



Swami Keshvanand Institute of Technology Management & Gramothan Jaipur

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CHAPTER-ENGINEERING MATERIALS

TOPIC: GLASS



Glass

CONTENTS

- **Glass: Definition**
- **Glass: Manufacturing by tank furnace**
- **Significance of Annealing,**
- **Types of Glass**
- **Properties of soft glass, hard glass, borosilicate glass, glass wool,safety glass**



Glass

Introduction-Glass

- An inorganic product of fusion which has cooled to a rigid condition without crystallizing.
- Uniform amorphous solid i.e.-
 - will only have ONE refractive index.
 - have atoms randomly arranged throughout the sample.
- Glass combines some properties of crystals and some of liquids but glass is distinctly different from both.
- Glass is rigid like a crystal but the molecules that make up glass are arranged randomly like liquids.



Glass

- In general glass is formed by melting crystalline substances and then cooling the liquid before the molecules can form a crystal.
- Glass is an amorphous, hard, brittle, transparent, or translucent, super cooled liquid of infinite viscosity, obtained by fusing a mixture of metallic silicates, most commonly of Na,K,Ca, and Pb.
- It has no sharp melting point and definite structural formula.
- It may be represented as $xR_2O.yMO.6SiO_2$,
 - ✓ Where R is an atom of a monovalent alkali metal like Na, K, etc.
 - ✓ M is an atom of a bivalent metal like Ca,Pb,Zn, etc.
 - ✓ x and y are whole numbers



Glass

- In some glasses, SiO_2 is replaced by Al_2O_3 , B_2O_3 , P_2O_5 , etc.
- General formula of ordinary glass or soda-lime glass is $\text{Na}_2\text{O} \cdot \text{CaO} \cdot \text{SiO}_2$.
- Soda-lime glass also known as soft glass.
- Potash –lime glass known as hard glass.



Glass

Properties of Glass: Physical properties

- **Mechanically Strong** – Glass has great inherent strength and is weakened only by surface imperfections.
- **Hard surface** – Glass resists scratches and abrasions.
- **Elastic** – Glass “gives” under stress – up to a breaking point – but rebounds exactly to its original shape.
- **Thermal shock-resistant** – Glass withstands intense heat or cold as well as sudden temperature changes.
- **Super cooled liquid**-liquid which is cooled to a stage where its viscosity is so great that the molecules do not move freely enough to form crystals.



Glass

- **Heat-absorbent** – Glass retains heat, rather than conducts it. Glass absorbs heat better than metal.
- **Optical Properties** – Glass reflects, bends, transmits and absorbs light with great accuracy.
- They have high viscosity.
- It has no sharp melting point
- They are transparent and amorphous solids.
- Glass is completely vitrified product.



Glass

Devitrification-

- When glass is softened by heating and kept as such for a long time.
- It appears to lose its transparency on account of the crystallisation of the individual silicates i.e. the formation of Na_2SiO_3 and CaSiO_3 .
- This phenomenon is called devitrification of glass.

Vitrification-

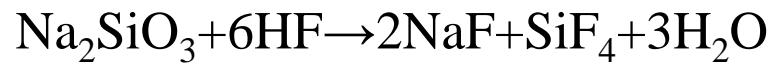
Fused mixture of Na_2SiO_3 and CaSiO_3 is called as vitrification.



Glass

Chemical properties

- **Chemical corrosion-resistant** – Glass is affected by few chemicals. It resists most industrial and food acids.
- It is readily attacked by alkalies.
- It is not affected by air, water and oxidizing agents.
- It is very resistant to acids, except HF acid (which dissolve glass), reacts with HF to form SiF₄





Glass

Raw materials used in manufacturing glass

- Sodium as Na_2CO_3 (used in soft glass).
- Potassium as K_2CO_3 (used in Hard Glass).
- Calcium as CaCO_3 lime stone, chalk and lime.
- Lead as litharge, red lead (flint glass).
- Silica arc quartz, white sand and ignited flint.
- Zinc is zinc oxide (Heat and shock proof glass).
- Borates are borax, Boric acid (Heat and shock proof glass).
- Cullet's or pieces of broken glass to increase fusibility.



Glass

Raw materials used in manufacturing glass

- Modifiers: To reduce the melting and working temperatures.Eg-IA gp,IIA Gp, PbO, ZnO.
- Melting and refining agents: Removal of small gas bubble from the glass in small amount,eg- Na_2SO_4 , NaNO_3 , NaCl .
- Fluxes-Softeners- Na_2O , K_2O , LiO , Al_2O_3 , B_2O_3 , Cs_2O
- Stabilizers – Provide Chemical Resistance- CaO , MgO , Al_2O_3 , PbO , SrO , BaO , ZnO , ZrO
- Decoloring Salts- antimony oxide (Sb_2O_3), arsenic oxide (AS_2O_3), cobalt oxide (CoO), manganese dioxide (MnO_2) and nickel oxide (NiO).



Glass

Colors-Coloring salts

Yellow- ferric salt

Green- ferrous and chromium salts

Blue- cobalt salts

Purple-manganese dioxide

Red- nickel salts or Cu_2O

Fluorescent greenish- yellow- uranium oxide

Opaque milky white- Cryolite (Na_3AlF_3) or calcium phosphate.



