Definition of Glass:

Glass is an amorphous, hard, brittle, transparent or translucent, super-cooled liquid, obtained by fusing a mixture of a number of metallic silicates, most commonly Na, K, Ca and Pb". It possesses no sharp melting point, crystalling structure and definite formula Represented as $xR_2O.\ yMO.\ 6SiO_2$

R = monovalent alkali metals like Na, K

M = Divalent metals like Ca, Pb, Zn, etc

x & y = whole numbers

General Properties of glass:

1. Amorphous Solid
2. No definite melting point
3. Very brittle
4. Softens on heating
5. Can absorb, reflect and transmit light
6. Good electrical insulator
7. Affected by alkalis
8. Not affected by air, water, acid or chemical reagents.
9. But soluble in HF which converts into SiF_4.
10. Possesses high compressive strength and since it doesn't have any crystalline structure, no slippage between planes can occur.
11. Light in weight because it has homogeneous internal structure similar to liquids

Glass Manufacturing:

Manufacturing of glass consists of following high level steps

1. Melting

a. Pot furnace b. Tank furnace

2. Forming and shaping
3. Annealing
4. Finishing

Melting: Raw materials in proper proportions (sand, soda ash and lime stone) are mixed and finely powdered. The homogenous mixture known as Batch is fused with some broken glass, called "Cullet" in any of the two types of furnaces. The homogeneous mixture is melted either in

a. Pot furnace or b. Tank furnace.

The batch melts and fuses at 1800 ^oC.

Melting:

Pot furnace: Two types of pots are used (a). Open crucible type pot (b). Closed covered type pot. Generally closed covered type pot is used. Pot is placed in a circle around a central opening in its bottom. Heated by burning producer gas and air. Roof of the pot is constructed with refractory material which also reflects the heat. Also called as batch process.

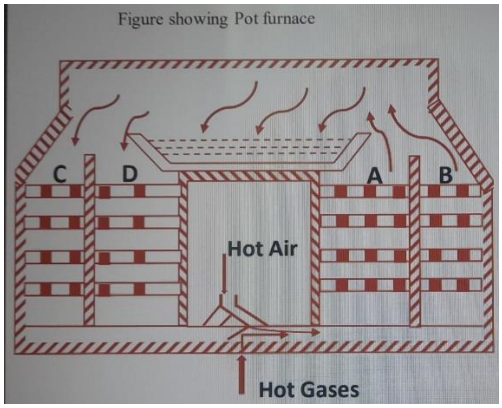

Figure showing Pot furnace

Tank Furnace:

The “batch” is melted in the tank using producer gas and air. It follows “regenerative system of heat economy”. Air and fuel are passes through A & B. The burnt gases are deflected by the roof and “batch” gets melted. Hot waste gas escapes through firebricks C & D. The direction of the fuel gas & air is reversed through C & D, which absorbs the heat of the waste gas and burns. The waste gas now escapes through A & B.

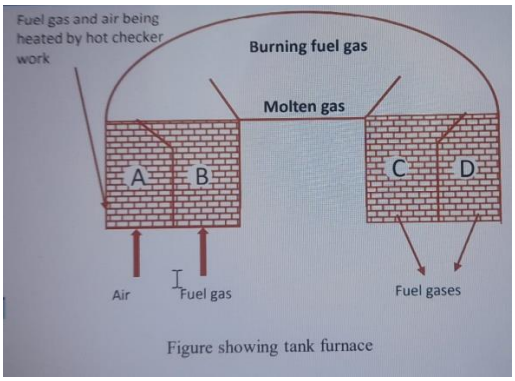

Figure showing tank furnace

Chemical reactions:

Cullet melts at relatively low temperature and assists in melting of rest of the charge. During the melting process following reactions occur:

$CaCO_3 + SiO_2 \rightarrow CaSiO_3 + CO_2$

$Na_2CO_3 + SiO_2 \rightarrow Na_2SiO_3 + CO_2$

The molten mass is heated till its free from air bubbles. For coloured gases desired pigment is added. The molten mass is then cooled at about 800 ^oC at later point of time.

Forming & Shaping, Annealing and Finishing:

Molten gas is converted to desired shape by blowing or moulding or pressing between rollers and the process is called "Forming and Shaping". In the "Annealing" process the articles are then cooled gradually at room temperature. The longer the annealing period better the quality of glass. After annealing, the articles are subjected to cleaning, polishing, cutting, sand blasting etc., "Finishing".

Types of glasses:

1. Soda-lime or soda glass
2. Potash lime or hard glass
3. Lead glass or Flint glass
4. Borosilicate glass or Pyrex glass or Jena glass
5. Alumina silicate glass
6. Optical or Crookes glass
7. Glass wool
8. Quartz glass
9. Opal glass

Soda-lime (or) Soft glass:

Raw Materials:

1. Silica, SiO_2
2. $CaCO_3$
3. Soda ash

Composition: $Na_2O.\ CaO.\ 6SiO_2$

Properties:

(i) Low cost,

(ii) Resistant to water,

(iii) Attacked by acids

(iv) Melts easily

(v) Moulded easily to any shape

(vi) Poor thermal & chemical resistance

Uses: Window glasses, electric bulbs, bottles, jars, table wares etc.,

Lead glass (or) Flint glass:

Raw Materials (i). Silica, SiO_2 (ii). Lead Oxide, PbO_2 (iii). Potassium Oxide, K_2O

Composition: K_2O. PbO. $6SiO_2$

Properties:

(i). Bright, lustrous and possesses high specific gravity

(ii). Expensive to manufacture, than ordinary lime-soda glass

(iii). Lower softening temperature than soda-lime glass

(iv). Higher refractive index and excellent electrical properties

Uses: (i). High quality table wares, neon sign tubings, optical lenses.

