – 44%. It is used in the manufacture of lens, prism and artificial jewellery.

(4) **Pyrex or Jena glass :** It is the mixture of boron silicates of sodium (Na) and aluminium (Al). Its percentage composition is – SiO_2 – 81%, B_2O_3 – 12%, Al_2O_3 – 2.8% and Na_2O – 4.2%. Its coefficient of expansion is less hence it does not break with incidental changes. It is used in the manufacture of high quality laboratory apparatus, television, tube and pipe lines etc.

(5) **Crooks glass :** It consists of oxides of rare earth metals. It consists of cerium oxide. It has a characteristic to stop the ultraviolet rays entering into the eyes. It is soft and having low melting point. It is used in the manufacture of lenses of goggles.

(6) **Quartz glass :** It is prepared by heating and melting silica or quartz in electric furnaces at high temperature. It has very less coefficient of expansion. It is unaffected by chemical reagents, acids and bases. It allows to pass the ultraviolet rays through its objects.

(7) **Glass wool :** When melted glass is passed through small pores at high temperature and pressure in the presence of jets of steam, very fine fibres of glass are obtained. These fibres are used as non-conductor materials in the manufacture of heat

Manufacture of Glass

First of all the raw materials used in the process are finely powdered separately and mixed in the proper medium to form a homogenous mixture. This mixture is again finely powdered. This mixture is now called '**batch**'. To prepare the ordinary glass sand (SiO_2), sodium carbonate (Na_2CO_3) and lime stone (CaCO_3) are mixed in the ratio of 100 : 35 : 15. Now some cullets are mixed in this batch and the mixture is melted. The broken pieces of glass are called '**cullets**'. The quantity of cullet may be at least 10% and maximum up to 80% of the total charge. For the fusion of glass two types of furnaces are used :

- (i) Pot furnace
- (ii) Tank furnace

(1) **Pot furnace :** It is shown in the Fig. 5.1.

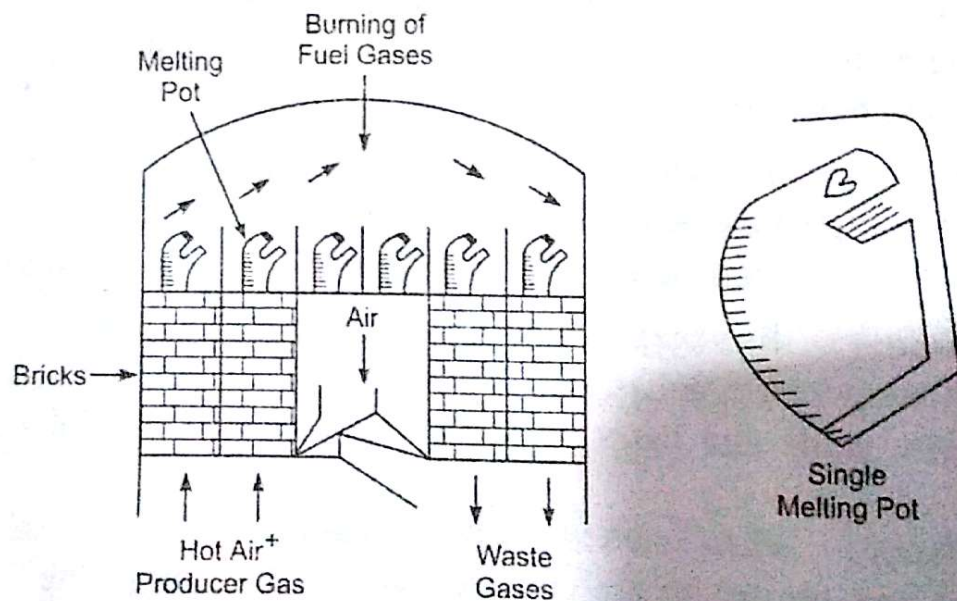


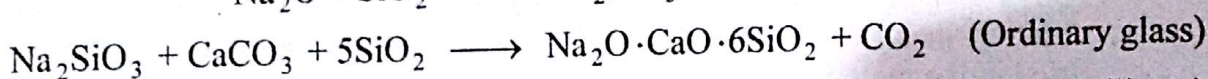
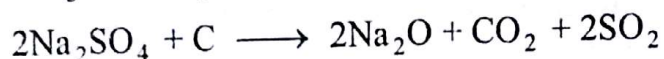
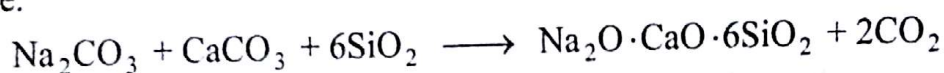
Fig. 5.1 Pot Furnace