Glass

➤ Glass: Manufacturing by tank furnace

Manufacturing Steps:

- 1.Melting
- 2.Forming and Shaping
- 3.Annealing
- 4.Finishing



Glass

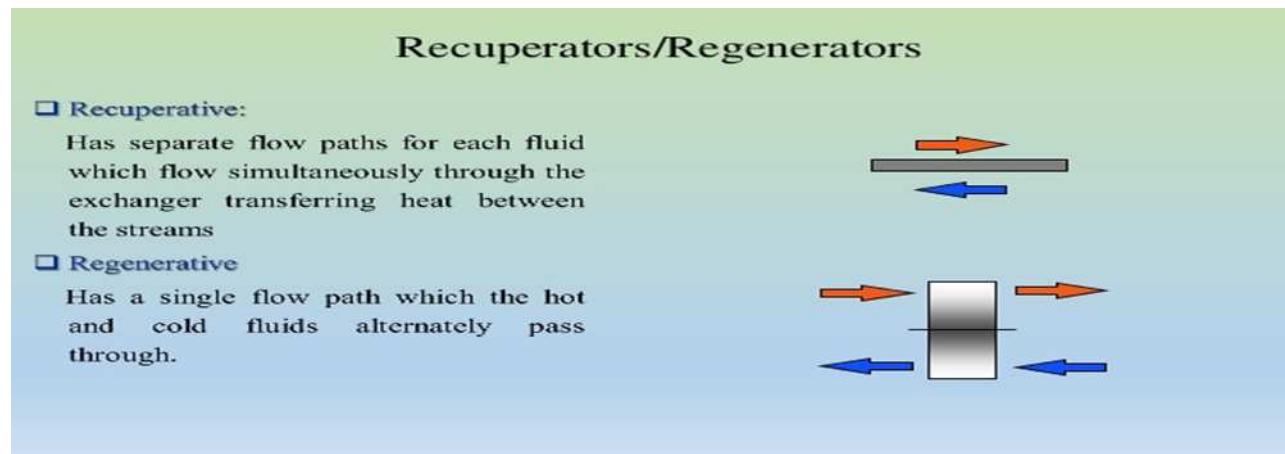
1. Melting :

- Raw materials (e.g. sand, soda, ash and limestone for common glass) in proper proportions are mixed with cullet's.
- The cullet indicates waste glass or pieces of broken glass.
- The raw materials and cullet are finely powdered in grinding machines.
- It is finely powdered and intimate mixture called batch is fused in furnace at high temperature of 1800°C this charge melts and fuses into a viscous fluid.
- The batch is melted either in a pot furnace or in a tank furnace. The heating is continued until the evolution of carbon dioxide, oxygen, sulphur dioxide and other gases stops.



Glass

- Both pot and tank furnace can be of regenerative or recuperative type.
- Regeneration-The utilization of heat of flue (waste) gases for heating the incoming gaseous fuel and air mixture.
- Recuperation-Same as that of regeneration i.e. Utilization of heat of waste gases and production of higher temperatures in the furnace, but different in the sense that incoming gases flow continuously in one direction only.





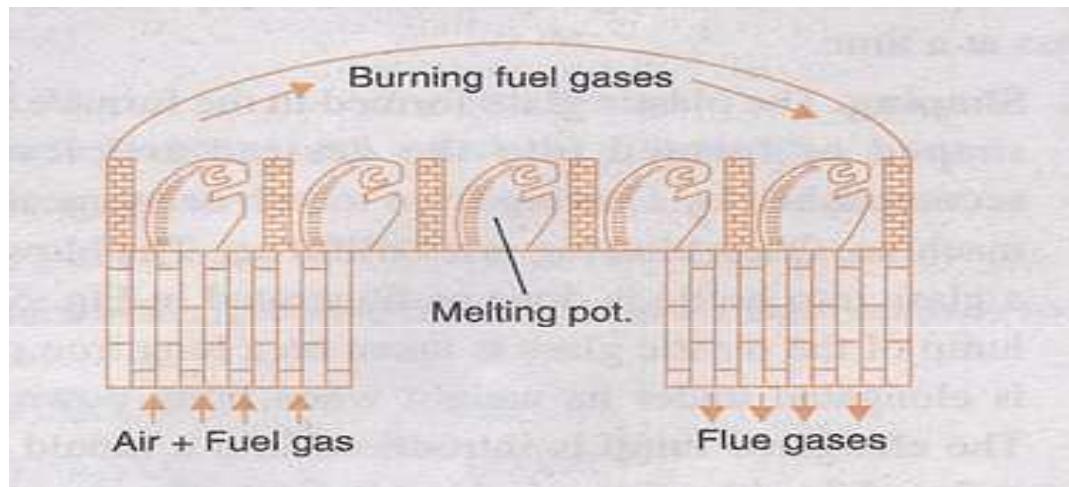
Glass

1. Pot Furnace.

- In this furnace, the charge is fused in fire clay pots.
- The pots may be opened or closed.
- The closed pots are used when the-glass is to be protected from the products of combustion.
- The batch materials are put in the pots.
- They are placed in a circle inside a furnace and heated by burning producer gas around them (Fig.).



