Akij Glass Industries Ltd.

(One of the largest glass manufacturers in Bangladesh)

A Report

On

Production of a glass industry

(Akij Glass Industries Ltd.)

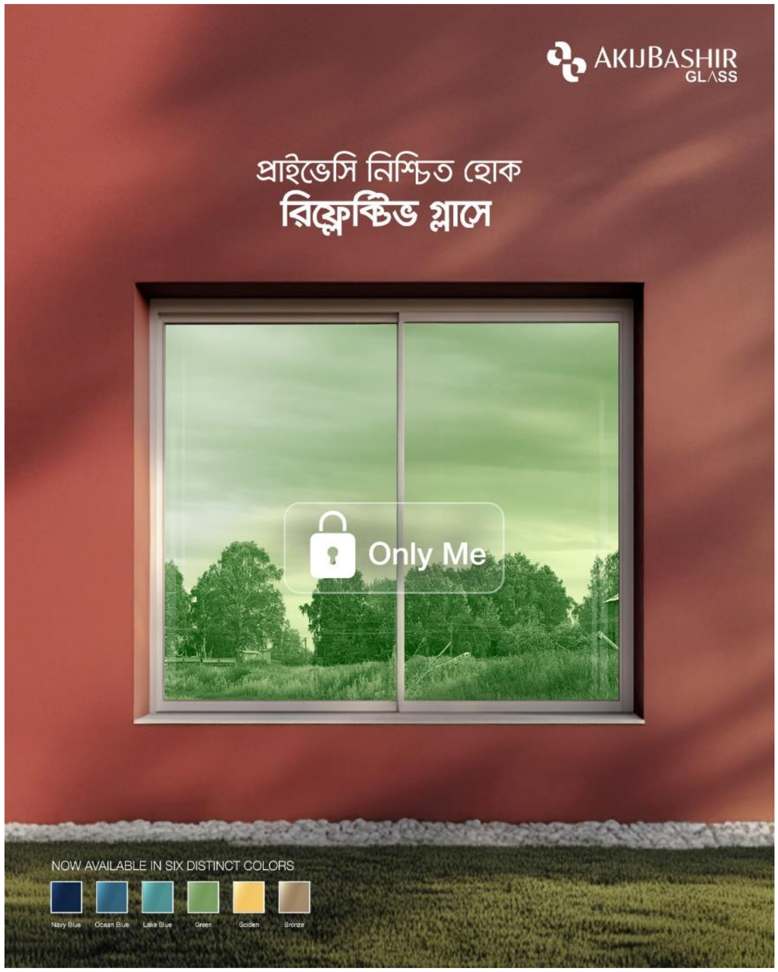

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Table of Contents

Chapter 1

1.1 Basic introduction of Glass

Glass is a transparent and sol material used in many areas of daily life. One of the most common types is float glass, which is made by floating molten glass on a bed of molten tin. This process creates smooth, flat, and high-quality glass sheets. Float glass is widely used in windows, doors, mirrors, and modern buildings because of its clarity and strength. It is also used in vehicles, furniture, and electronic screens. Due to its versatility and durability, float glass plays an important role in construction and industrial applications.

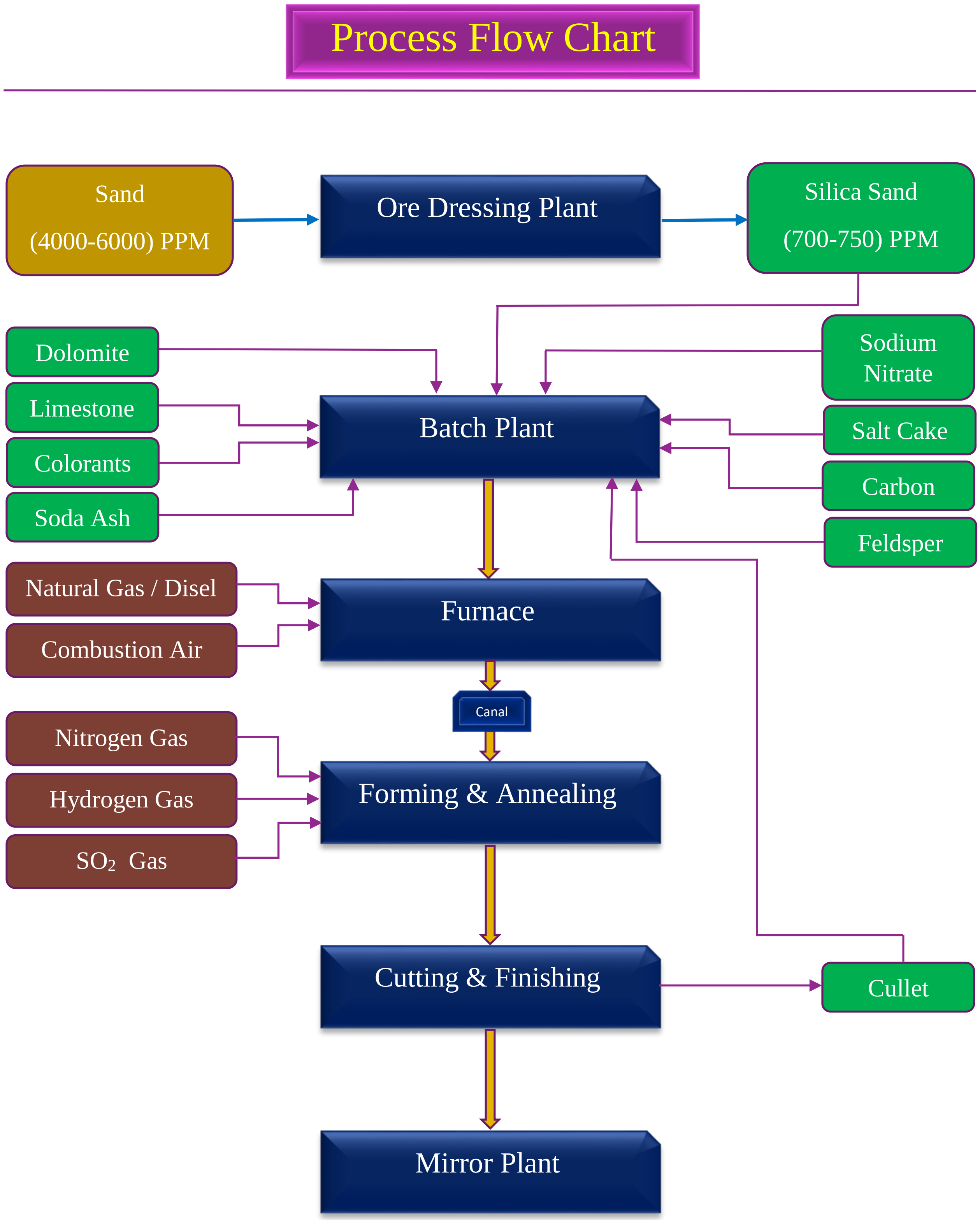
Also, tempered glass is a type of safety glass that is much stronger than normal glass. It is made by heating float glass to a high temperature and then cooling it quickly. This process makes the glass tough and resistant to breaking. If tempered glass does break, it shatters into small, harmless pieces instead of sharp shards, making it safer.

In Bangladesh, Akij Glass Industries Ltd. is one of the biggest industries for float glass and tempered glass production, which is situated in Andiura, Madhabpur, Habiganj District, Syhlet Division, Bangladesh. Here almost 600 tons of glass can be produced. The minimum width of the produced glasses is 3400 mm and the maximum is 4150 mm. The minimum thickness of the produced glasses is 2.5 mm and the maximum is 12 mm. They also produce mirror glasses, tempered glasses, and colored glasses using float glasses.

In this industry, there are various sections are required for making float glass including,

1. Ore Dressing Plant
2. Batch Plant
3. Furnace
4. Forming & Annealing
5. Cutting & Finishing
6. Mirror Plant

1.2 Glass manufacturing process flow chart



Chapter 2: Ore Dressing Plant

2.1 Introduction

Glass manufacturing starts with high quality raw materials, and one of the most important is glass sand that a type of silica sand with high purity 98% almost. However, raw sand from natural sources often contains impurities like clay, iron, and other minerals that can affect the clarity and strength of glass. To ensure the best quality, the sand must go through a process called ore dressing (or beneficiation) which removes unwanted materials and enhances its purity.

A glass sand Ore Dressing Plant is a facility designed to process raw silica sand and make it suitable for glass production. Here we input sand that (4000-6000) PPM and after washing we get (700-750) PPM almost pure silica sand. The plant uses several techniques such as washing, screening, gravity separation, magnetic separation, acid solution use to remove impurities like iron oxides, firewood and clay. The purified sand is then used in glass manufacturing where high clarity and purity are essential.

2.2 Introduction of basic machineries

2.2.1 Linear vibrating screen machine:

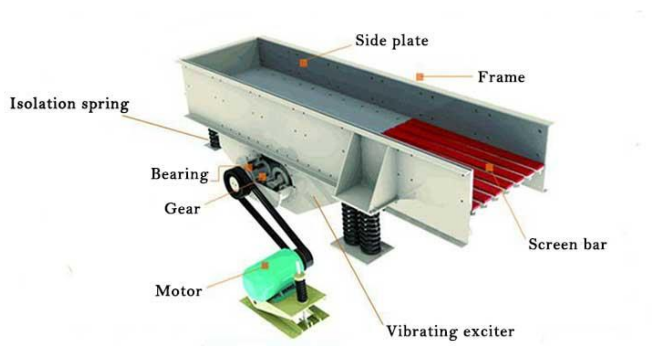


Fig 2.2.1: Linear vibrating screen machine

A linear vibrating screen machine is an essential piece of equipment in the ore dressing process for the glass industry. It is used to separate and classify raw silica sand and other materials based on particle size.