(ii). High dense glasses are used for windows to protect from X-rays and gamma rays.

Armoured glass: One-way bulletproof glass is composed of two layers. **The outside layer – on the threat side – is made of a brittle glass and the inside layer is a flexible polycarbonate**. A bullet that strikes the brittle external layer first causes the glass to break inward toward the polycarbonate layer. Newer, stronger kinds of bulletproof glass use a sandwich of glass and plastic made of acrylic glass, ionoplast polymers (such as Sentry Glas®), ethylene vinyl acetate, or polycarbonate, with the thick glass and plastic layers separated by thinner films of various plastics, such as PVB or polyurethane.

The bulletproof glass normally synthesized from laminating multiple layers of glass with a layer of polymer material in between them.

Composition: The polymer which are usually used in the formation of bulletproof glass are given below:

(i). Polycarbonate:

(ii). Polyvinyl butyral (PVB):

(iii). Ethylene-vinyl acetate (EVA):

(iv). Acrylic

Properties of bullet proof glass:

The key properties of bullet proof glass has given below:

1. High impact resistance:
2. Multiple layers:
3. Customizable thickness:
4. Optical clarity:
5. Durability:
6. Fire resistance:
7. Sound insulation:

Borosilicate:

Borosilicate glasses (e.g. Pyrex, Duran) typically contain **5–13% boron trioxide (B2O3).** Borosilicate glasses have fairly low coefficients of thermal expansion (7740 Pyrex CTE is 3.25×10^{-6}/°C] as compared to about 9×10^{-6}/°C for a typical soda-lime glass). They are, therefore, less subject to stress caused by thermal expansion and thus less vulnerable to cracking from thermal shock. **They are commonly used for e.g. labware, household cookware, and sealed beam car head lamps.**

Safety Glass:

It is glass with additional safety features that make it less likely to break, or less likely to pose a threat when broken. Common designs include toughened glass (also known as tempered glass), laminated glass, wire mesh glass (also known as wired glass) and engraved glass.

These four approaches can easily be combined, allowing for the creation of glass that is at the same time toughened, laminated, and contains a wire mesh. However, combination of a wire mesh with other techniques is unusual, as it typically betrays their individual qualities. Toughened glass is processed by controlled thermal or chemical treatments to increase its strength compared with normal glass. Tempering, by design, creates balanced internal stresses which causes the glass sheet, when broken, to crumble into small granular chunks of similar size and shape instead of splintering into random, jagged shards. The granular chunks are less likely to cause injury.

Laminated glass is composed layers of glass and plastic held together by an Interlayer. When laminated glass is broken, it is held in place by an interlayer, typically of polyvinyl butyral (PVB),

between its two or more layers of glass, which crumble into small pieces. The interlayer keeps the layers of glass bonded even when broken, and its toughening prevents the glass from breaking up into large sharp pieces. This produces a characteristic "spider web" cracking pattern (radial and concentric cracks) when the impact is not enough to completely pierce the glass.

Wire mesh glass (also known as Georgian Wired Glass) has a grid or mesh of thin metal wire embedded within the glass. Wired glass is used in the US for its fire-resistant abilities, and is well-rated to withstand both heat and hose streams. This is why wired glass exclusively is used on service elevators to prevent fire ingress to the shaft, and also why it is commonly found in institutional settings which are often well-protected and partitioned against fire. The wire prevents the glass from falling out of the frame even if it cracks under thermal stress, and is far more heat-resistant than a laminating material

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Fluorosilicate glass(FSG):

It is a glass material **composed primarily of fluorine, silicon and oxygen.** It has a number of uses in industry and manufacturing, especially in semiconductor fabrication where it forms an insulating dielectric. The related fluorosilicate glass-ceramics have good mechanical and chemical properties.

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They find a number of uses and can be used in high vacuum and as dielectrics and precision ceramic components. A number of mica and mica-fluoroapatite glass-ceramics were studied as biomaterials.

Photosensitive glass:

It is also known as protostructure glass (PSG), or photo machinable glass, is a crystal-clear glass that belongs to **the lithium-silicate family of glasses,** in which an image of a mask can be captured by microscopic metallic particles in the glass when it is exposed to short wave radiations such as ultraviolet light. Photosensitive glass was first discovered by S. Donald Stookey in 1937.

Photosensitive glass contains microscopic metallic particles. These microscopic metallic ion nanoparticles are made of gold or silver which is responsible for the refractive index change. **Photosensitive glass** is similar to photographic film.

Coloured Glass:-

These are produced by the addition of metallic oxides to soda lime silica glass. Chromium oxide produces green colour, Cobalt produces blue colour, Iron produces greenish blue colour ,& Gold, Copper, Selenium, Colloidal particles produces red colour.

Uses:- Used for window panels , fancy articles, decorative tiles etc.