Glass



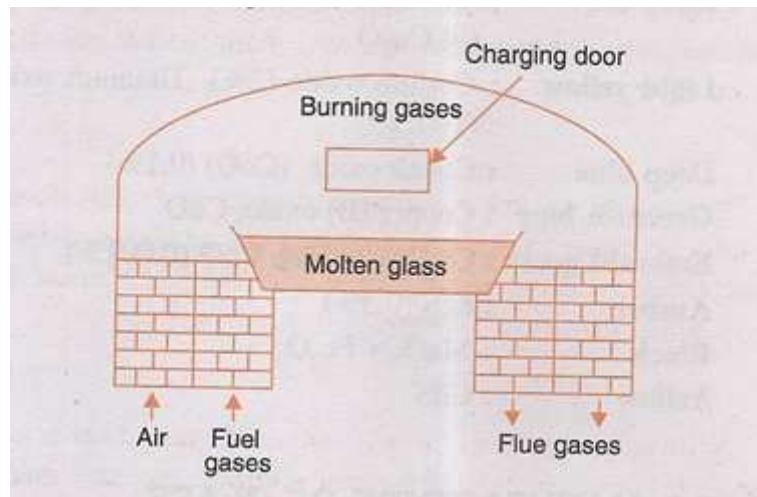
- When the fusion is complete the pots are removed from the furnace and the fused plastic mass is taken out for shaping.
- Pot furnace are used to prepare optical glass, special glass and high quality glass (fine quality glass).



Glass

2. Tank Furnace.

- It consists of a large rectangular tank built of fire clay blocks.
- The batch materials are fed into the tank and producer gas is used as a fuel in the furnace. (Fig.).





Glass

The charge is heated at 1400°- 1500°C for 10-12 hours. The chemical reactions involved in both the furnaces are:

- $\text{Na}_2\text{CO}_3 + \text{SiO}_2 \rightarrow \text{Na}_2\text{SiO}_3 + \text{CO}_2$
- $\text{CaCO}_3 + \text{SiO}_2 \rightarrow \text{CaSiO}_3 + \text{CO}_2$

At 1400°C silica also in silicates of calcium and sodium





Glass

- During the melting lot of frothing is caused owing to the evolution of the gases like CO_2 , SO_2 , O_2 , etc.
- When the frothing subsides, the temperature is raised and the molten glass is allowed to stand for some time. This is called refining, and its objective is to form a homogeneous mass free from gas bubbles and bits of undissolved material or batch stones.
- Tank furnace is a continuous process and usually employed for the production of large quantities of only one variety of glass at a time.



Glass

- When all the carbon dioxide has escaped out of the molten mass, decolorizers (such as MnO_2 or nitre) are added to do away with ferrous compounds and carbon if present.
- If a coloured glass is desired, the colouring salts are added at this stage.
- Heating is continued, till the molten mass is free from bubbles and glass-balls and then cooled to about 800°C .



Glass

2. Forming and Shaping:

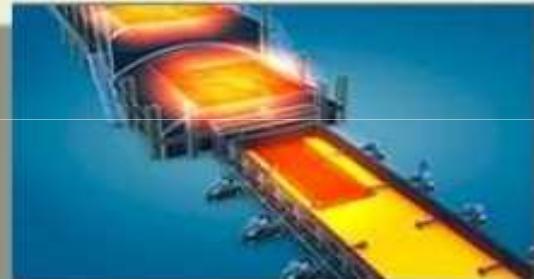
The viscous mass obtained from melting is poured into moulds to get different types of articles of desired shape by either blowing or pressing between the rollers.

- **Pressing** - Moulds of the required shapes are filled with the molten glass. It is then cooled while under desired pressure. Sheets of glass are made by this method.
- **Blowing**- Air is blown in a controlled manner through the molten glass in proper containers. This air pressure drags the glass liquid to a desired shape.
- **Drawing** - In this process, stream of molten glass is made to pass through the molten rolls. It comes out from the other side in the desired drawn form on cooling.



Glass

Manufacturing





Glass

3. Annealing: After shaping glass articles are cooled very slowly and this process of slow cooling ,which is used to reduce the strain ,is known as annealing.

Significance of annealing:

- Glass is bad conductor of heat i.e. insulator and cannot be cooled rapidly.
- If it is cooled rapidly the superficial layer (outer surfaces) cools down more quickly than the inner layer (internal portion).
- This unequal cooling causes internal strain and cause to crack or break.
- Due to this reason glass articles are then allowed to cool gradually at room temperature by passing through different chambers with descending temperatures.
- This reduces the internal strain in the glass and this process is known as **annealing**.



Glass

Annealing Process-Annealing Process is carried out in annealing lehrs or annealing chambers.