The linear vibrating screen operates using vibration motors that generate a straight line motion. When raw sand is fed onto the screen surface, the vibration helps separate fine and coarse particles. Smaller particles pass through the mesh, while larger impurities like firewood, bigger stone and other organic chemical are removed where using continuous water flow.

2.2.2 Scrubbing machine:

Fig 2.2.2: Scrubbing machine

A Scrubbing machine is used to remove surface impurities, such as clay, iron stains, and organic matter, ensuring the sand is clean and pure for high quality glass manufacturing.

A scrubbing machine works by using high speed rotation and friction between sand particles in a water based environment. This process helps to break down and remove impurities stuck to the sand grains. The cleaned sand is then separated from the dirty water using a hydro cyclone or dewatering screen.

2.2.3 Pumping Motor:

Fig 2.2.3: Pumping Motor

A sand slurry pump motor is an essential component in ore dressing plants for transporting silica sand slurry during the purification process. It powers the slurry pump, which moves a mixture of sand and water through different processing stages such as washing, scrubbing, classification, etc.

2.2.4 Ball Milling machine:

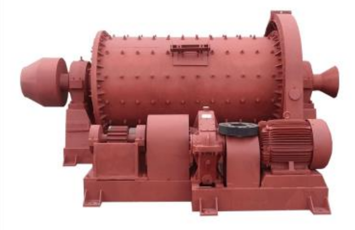


Fig 2.2.4: Ball Milling machine

Ball Milling machine is primarily used to grind, mix, and reduce the particle size of materials, ensuring uniformity and purity for high quality glass manufacturing.

The ball mill consists of a rotating cylindrical drum filled with porcelain balls. When raw materials (like silica sand) are fed into the drum, it rotates, causing the balls to impact and grind the material into finer particles. The grinding process can be wet or dry, depending on the requirements.

2.2.5 Hydro-cyclone machine:

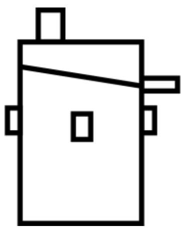


Fig 2.2.5: Hydro-cyclone machine

A hydro-cyclone machine is an essential piece of equipment that used in ore dressing plants for the glass industry. It is primarily used for classifying, separating, and removing fine impurities from silica sand, ensuring high purity for glass production.

A hydro-cyclone works by using centrifugal force to separate particles based on size and density. When a mixture of sand and water enters the cyclone at high speed, heavier sand particles move to the outer walls and settle at the bottom, while lighter impurities and fine particles are carried away with the overflow water.

2.2.6 Roller screen machine:

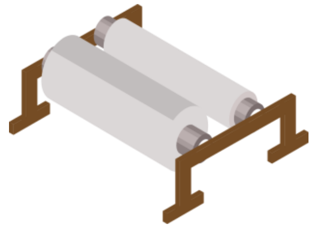


Fig 2.2.6: Roller screen machine

Roller screen machine is used to separate and classify raw silica sand based on particle size, ensuring that only the best-quality sand is used in glass manufacturing.

The roller screen machine consists of multiple rotating rollers placed in parallel. As the raw material moves across the rollers, smaller particles pass through the gaps between them, while larger impurities and oversized grains are removed. The machine works efficiently by using controlled rotation speed and adjustable roller spacing to achieve precise screening.

2.2.7 Permanent magnet machine (0.6 Tesla):

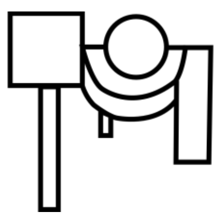


Fig 2.2.7: Permanent magnet machine (0.6 Tesla)

Permanent magnet machine plays a crucial role in removing magnetic impurities, such as iron and other ferrous materials, from the raw silica sand. These impurities can affect the quality of the glass and cause defects, making the removal of magnetic materials vital for producing high quality glass.

The permanent magnet machine uses magnetic fields to attract and remove ferrous materials from the raw sand. The raw material is fed onto a conveyor belt or through a drum equipped with strong permanent magnets. As the material moves past the magnets, the magnetic particles are attracted to the magnets and separated from the non-magnetic silica sand. The non-magnetic sand is then further processed for use in glassmaking.

2.2.8 Classifier machine:

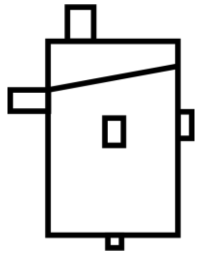


Fig 2.2.8: Classifier machine

A classifier machine is an essential piece of equipment in an ore dressing plant that helps separate materials based on their particle size and density.

the sand is mixed with water and then fed into a rotating drum or spiral mechanism. The finer particles, being lighter, are carried away by the water flow, while the actual particles that we need this particles remain behind. This separation process ensures that only the correctly sized sand is used in glass manufacturing.

2.2.9 Centrifugal system:

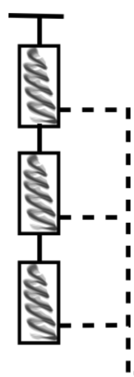


Fig 2.2.9: Centrifugal system

The Centrifuge system is a high-efficiency centrifugal separation method designed to remove iron impurities from raw materials, particularly silica sand. It uses centrifugal force to separate the heavier iron particles from the lighter, purer materials like silica sand.

The system rotates at high speeds, creating a powerful centrifugal force. This force pushes the heavier iron particles toward the outer wall of the system, while the lighter silica sand stays in the center. The iron-rich particles are separated and collected for disposal, while the purified silica sand continues to the next stage of the ore dressing process.

2.2.10 High intensity magnet (1.3 Tesla):

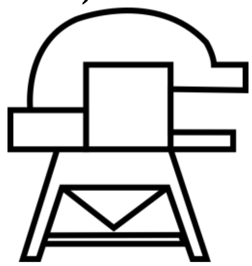


Fig 2.2.10: High intensity magnet (1.3 Tesla)

High-intensity magnetic separators are used to effectively remove iron and other ferrous impurities from the raw sand before it is used in glass production.

A high-intensity magnet with a strength of 1.3 Tesla operates on the principle of magnetic separation. It generates a strong magnetic field that attracts and pulls ferrous particles (such as iron and steel) from the raw sand. As the material passes through the magnetic field, the iron particles are captured by the magnet, leaving behind the non-ferrous material, which is then used in the glassmaking process.

2.2.11 De-water screen machine:

Fig 2.2.11: De-water screen machine

By removing water, it ensures that the sand reaches the appropriate moisture level needed for high-quality glass manufacturing. This step is vital for maintaining the quality and consistency of the final product.

The machine utilizes a vibrating screen that creates motion, which helps in separating water from the sand. Water is drained through the screen's mesh while the solid particles (sand) remain on the screen. The resulting sand has a controlled moisture level that is ideal for glass production.

2.3 Working procedure

In this process we divide into two part,

2.3.1 Sand washed up to 3rd iron remover (if H_2SO_4 acid solution is not required)

2.3.2 Sand washed after 3rd iron remover (if H_2SO_4 acid solution is required)

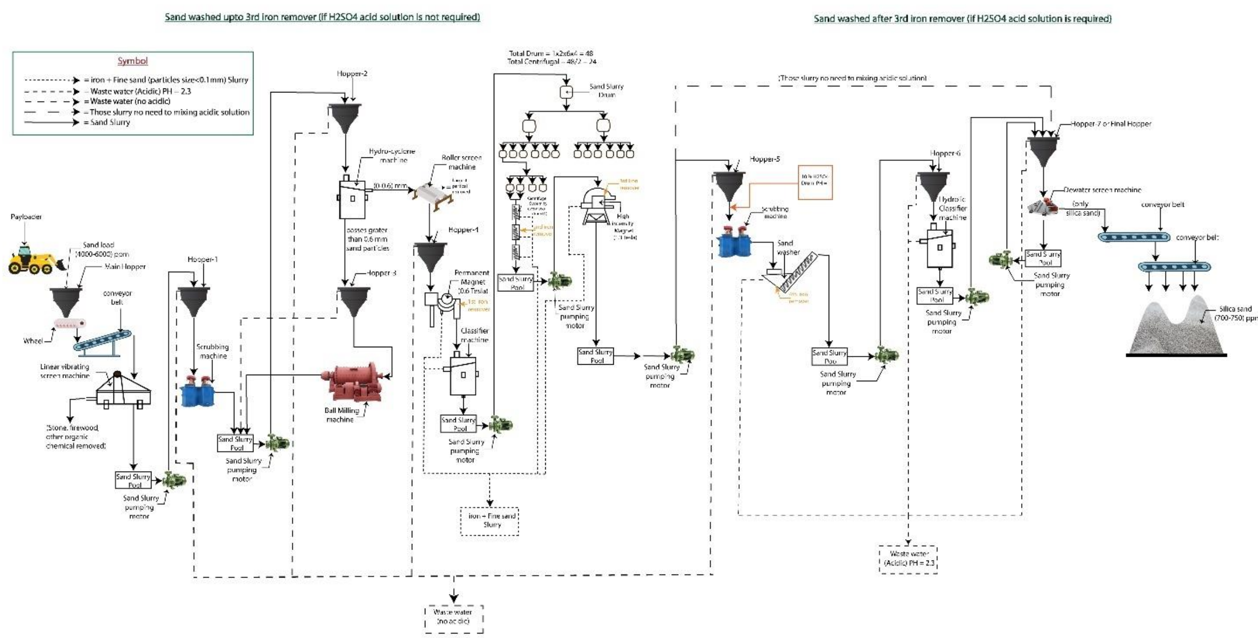


Fig 2.3: Ore Dressing process

Sand washed process 2.3.1 no is given below:-

2.3.1 <u>Sand washed upto 3rd iron remover (if H_2SO_4 acid solution is not required):</u>