In this furnace there are big monkey shaped pots which are made up of fire clay. They are arranged in a circular way. This furnace is based on regenerative principle. The mixture of raw materials of glass is fused by producer gas. To prepare the coloured glass various colouring materials are mixed in the mixture. The furnace is heated at about 1400°C to 1500°C temperature. Its capacity is about two tonnes. We obtain the good quality glass from this furnace. The manufacture of glass takes about 10–12 hours.

(2) **Tank furnace :** It is shown in the fig. 5.2.

It is a rectangular furnace made up of fire clay soil. It is of about 125 feet long, about 1400 tonne of molten glass. The mixture of this furnace is fused by producer gas. This furnace is based on regenerative principle of **William Siemens**.

The following chemical reactions occur during the manufacture of glass in this furnace.



The melted glass is heated until CO_2 and SO_2 gases are evolved completely.

Now, we add the desired colouring materials in the molten glass. Now it is cooled and moulded into different types of objects. Generally, tank furnace is used for the manufacture of glass.

Annealing of glass : It is most important and necessary process. If the freshly prepared articles of glass are cooled hurriedly then due to the non-conductor of heat an uneven contraction of glass takes place. As a result internal strain is produced because the outer part of glass cools first than that of internal part of the article. Hence, the possibility of breaking the glass articles is increased. Hence, the cooling of hot glass articles with a slow rate is called '**annealing of glass**'.

The process of annealing of glass is done in a 20 fit long furnace which is called '**leher furnace**.' The temperature of one end of furnace is 600°C and it remains like an ordinary temperature up to the other end. In this furnace the freshly prepared articles of glass are sent from hot end to the cold end through a moving belt hence the glass is cooled slowly

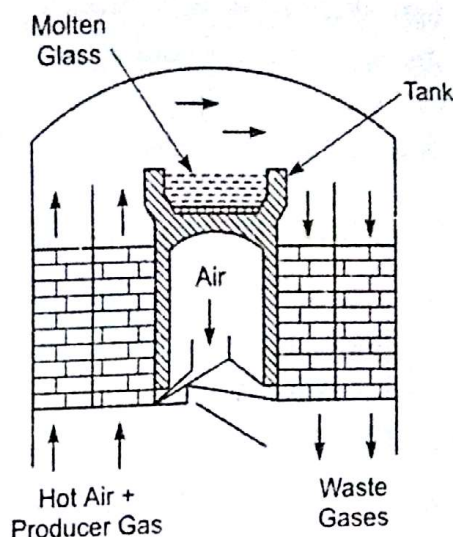


Fig. 5.2 Tank Furnace

Industrial Applications of Glass

The industrial applications of glass are as follows :

- (1) Soft glass is used in the manufacture of glass tubes, plates, bottles, electric bulbs, test tubes and other instruments. It is also called 'crown glass'.
- (2) Hard glass is used in the manufacture of laboratory instruments working at high temperature *e.g.*, flask etc. It is unaffected by water and acids. It is comparatively costlier than that of soft glass.
- (3) Flint glass is used in the manufacture of lenses of camera and telescope, prism, bulb, radio valve etc. It is also used in the manufacture of optical instruments.
- (4) Pyrex glass is used in the manufacture of high quality instrument of laboratory and utensils of cooking the food because it does not break with change in temperature. It is also used in the manufacture of chemical instruments, electrical insulators and pipe lines etc.
- (5) Crooks glass is used in the manufacture of lenses of goggles. It prevents the ultraviolet rays of sun from coming in the eyes.
- (6) Silica or quartz glass is used in the manufacture of crucible, tubes and other special types of instruments. The ultra violet rays are passed through this glass hence it is used in the manufacture of ultraviolet lamps.
- (7) Glass wool fibres are used as non-conductors in the manufacture of heat resistant curtains and fire proof clothes etc. It is not affected by water, moisture and chemical substances.
- (8) Laminated safety glass is used in the manufacture of window panes used in the manufacture of windows, aeroplanes etc.
- (9) Safety glass is used in the manufacture of window panes of aeroplanes.
- (10) Alumino silicate glass is used in the manufacture of domestic instrument and mercury discharge tube etc.