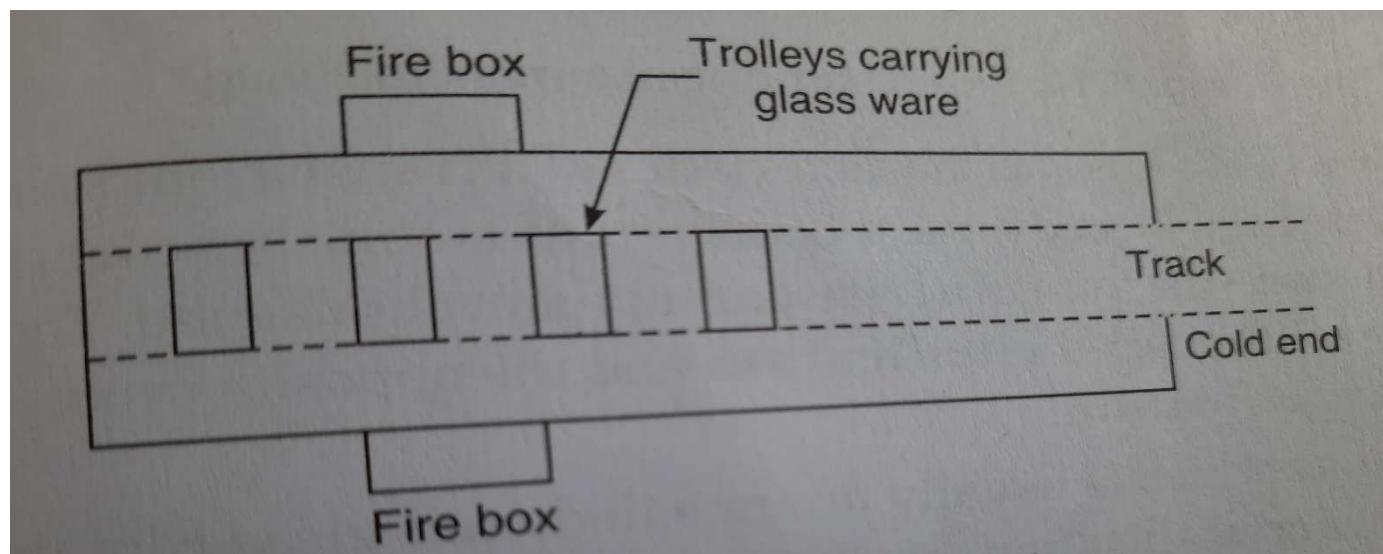
Annealing lehrs- Commonly used

- Annealing is done in a tunnel like oven called lehr which is 50 to 60 feet long.
- At one end the temperature is a little below the softening point of glass, i.e., $500-600^{\circ}\text{C}$ and it gradually falls along the length of the oven.
- At the other end the temperature is almost the same as the room temperature.



Glass

- Immediately after shaping, the articles are introduced into the lehr at the hotter end and travel towards the cooler end by means of a moving belt.
- It takes a few hours for the articles to move along through the tunnel.
- Some high quality glasses require long annealing.

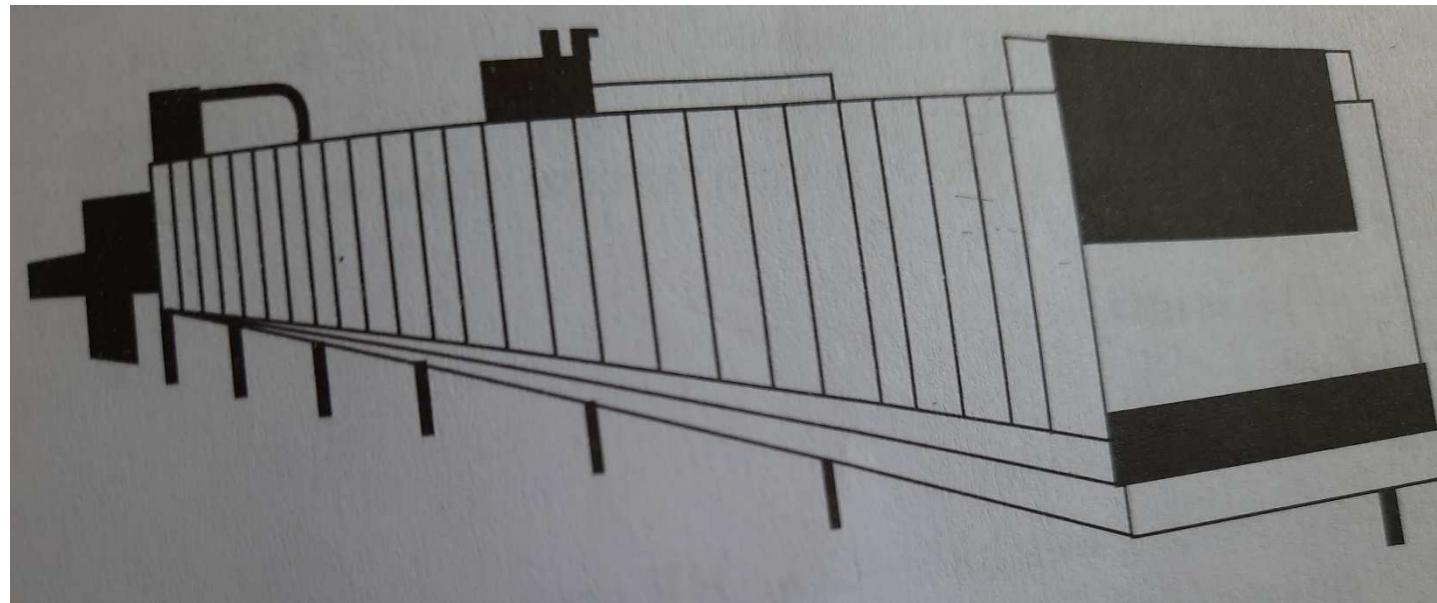


Annealing lehr



Glass

Annealing Chambers- These are chambers in which glass wares are stacked and the chamber is heated up and then slowly cooled by closing the chamber from all sides.