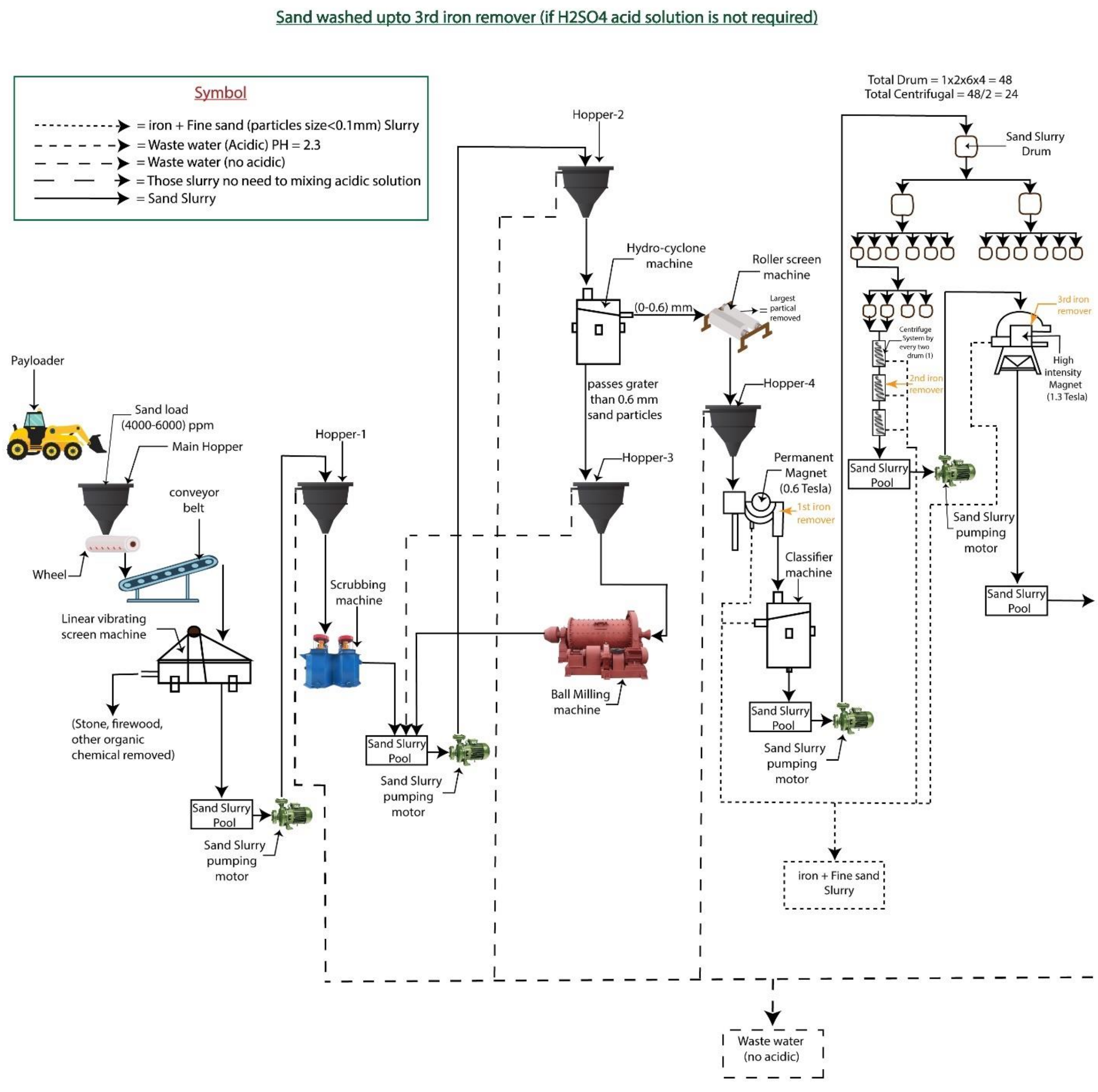


Fig 2.3.1: Sand washed upto 3rd iron remover

Sand Loading

Raw Sand (4000-6000 ppm) is transported to using a payloader to the main hopper

Preliminary Screening

A conveyor belt transfers the sand to a linear vibrating screen machine, which removes stones, firewood, and other organic chemicals

Initial Processing

The screened sand moves to Hopper-1 and is then processed through a scrubbing machine to remove impurities. The resulting sand slurry is collected in a sand slurry pool and pumped using a sand slurry pumping motor

Further Grinding

The sand slurry is transferred to Hopper-2 and then sent to a ball milling machine for further size reduction. The processed slurry is collected again in a sand slurry pool and pumped

Particle Separation

The slurry enters a hydro-cyclone machine (at Hopper-3), which separates particles smaller than 0.6 mm. Larger particles are removed using a roller screen machine, while sand particles smaller than 0.6 mm proceed to the next stage

First Iron Removal

The slurry is transferred to Hopper-4, where it passes through a permanent magnet (0.6 Tesla), which removes 1st stage iron impurities

Second Iron Removal

The slurry is sent to a classifier machine and processed further. The processed slurry is collected in another sand slurry pool and pumped. The 2nd iron remover removes additional iron contaminants.

Final (3rd) Iron Removal without acidifying

The slurry passes through a high-intensity magnet (1.3 Tesla) for the 3rd iron removal. The cleaned slurry is stored in sand slurry drums for further processing.

Final Processing

The slurry is transferred to Hopper-7 (Final Hopper). It then moves to a dewatering screen machine, which removes excess water and ensures that only silica sand remains

Final Product Collection

The cleaned silica sand (700-750 ppm) or 98% silica is transported via conveyor belts and collected in the silica shed.

3.2.2 Sand washed after 3rd iron remover (if H_2SO_4 acid solution is required):

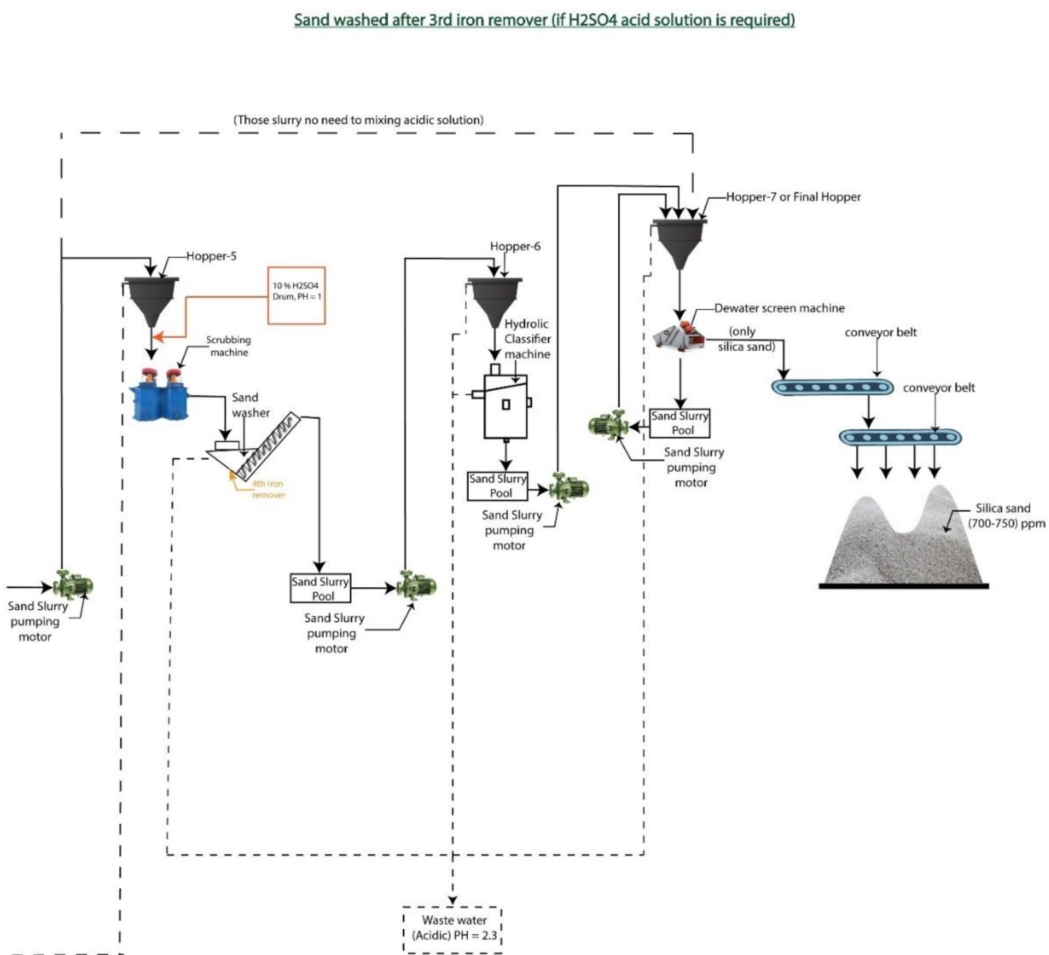


Fig 2.3.2: Sand washed after 3rd iron remover

Additional Processing in Hopper-5

The sand slurry from the 3rd iron remover is transferred to Hopper-5. A scrubbing machine is used to clean the sand further. 10% H_2SO_4 solution (pH = 1) is added to the slurry for chemical iron removal.

Acid Washing & 4th Iron Removal

The acid-treated slurry moves through a sand washer, where the 4th iron remover eliminates remaining iron impurities. The washed sand slurry is collected in a sand slurry pool and pumped.

Hydraulic Classification

The slurry is transferred to Hopper-6, where a hydraulic classifier machine separates fine silica particles from unwanted materials. The classified slurry is collected in another sand slurry pool and pumped.