Annealing Chambers



Glass

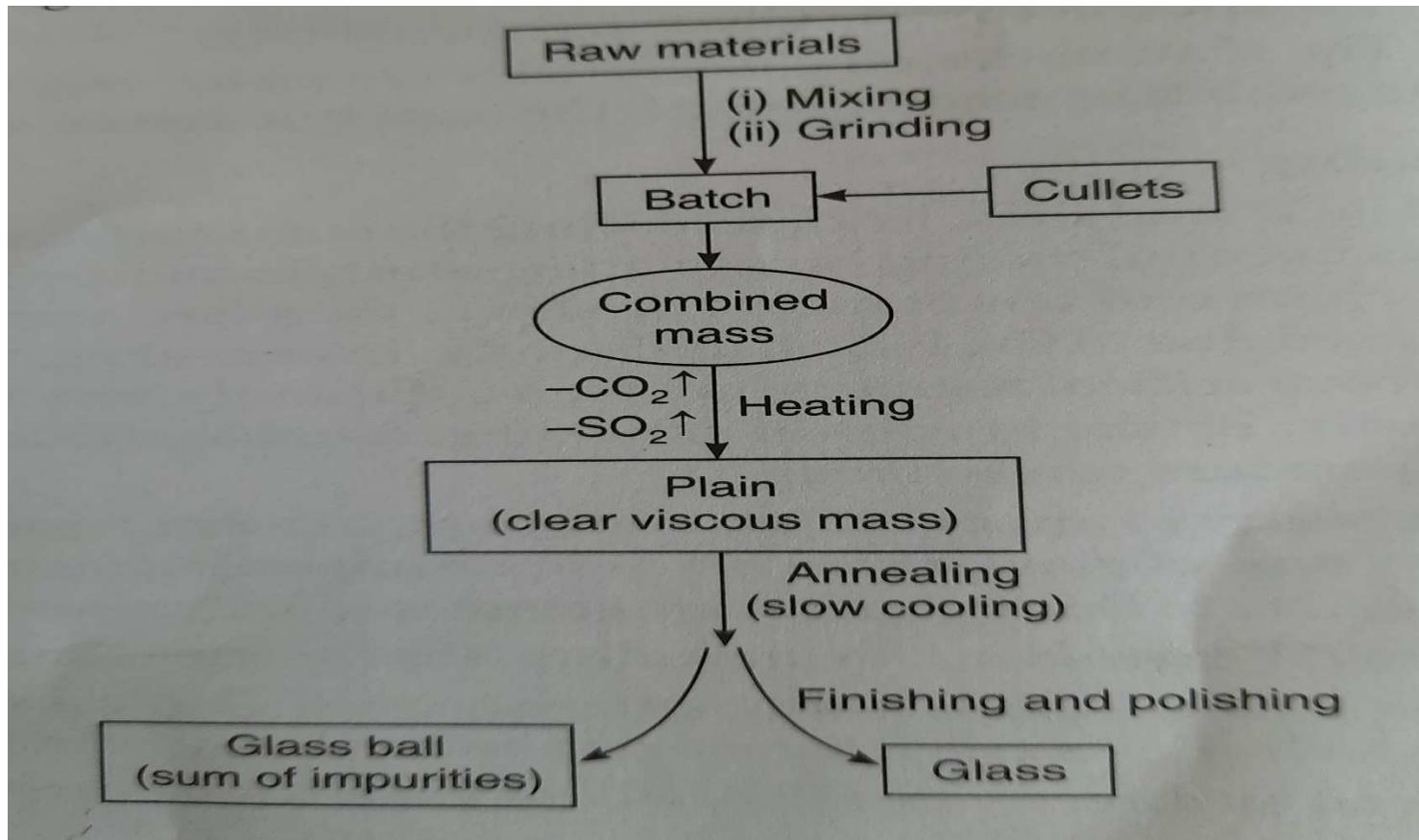
4. Finishing

All glass articles, after annealing, are subjected to finishing processes such as-

- Cleaning,
- Grinding,
- Polishing,
- Cutting,
- Sand-blasting, etc.



Glass



Flow Chart of Glass Manufacture



Glass

1. Soft Glass (soda-lime glass):

- Structural formula of soft glass is $\text{Na}_2\text{O} \cdot \text{CaO} \cdot 6\text{SiO}_2$
- Sodium carbonate, calcium carbonate, silica are raw materials for the preparation of soft glass
- They are resistant to water and melt easily
- However they are easily attacked by acids