Final Processing

The slurry is transferred to Hopper-7 (Final Hopper). It then moves to a dewatering screen machine, which removes excess water and ensures that only silica sand remains.

Final Product Collection

The cleaned silica sand (700-750 ppm) or 98% silica is transported via conveyor belts and collected in the silica shed.

Chapter 3: Batch Plant

3.1 Introduction

A batch plant is an important part of the glass-making process. It is where raw materials like sand, soda ash, limestone, and recycled glass (cullet) are measured, mixed, and prepared before being melted in the furnace. The quality of this process affects the final glass product's strength, clarity, and cost.

Akij Glass Industries Ltd. batch plants use automated systems to accurately weigh and mix materials, reducing waste and ensuring consistency. They also have dust control systems to keep the environment clean and safe for workers. With new technology, batch plants are becoming more efficient, using smart systems to monitor and improve the process. This helps produce high-quality glass for different uses.

3.2 Understanding the Raw Materials in Glass Manufacturing

In the glass industry, the quality and properties of the final product depend a lot on the raw materials used in the batch process. These materials are chosen carefully based on their chemical properties and how they affect the glass. Akij Glass Industries Ltd. typically uses silica sand, dolomite, limestone, soda ash, colorants, salt cake, and carbon. Each of these materials is important for shaping the glass, making it clear, and ensuring it is strong and durable.

Raw materials that use in batch mixing are given bellow-

1) Silica Sand (SiO_2)

2) Dolomite ($CaMg(CO_3)_2$)

3) Limestone ($CaCO_3$)

4) Soda Ash (Na_2CO_3)

5) Salt Cake (Na_2SO_4)

6) Sodium Nitrate ($NaNO_3$)

7) Carbon

8) Colorants

3.2.1 Silica Sand (SiO_2)

Fig 3.2.1: Silica Sand (SiO_2)

Silica sand, also called quartz, is the main ingredient in most glass batches, making up about 70% of the total material. It provides the basic structure of glass because of its high silica content. When heated, silica melts and forms a glassy network. However, its melting point is very high (1723°C), so other materials like soda ash are added to lower the temperature needed for glass formation.

Compound	Percentages (%)
SiO_2	96
Al_2O_3	1.63
MgO	0.145
Fe_2O_3	1.65

Importance of Silica in Glass:

a) **Forms the Backbone of Glass:** Silica (SiO_2) is the key material in glass, creating a strong network of silicon-oxygen bonds when melted. This network gives glass its shape and structure. Without silica, glass would not have its solid and stable form.

b) **Adds Clarity and Hardness:** Pure silica is transparent, allowing light to pass through without distortion, which is important for making clear glass used in windows and lenses. Silica also makes glass hard and resistant to scratches, ensuring durability in everyday use.

c) **Provides Chemical Resistance:** Glass with a high amount of silica is resistant to acids, alkalis, and other chemicals. This makes it ideal for laboratory equipment and industrial applications where exposure to chemicals is common. Its chemical resistance also helps glass last longer without breaking down.

3.2.2 Dolomite ($CaMg(CO_3)_2$)

Fig 3.2.2: Dolomite ($CaMg(CO_3)_2$)

Dolomite is a mineral that contains calcium and magnesium carbonates. It is added to the glass batch to improve the strength, durability, and chemical resistance of the final glass product. When heated, dolomite releases calcium oxide (CaO) and magnesium oxide (MgO), which enhance the quality of the glass.

Compound	**Percentages (%)**
CaO	74.26
MgO	21.42
Al_2O_3	1.09
Fe_2O_3	0.22

Importance of Dolomite in Glass:

a) **Increases Durability and Chemical Resistance:** Dolomite adds calcium oxide (CaO) and magnesium oxide (MgO) to the glass, making it more resistant to chemicals. This helps prevent damage from acids, alkalis, and cleaning agents, making the glass last longer, especially in industrial environments.

b) **Improves Strength and Toughness:** The calcium and magnesium in dolomite make the glass harder and more resistant to breaking. This added strength is important for glass used in buildings, vehicles, and other applications where durability is needed.

c) **Prevents Crystallization During Cooling:** When glass cools after melting, it can sometimes form unwanted crystals, making it brittle and unclear. Dolomite helps prevent this by keeping the glass structure stable, ensuring the final product remains smooth, transparent, and strong.

3.2.3 Limestone ($CaCO_3$)

Fig 3.2.3: Limestone ($CaCO_3$)

Limestone is an important raw material in glass production. It mainly adds calcium oxide (CaO) to the batch, which helps improve the glass's stability and durability. While it has a similar function to dolomite, limestone focuses more on reducing solubility and increasing chemical resistance.

Compounds	**Percentages (%)**
CaO	71.39
SiO_2	8.20
Al_2O_3	1.53
Fe_2O_3	0.96

Importance of Limestone in Glass:

a) **Improves Chemical Durability:** The calcium oxide (CaO) from limestone makes glass more resistant to damage from moisture, chemicals, and temperature changes. This helps the glass last longer in different applications, such as buildings, containers, and scientific instruments.

b) **Reduces Solubility in Water and Chemicals:** Without limestone, glass could slowly dissolve or weaken when exposed to liquids or chemicals. Calcium oxide helps prevent this, making the glass more resistant to weathering and chemical reactions, which is especially important in environments with moisture or strong chemicals.

c) **Prevents Brittleness and Strengthens Glass:** Limestone acts as a stabilizer, ensuring the glass does not become too fragile. If glass were too brittle, it would break easily under pressure. Calcium oxide helps balance the hardness and strength of the glass, making it tough yet durable for everyday use.

3.2.4 Soda Ash (Na_2CO_3)

Fig 3.2.4: Soda Ash (Na_2CO_3)

Soda ash, also known as sodium carbonate, is an important ingredient in glass production. It is mainly used as a fluxing agent, meaning it helps lower the melting temperature of silica, making the glass-making process easier and more energy-efficient.

Compounds	Percentages (%)
Na_2CO_3	83.6
NaCl	16.4

Importance of Soda Ash in Glass:

a) **Lowers the Melting Temperature of Silica:** Silica (SiO_2), the main component of glass, has a very high melting point of about 1723°C, which makes it hard to melt in industrial settings. Soda ash helps reduce this melting temperature to around 1000–1200°C, making it easier and more practical to produce glass.

b) **Reduces Energy Consumption:** Since soda ash lowers the melting temperature, less energy is needed to heat and melt the raw materials. This makes the glass production process more cost-effective and helps reduce fuel and electricity use, which is also better for the environment.

c) **Helps Maintain Chemical Durability:** While soda ash makes melting easier, it can also make glass more soluble in water, which weakens it. To prevent this, lime (calcium oxide) is added to the glass batch to balance the composition and increase durability. Together, soda ash and lime create strong, long-lasting glass used in windows, bottles, and many other products.

3.2.5 Salt Cake (Na_2SO_4)

Fig 3.2.5: Salt Cake (Na_2SO_4)

Salt cake, also known as sodium sulfate, is added to the glass batch to remove bubbles and impurities during the melting process. It works as a fining agent, helping to make the glass smooth, clear, and high quality.

Components	Percentages (%)
Sodium	32.37%
Sulfur	22.57%
Oxygen	45.06%

Importance of Salt Cake in Glass:

a) **Removes Bubbles from Molten Glass:** During melting, gases can get trapped in the glass, forming unwanted bubbles. Salt cake breaks down at high temperatures and releases gases that help push these bubbles to the surface, allowing them to escape. This helps create a bubble-free glass product.

b) **Ensures Smooth and Even Glass:** By removing bubbles, salt cake helps keep the glass surface uniform and smooth. Bubbles and other defects can make glass weaker and affect its appearance. Adding salt cake ensures the glass is strong, flawless, and suitable for various uses.

c) **Improves Clarity and Quality:** Trapped bubbles can make glass cloudy and reduce its transparency. Salt cake helps eliminate these imperfections, making the glass clearer and more visually appealing. This is especially important for products like windows, lenses, and glass containers, where clarity is essential.

3.2.6 Sodium Nitrate ($NaNO_3$)

Fig 3.2.6: Sodium Nitrate ($NaNO_3$)

Sodium nitrate ($NaNO_3$) is used in the glass batch as an oxidizing agent and refining aid. It helps improve the melting process, removes impurities, and enhances the final quality of the glass.

Importance of Sodium nitrate in Glass:

a) **Acts as an Oxidizing Agent:** Sodium nitrate provides oxygen during melting, which helps oxidize impurities and maintain a balanced redox state. This prevents unwanted color variations and ensures a consistent glass composition.

b) **Helps Remove Gas Bubbles (Fining Agent):** During melting, gases like carbon dioxide and sulfur compounds can get trapped in the glass, causing bubbles and defects. Sodium nitrate helps release these gases by decomposing and promoting their escape, leading to a smoother and clearer glass.

c) **Improves the Melting Process:** Sodium nitrate lowers the viscosity of molten glass, making it easier to mix and melt. This ensures that all raw materials combine uniformly, reducing melting time and improving energy efficiency.

d) **Prevents the Formation of Undesirable Sulfides:** If sulfur compounds are present in the batch, they can create unwanted dark colors in the glass. Sodium nitrate helps oxidize these sulfides, ensuring that the glass remains clear and free from discoloration.

3.2.7 Carbon

Fig 3.2.7: Carbon

Carbon is added to the glass batch to control the redox state, which affects the color and quality of the final glass. It also acts as a reducing agent, helping to remove oxygen and refine the glass.