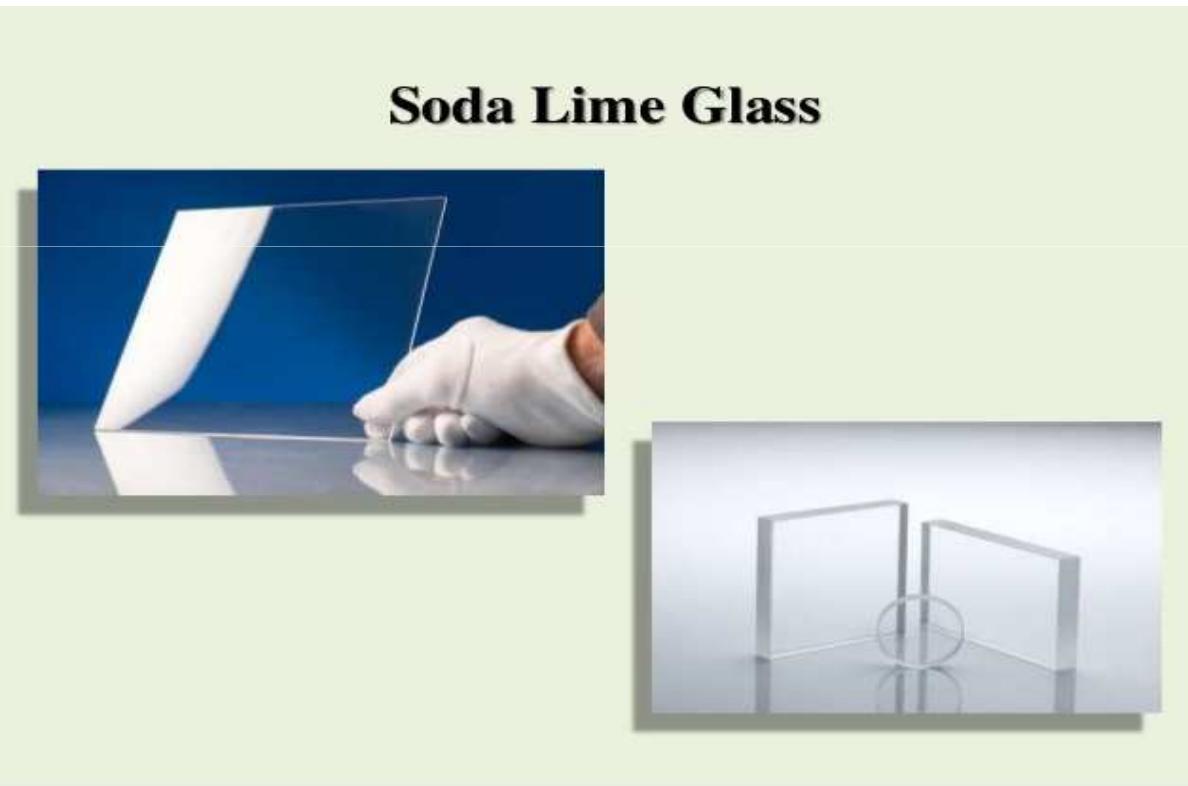
Uses

- They are widely used as window glasses, electric bulbs, plate-glasses, bottles, jars, building blocks, and cheaper table wares where high temperature-resistance and chemical stability are not required.



Glass

Soda Lime Glass





Glass

2. Hard Glass (Potash-Lime Glass)

- Composition of Hard-Lime glass is $K_2O \cdot CaO \cdot 6SiO_2$
- Silica, Potassium carbonate and sodium carbonate are raw materials for preparation of hard glass.
- They have high melting points and less acted by alkalis, acids.

Uses • These glasses (costlier than soda-lime glasses) are used for chemical apparatus combustion tubes, etc., which are to be used for heating purposes.



Glass

Leaded Glass:

- This glass has a high reflective Index.
- This property is Induced into the Glass by adding lead Oxide with Silica during the manufacturing Stage.
- A usual Composition of lead glass is SiO_2 , PbO , K_2O , Na_2O .

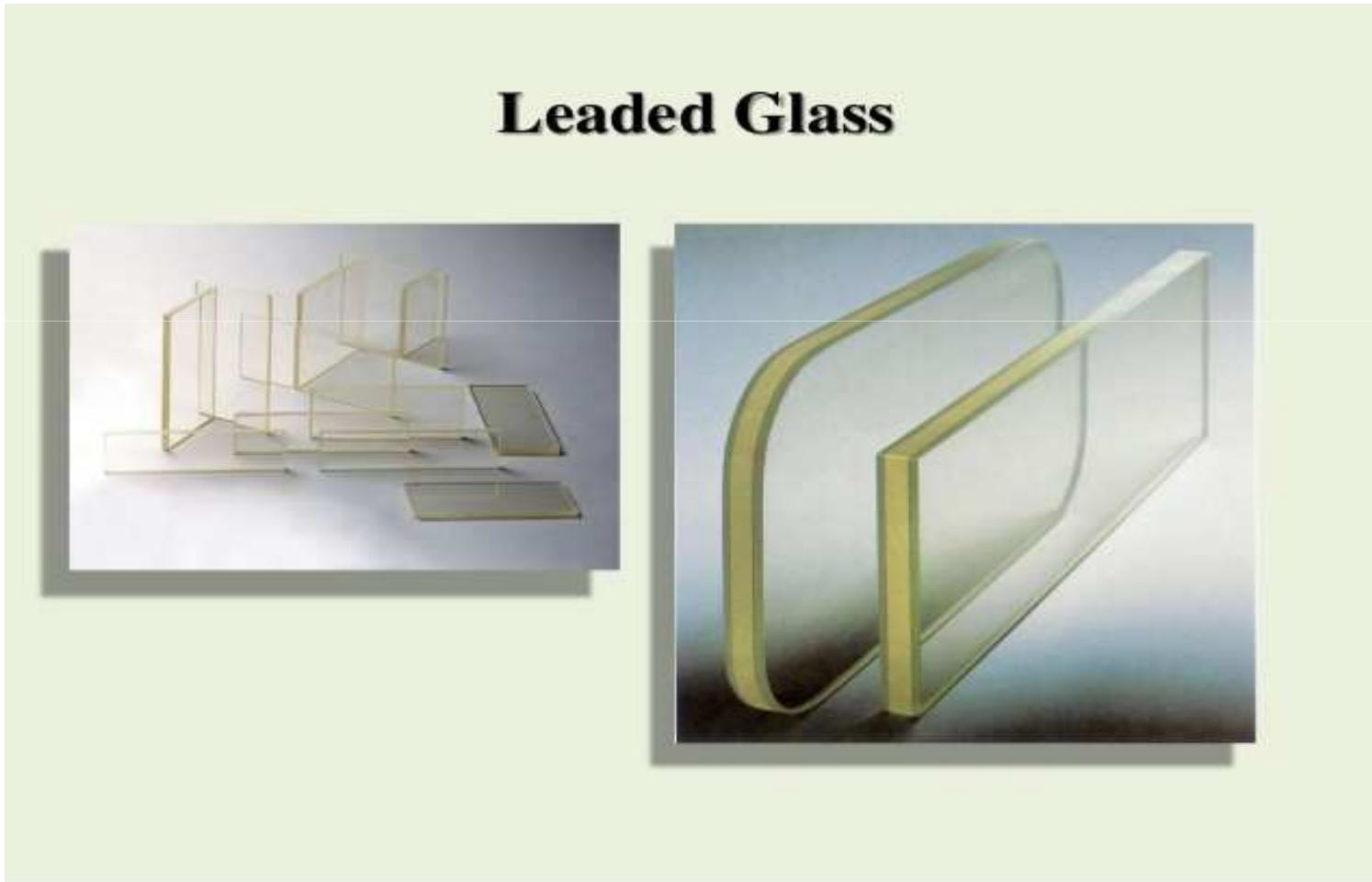
Uses:

- This Lead glass has special application such as; in Making shields for protection against gamma radiations.
- In the manufacturing of optical Instruments.
- For Making Neon Signs.



Glass

Leaded Glass





Glass

Borosilicate Glass (Pyrex)

- It is special type of glass made by adding Boron Oxide as the chief additive with Silica at the time of Manufacturing.
- This property of boron oxide gives the special property of increasing its melting point and resistance against thermal shock.
- This Glass can be heated or cooled again & again without any risk of damage.
- This is because the coefficient of expansion gets reduced considerably by the addition of boron Oxide.



Glass

Uses: Borosilicate Glass is used extensively in high temperature conditions such as ;

- Making of Laboratory wares for experiments;
- Cooking Utensils
- It is also used for telescope and Glass piping.
- Pyrex is the trade name for Borosilicate.



Glass

Borosilicate Glass (Pyrex)





Glass

Industrial Forms of Glasses - Glass used in Industry in variety of forms.

Some Common forms are as Follows-

Glass Building Blocks

- These are manufactured from pressed glass by fusing two or more sheets in such a way that partial vacuum is caused in the interior of the blocks.
- These blocks are used in masonry construction for permitting transmission of Light without being transparent and without bearing any load.



Glass

Glass Building Blocks





Glass

Glass Fibres

- It has been found that very thin fibres of Glass possess very high tensile strength. The thinner the fibre the higher the strength.
- This property has resulted in a separate industry of Considerable importance the glass fibre industry fibre of glass are made in a special manner the molten glass is forced out through numerous minute openings in the form of thin streams upon these stream is impinged a blast of air or stream under a pre-calculated pressure.
- The stream solidifies into thin fibres. The Glass-reinforced plastic is commonly known as FIBRE GLASS and has acquired a place of its own as a composite engineering Material.



Glass

Glass Fibres





Glass

Laminated Glass

- The laminated glass is composed by two glass plates intercalated by a plastic skin of great resistance.
- The laminated glass is used as cover, facades, balconies, guardrail, doors, windows, partitions, showcase, floorings and others.
- The laminated glass has other benefits, as the reduction of external noise entrance (when compared to the common glasses) and the protection against UV (Ultraviolet) rays.



Glass

Laminated Glass

- These are made by bounding together two or more plates of glass. Sometimes, layer of a third material like asphalt, rubber or resin are also made a part of the laminated glass.

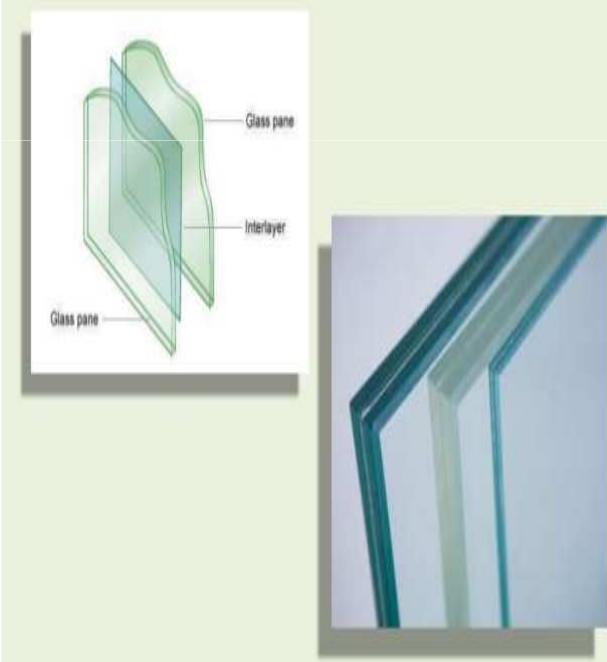
Laminated Glass can be characterized as :

- Shattering Resistance - Its pieces do not fly away in all the direction on it broken suddenly under impact. This makes the laminated Glass an ideal material for use as a safety glass in automobile and air craft.
- Shock Resistance - It can bear safely sudden impacts up to desired value. This property also plays in laminated glass being Used as a safety Glass.