Importance of Carbon in Glass:

a) **Controls Color by Adjusting the Redox State:** The redox (reduction-oxidation) balance in molten glass affects its final color. Carbon helps control this balance by reducing metal oxides, which can change the intensity and shade of colorants. Proper redox control ensures the desired glass color and prevents unwanted shades. Also control salt cake (Na_2SO_4) reactivity.

b) **Removes Oxygen and Prevents Bubbles:** Oxygen in molten glass can cause bubbles and defects. Carbon reacts with oxygen to form carbon dioxide gas, which escapes from the glass. This helps refine the glass, making it smoother and more uniform.

c) **Improves Clarity and Quality:** By removing oxygen impurities and controlling redox, carbon makes the glass clearer, purer, and free of defects. This is especially important for high-quality glass products like optical glass and premium windows, where transparency and smoothness are essential.

3.2.8 Colorants

Akij Glass produce some of type color glass:-

Navy Blue → Fe_2O_3, CoO

Lake Blue → Fe_2O_3, CoO

Green → Fe_2O_3

Dark Gray → Fe_2O_3

Light Bronze → Fe_2O_3 , $NaNO_3$, Se- Powder.

Ocean Blue → Fe_2O_3 , $NaNO_3$, CuO

Colorants are special compounds added to the glass batch to create different colors. The type and amount of colorant determine the final shade and transparency of the glass. For example, iron oxide gives green or brown glass, while cobalt oxide produces blue glass.

Importance of Colorants in Glass:

a) **Creates Different Colors and Designs:** Colorants are metal oxides or chemicals that give glass its color and appearance. For example, iron oxide makes green or brown glass, cobalt oxide gives a blue tint, and chromium oxide creates a green shade. These colors are used for decorative glass, bottles, stained glass, and artistic glass products.

b) **Controls Transparency or Opacity:** The amount of colorant added can make the glass transparent, tinted, or opaque. A small amount of iron oxide can make the glass light green and clear, while a larger amount can make it dark and opaque. This allows manufacturers to adjust how much light passes through, making the glass useful for windows, decorations, or privacy screens.

c) **Affects Heat and Light Properties:** Colorants can change how glass absorbs, reflects, or transmits light and heat. Some glass absorbs heat, making it useful for energy-efficient windows, while others reflect heat to keep buildings cool. This is important for architectural glass, solar panels, and optical lenses.

3.2.9 Cullet

Fig 3.2.9: Cullet

Glass cullet is recycled broken or waste glass used as a raw material in glass manufacturing. It reduces energy consumption, lowers raw material costs, and minimizes environmental impact. Cullet melts at a lower temperature than virgin materials, improving efficiency in glass production. It is classified into online cullet and offline cullet. Cullet generally used in a batch weight (20-50)%, that depends on which type of glass we want to produce. For clear glass cullet use generally (20-30)% depends on lab through sample information of this day batch ratio.

3.2.10 Batch Plant Lab

Fe separation,

Sand Solution + H_2SO_4 → $FeSO_4$ + SiO_2→ Fe → Fe solution

Here the temperature of the reaction between Sand Solution between Sulfuric Acid is 100 to 150 Degree Celsius.

Then, 0.1g Sample + 98% H_2SO_4 + H_2O → Solution

Solution + 10 drop Sulfuric Acid + HF → Fe Solution

Fe solution + HCl → Solution

Again,

5mL Solution → 100mL solution

100mL Solution + Tartaric acid + Para-nitrophenol + ammonium hydroxide + HCl (to remove yellow) + Hydroxylamine hydrochloride + 1/10 phinanthaline or 10% ethanol → Solution

The solution is experiment in the spectrometer.

3.3 Introduction of basic machineries

1) Jaw Crusher

2) Double Roll Crusher

3) Octagonal shive screen

4) Dust Remover

5) Electromagnetic vibrator

3.3.1 Jaw Crusher

Fig 3.3.1: Jaw Crusher

A jaw crusher is a machine used to crush and break down large materials into smaller pieces. It is widely used in industries like glass manufacturing, mining, construction, and recycling to process raw materials efficiently.

The jaw crusher consists of two plates (jaws) one fixed and one movable. When the machine operates, the movable jaw moves back and forth, crushing the material against the fixed jaw until it is broken into smaller pieces. The crushed material is then discharged through the bottom opening.

3.3.2 Double Roll Crusher

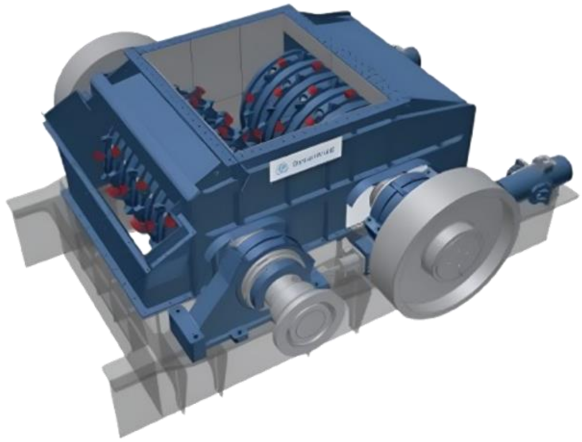


Fig 3.3.2: Double Roll Crusher

A Double Roll Crusher machine consists of two cylindrical rolls, which rotate in opposite directions, and these rolls crush the material between them.

The Double Roll Crusher works by pressing and shearing materials between two rotating rolls. As the material enters the crusher, it is fed between the rolls, where the gap between the rolls can be adjusted to control the size of the output material. The material is crushed through a combination of compression, shear, and friction.

3.3.3 Octagonal shive screen

Fig 3.3.3: Octagonal shive screen

An Octagonal Shive Screen Machine is use for sieving, sorting, and grading materials based on their size and texture. The machine typically features an octagonal-shaped screen that facilitates the separation of materials into different grades, ensuring a high level of consistency in the final product.

The Octagonal Shive Screen Machine operates on the principle of vibrating sieving. The material to be sorted is fed onto the screen, which is vibrated either mechanically or via an electromagnetic system. As the material passes through the screen, particles are separated based on size. The octagonal design allows for optimal flow distribution across the screen, helping to reduce blockages and ensure smooth material flow.

3.3.4 Dust Remover

Fig 3.3.4: Dust Remover

A Dust Remover Machine is an industrial equipment used to remove dust and fine particles from the air or materials during various manufacturing processes. These machines are crucial for ensuring clean and safe working environments, improving air quality, and maintaining the quality of products in industries like glass manufacturing.

Dust remover machines operate based on various filtration or collection methods to capture and remove dust from the air or materials. The most common methods used are filtration, cyclonic separation, or electrostatic precipitation. Typically, these machines suck in dust air or materials through intake ducts, and then use a series of filters or separators to trap the dust particles.

3.3.5 Electromagnetic vibrator

Fig 3.3.5: Electromagnetic vibrator

An Electromagnetic Vibrator Machine is a device commonly used in various industries for material handling, sorting, and feeding applications. It uses electromagnetic forces to create vibrations that help move materials through a production process or keep materials in motion. The machine is widely used in industries like mining, glass production, ceramics, food processing, and pharmaceuticals for tasks like feeding, screening, and conveying materials.

The electromagnetic vibrator operates based on electromagnetic forces that cause the vibrating action. Inside the machine, an electromagnetic coil is energized by an electrical current. This causes the coil to generate a magnetic field, which is used to create a vibratory motion in the machine. The vibration frequency and amplitude can be controlled by adjusting the current supplied to the coil. This allows for precise control of the vibrations, which can be adjusted to suit specific material handling needs.

3.4 Dolomite wash and sorting process

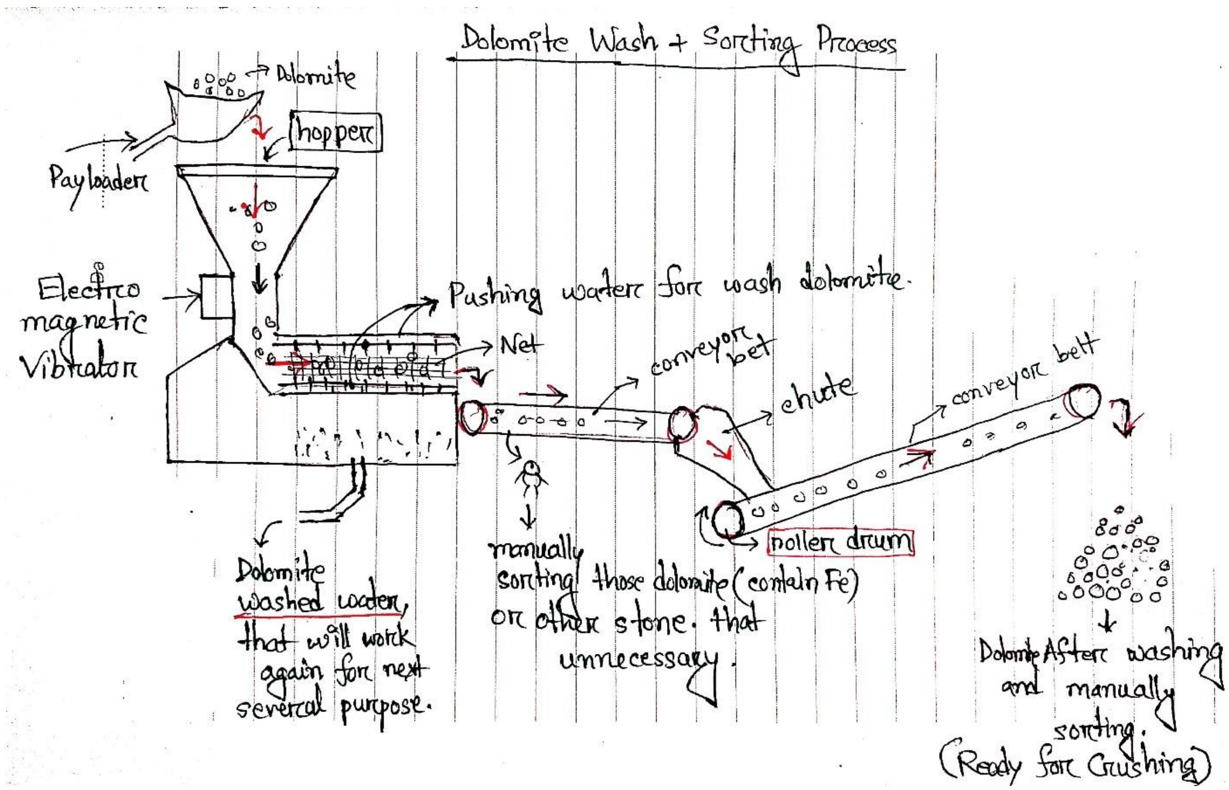


Fig 3.4: Dolomite wash and sorting process

Loading Dolomite

A payloader loads raw dolomite into the hopper

Feeding with Electromagnetic Vibrator

The electromagnetic vibrator regulates the flow of dolomite from the hopper, ensuring a controlled release into the washing section

Washing Process

Water is pushed into the washing section to clean the dolomite. A net is used to filter out unwanted particles, while the dolomite-washed water is collected for reuse.

↓

Manual Sorting

Workers manually sort out unwanted materials, including iron-containing dolomite and other unnecessary stones.

↓

First Conveyor Belt Transport

The washed dolomite is transported via a conveyor belt to the next processing section.

↓

Chute Transfer

The dolomite is directed through a chute onto another conveyor belt.

↓

Final Conveyor Transport

The sorted dolomite is transported on another conveyor belt to the final collection area.

↓

Final Output (Ready for Crushing)

The cleaned and sorted dolomite is collected in a pile, ready for the crushing process.

3.5 Sedimentary Tank

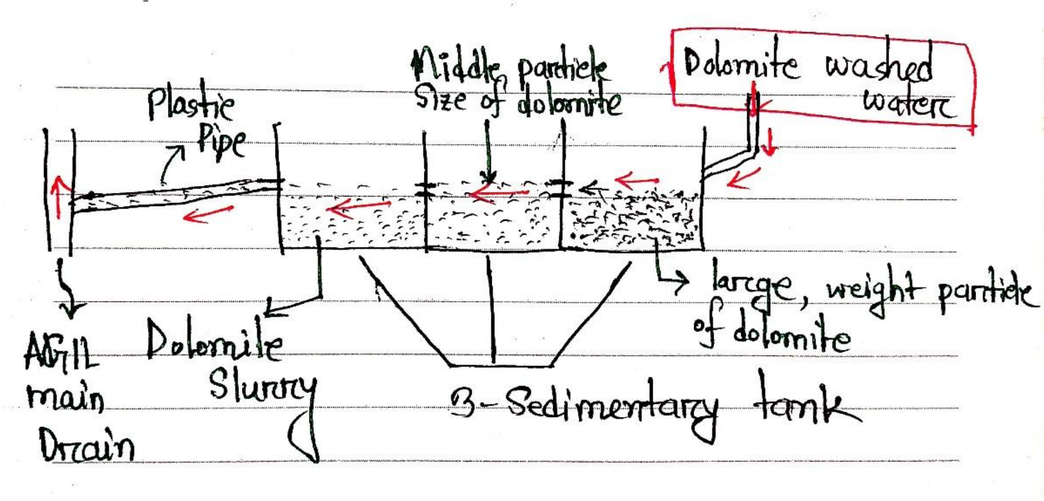


Fig 3.5: Sedimentary tank

Dolomite Slurry Collection in Sedimentary Tank

The dolomite slurry (water mixed with fine dolomite particles) is directed into a 3-stage sedimentary tank.

Separation of Dolomite Particles

a) The larger and heavier particles settle first.
b) The medium-sized particles settle in the second stage.
c) The fine particles are carried to the third stage.

3.6 Cullet wash process

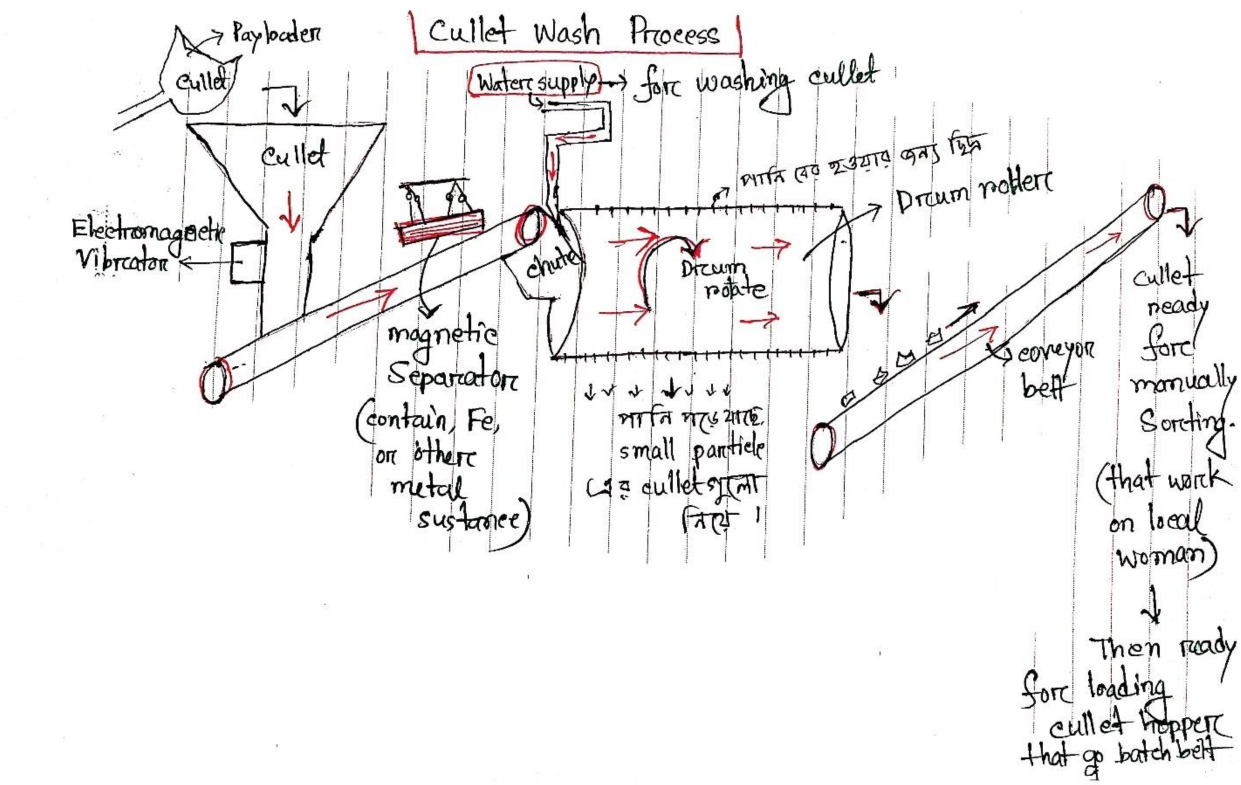


Fig 3.6: Cullet wash process

Loading Cullet

A payloader loads cullet (broken glass) into the hopper.

Controlled Feeding

An electromagnetic vibrator regulates the cullet flow from the hopper onto the conveyor belt.

Magnetic Separation

The cullet passes through a magnetic separator to remove any iron or other metal substances.

Water Washing Process

Water is supplied to wash the cullet before further processing

Drum Rotating Process

The cullet enters a rotating drum where it undergoes thorough washing. At the time Small unwanted particles are filtered out.

Conveyor Belt Transport

The washed cullet moves onto a conveyor belt for sorting

Manual Sorting

Local workers manually remove unwanted metal pieces or impurities.

Final Collection

The cleaned and sorted cullet is ready for loading into the cullet hopper for further processing (such as batching for glass production)