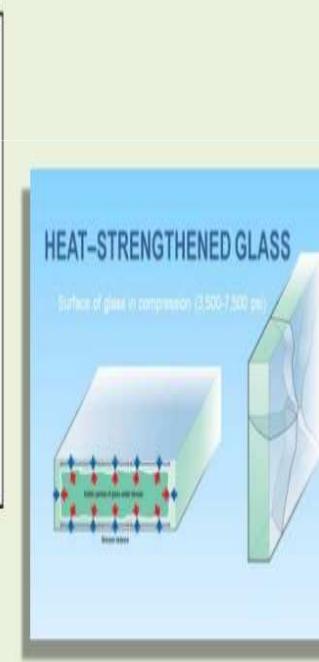


Glass

Laminated Glass



Shattering Resistance



Shock Resistance





Glass

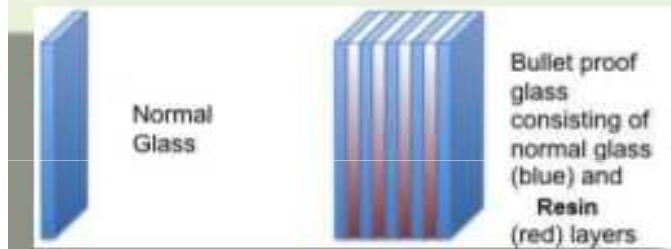
Bullet Resistant Glass

- This is specially useful in vehicles and other automobiles used for security reasons.
- It is in fact a variety of laminated glass which is made by pressing together several layers of glass and vinyl resins in alternate manner.
- Thickness of such Glass varies from 12 mm to 75 mm or more.

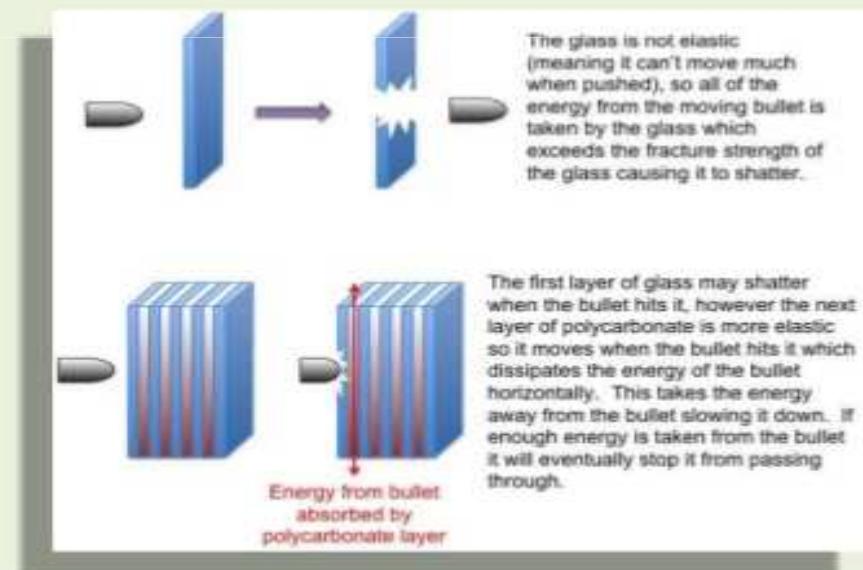


Glass

Bullet Resistant Glass



Bullet proof
glass
consisting of
normal glass
(blue) and
Resin
(red) layers





Glass

Applications/Uses of Glass

- Glass finds its application from the kitchen of poor man to most advanced scientific devices and in palatial building and Cabinet Rooms.
- It can be made in varieties possessing a combination of mechanical, electrical, optical, and chemical resistant properties that make them ideal industrial Material for variety of Applications.



Glass

Uses of Glass - Glass has a very wide field of Industrial Applications.

- **For an Architect** - Glass is an indispensable architectural material. In all the modern building including the high-rise buildings, Glass curtain walls make the skyline.

Uses Of Glass For An Architect





Glass

For an Civil Engineer- It is one of the most important material for construction which cannot be avoided.

For An Electrical Engineer- Glass is a useful insulating material in many situations, and is also an essential material for making tubes and valves.

Uses Of Glass For an Civil Engineer



Uses Of Glass For An Electrical Engineer





Glass

For a Mechanical Engineer- Glass alone or in a composite material is an integral part in automobiles and other locomotives including railway wagons.

Uses Of Glass For a Mechanical Engineer





Glass

For a Chemical Engineer- It is packaging material without any easy alternative.

Uses Of Glass For a Mechanical Engineer





Glass

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- Thanks