3.7 Dolomite or Limestone crushing process

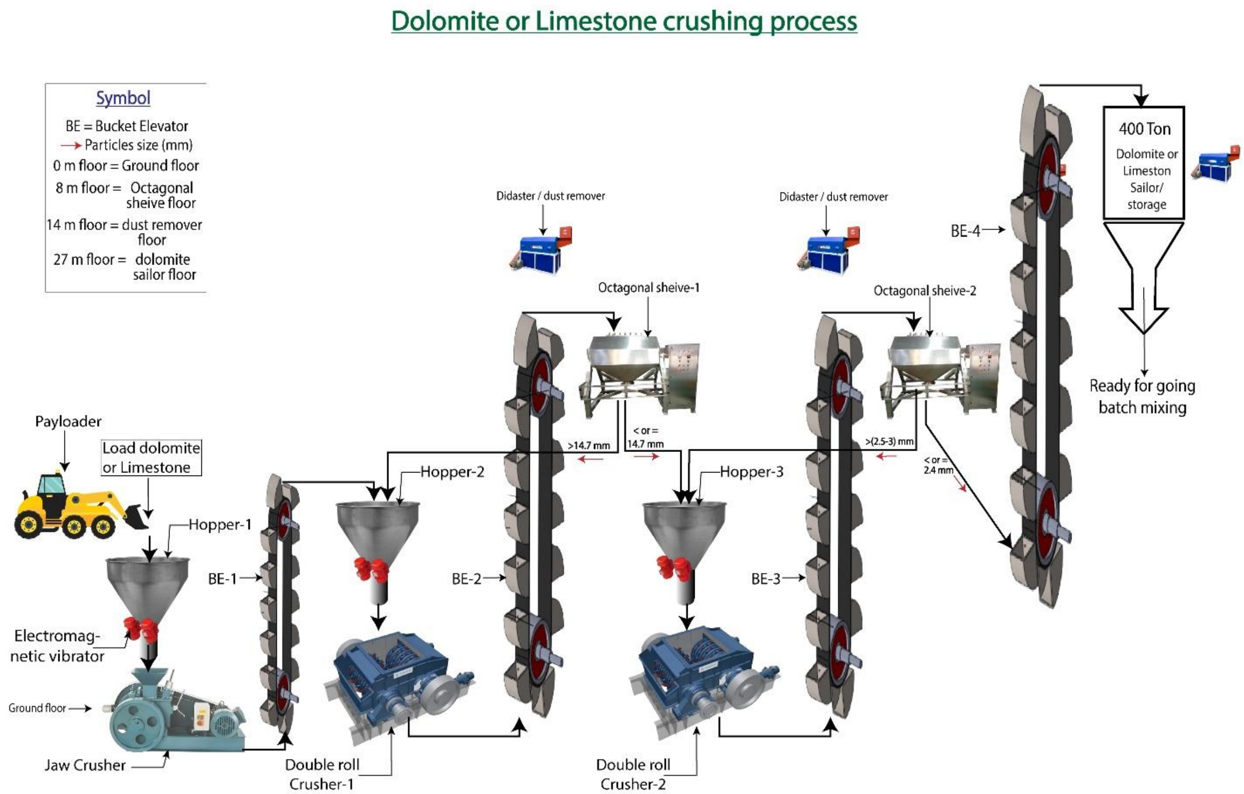


Fig 3.7: Dolomite or Limestone crushing process

Loading the Material

A payloader loads dolomite or limestone into Hopper-1 at the ground floor (0 m floor)

↓

Primary Crushing at Jaw Crusher

The material from Hopper-1 is processed through a Jaw Crusher, which reduces the size of the large rocks. An electromagnetic vibrator ensures a steady material flow

↓

First Elevation - Bucket Elevator (BE-1)

The crushed material is transported using Bucket Elevator-1 (BE-1) to Hopper-2 for further processing

↓

Secondary Crushing (Double Roll Crusher-1)

From Hopper-2, the material passes through Double Roll Crusher-1, further breaking down the particles.

↓

Second Elevation - Bucket Elevator (BE-2)

The crushed material is lifted again using Bucket Elevator-2 (BE-2) to the Octagonal Sieve Floor (8 m floor)

↓

Screening - Octagonal Sieve-1

The material is screened in Octagonal Sieve-1. Here, Particles larger than 14.7 mm are sent back for further crushing on hopper-2. Particles smaller than or equal to 14.7 mm continue to the next stage

Third Elevation - Bucket Elevator (BE-3)

The screened material is transported via Bucket Elevator-3 (BE-3) to Octagonal Sieve-2

Tertiary Crushing - Double Roll Crusher-2

The material in Hopper-3 is processed through Double Roll Crusher-2, further refining the particle size

Final Screening - Octagonal Sieve-2

Particles larger than 2.5 - 3 mm are reprocessed to hopper-3. Particles smaller than or equal to 2.4 mm move to the next stage

Fourth Elevation - Bucket Elevator (BE-4)

The processed material is transported again using Bucket Elevator-4 (BE-4) to 400-ton storage unit at 27 m floor (Dolomite/Limestone Sailor Floor). The final product is ready for batch mixing.

3.8 Conveyor Belt

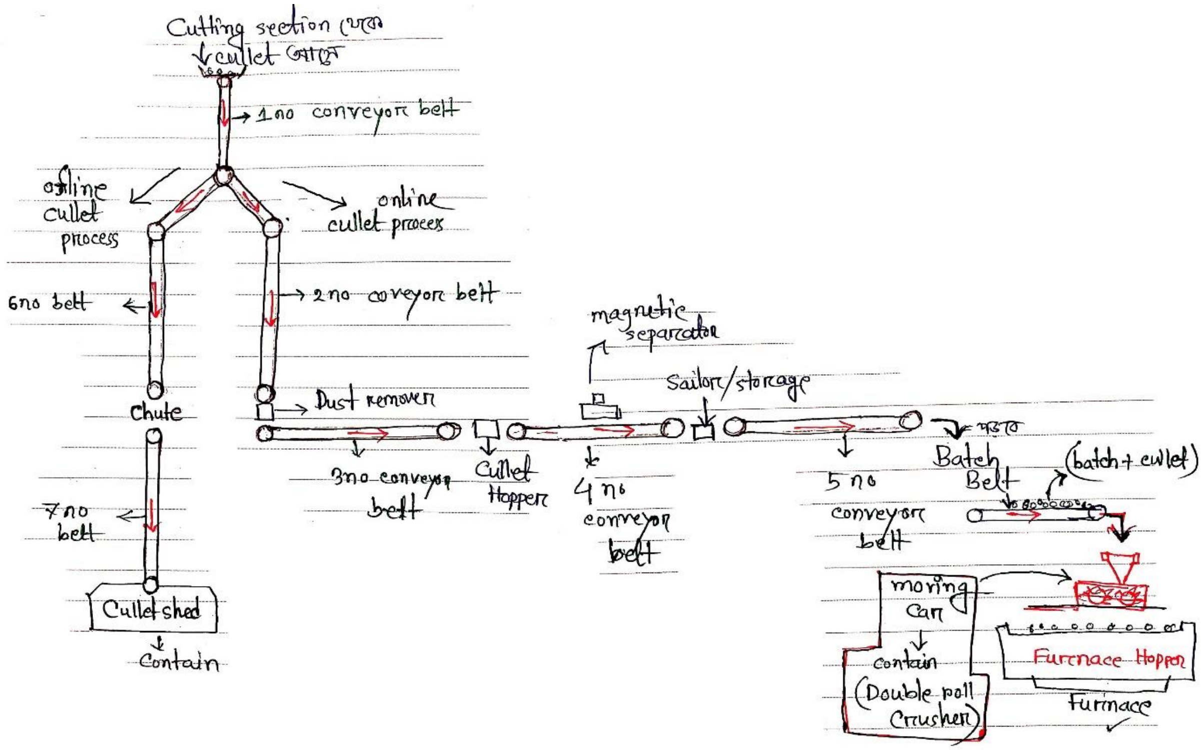


Fig 3.8: Conveyor belt

Cullet Collection from Cutting Section

Online and offline cullet processes collect glass waste from the cutting area.

↓

Initial Transport (1st Conveyor Belt)

The collected cullet is transported using Conveyor Belt-1.

↓

Separation of Online & Offline Cullet

The cullet splits into two paths. Offline Cullet Process: Moves through 6th Conveyor Belt to a chute. Online Cullet Process: Moves to 2nd Conveyor Belt for further processing.

↓

Dust Removal

The online cullet moves through dust removal to eliminate impurities

↓

Cullet Hopper Collection

The cleaned cullet is transported via 3rd Conveyor Belt to the cullet hopper.

↓

Magnetic Separation & Storage

A magnetic separator removes metal contaminants. The material is stored in the Sailor/Storage section.

Further Transport

The cullet is transported via 4th Conveyor Belt to Sailor/Storage section.

Final Transport & Processing

The material is transferred via 5th Conveyor Belt to the Batch belt.

3.9 The Batch Plant Process in Glass Manufacturing

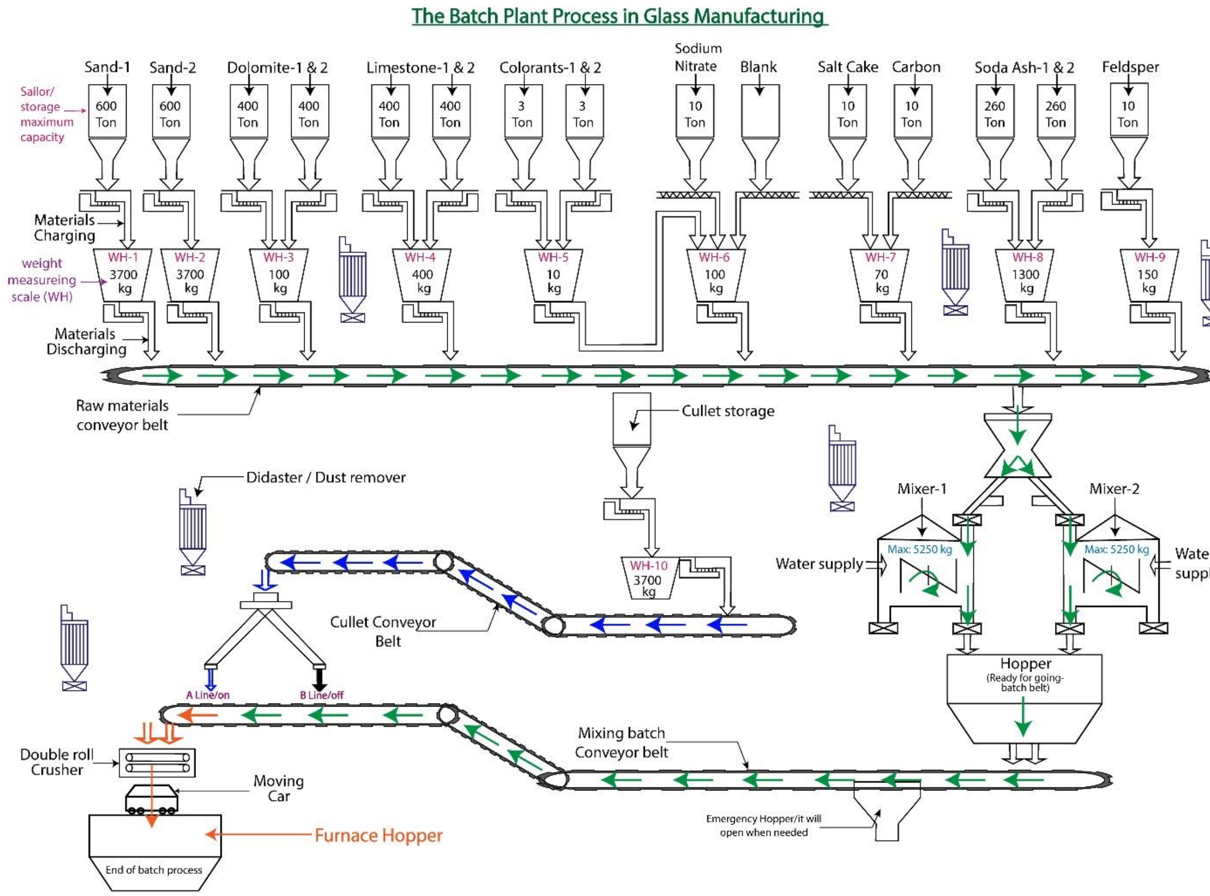


Fig 3.9: Batch Plant Process in Glass Manufacturing

Generally, for one batch mixing batch materials maximum mixing 5250 kg , and one final batch (after needed ratio cullet adding) fall into furnace hopper, those weight generally (6300-6500) kg. Everyday total 70-80 final batch go for furnace hopper. As our furnace pool capacity maximum 600 ton.

Generally we everyday produce (400-500) ton glass. We produce glass what amount our need, but minimum one of amount is remain that always produce due to furnace always is running. Those amount final batch we through to furnace, finally we can not get this equal amount glass production, due to different defect and others etc problem.

- **Raw Material Storage:**

  The raw materials are stored in separate silos with different maximum capacities:

  - **Sand-1 & Sand-2:** 600 tons each
  - **Dolomite-1 & 2:** 400 tons each
  - **Limestone-1 & 2:** 400 tons each
  - **Colorants-1 & 2:** 3 tons each
  - **Sodium Nitrate:** 10 tons
  - **Blank Material:** (No specified quantity)
  - **Salt Cake:** 10 tons
  - **Carbon:** 10 tons
  - **Soda Ash-1 & 2:** 260 tons each
  - **Feldspar:** 10 tons

- **Weighing Process (WH - Weighing Hoppers):**

  Each raw material is measured in dedicated weighing hoppers (WH) before being discharged onto the conveyor belt:

  - ✓ WH-1: **3700 kg** (Sand-1)
  - ✓ WH-2: **3700 kg** (Sand-2)
  - ✓ WH-3: **100 kg** (Dolomite)
  - ✓ WH-4: **400 kg** (Limestone)
  - ✓ WH-5: **100 kg** (Colorants)
  - ✓ WH-6: **100 kg** (Sodium Nitrate)
  - ✓ WH-7: **70 kg** (Salt Cake & Carbon)
  - ✓ WH-8: **1300 kg** (Soda Ash)
  - ✓ WH-9: **150 kg** (Feldspar)

Raw Materials Transportation

The measured raw materials are transported via a green-arrow conveyor belt towards the mixing section.

Cullet Collection & Processing

Cullet (recycled glass) is stored in the cullet storage section. It is weighed in WH-10 (3700 kg) before being transported via blue-arrow cullet conveyor belts.

Dust Removal

Raw materials pass through a dust remover to remove fine particles

Mixing of Raw Materials

The raw materials mixed in Mixer-1 and Mixer-2, with each mixer handling a maximum of 5250 kg of materials.

Mixing of Raw Materials

The raw materials mixed in Mixer-1 and Mixer-2, with each mixer handling a maximum of 5250 kg of materials. Water supply is added to enhance mixing efficiency

Final Mixing Hopper

The mixed materials from both mixers are discharged into a final Hopper, which ensures proper blending before batch processing.

Batch Conveyor Belt to Furnace

The mixed batch moves via the mixing batch conveyor belt towards the furnace hopper. An emergency hopper is available for overflow management.

Cullet Crushing (Double Roll Crusher)

Before entering the furnace, cullet is further crushed by a double roll crusher to achieve the required size.

Furnace Feeding

The final batch (raw materials + cullet) is transported via a moving car into the furnace hopper

Chapter 4: Furnace

4.1 Basic introduction

A furnace is the heart of any glass manufacturing process, responsible for melting raw materials at high temperatures to form molten glass. These furnaces operate continuously to ensure a steady production flow, making their design and efficiency critical to the overall glass manufacturing process.

Types of Furnaces in Glass Industries:

1. Pot Furnace
   - Used for small-scale or specialized glass production.
   - Consists of ceramic or refractory pots that hold the molten glass.
   - Ideal for producing high-quality, specialized glass batches.
2. Tank Furnace
   - Commonly used for large-scale, continuous glass production.
   - Features a large tank made of refractory materials to withstand extreme temperatures.
   - Operates continuously, ensuring consistent glass quality and efficiency.
3. Electric Furnace
   - Uses electrical energy to generate heat, reducing emissions compared to fossil-fuel furnaces.
   - Offers precise temperature control, improving glass quality.
   - Ideal for specialized or high-purity glass applications.
4. Regenerative and Recuperative Furnaces
   - Regenerative Furnace: Uses heat recovery systems with regenerators to improve energy efficiency.
   - Recuperative Furnace: Uses heat exchangers to preheat incoming air, reducing fuel consumption.

In this type of furnace, Akij Glass Industries furnace system is a merge of tank furnace and regenerative, recuperative furnace. Where a features of large tank made of refractory materials to withstand extreme temperatures. Also use heat recovery systems with regenerators to improve energy efficiency and use heat exchangers to preheat combustion air for reducing fuel consumption. Akij Glass furnace pool capacity is 600 ton. Also required almost 600 kW electric power for high power consuming blower.

4.2 Compressed natural air production process

Natural air is used in this station to produce compressed air which is then supplied to operate Solenoid valves and gas or diesel burners.

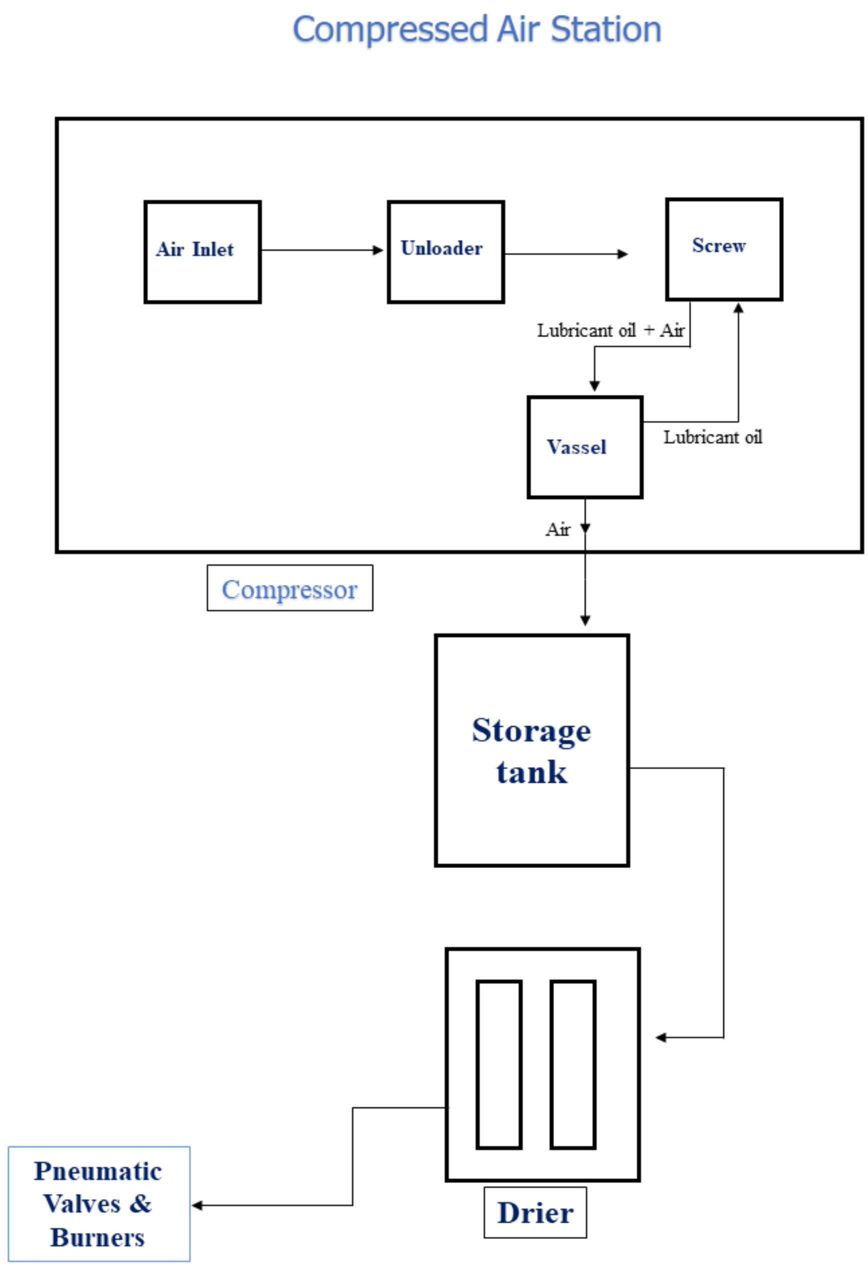


Fig 4.2: Compressed Air Station Process Flow Chart.

The equipment used here is given below:

1. Air Inlet

   Atmospheric air is drawn into the system through an air inlet filter to remove dust and impurities.

2. Unloader

   The unloader regulates air intake based on demand, ensuring the compressor runs efficiently.

3. Screw Compressor

   The air is compressed using a screw compressor, which increases air pressure by reducing its volume. Lubricant oil is used to minimize heat generation and friction.

4. Vessel (Oil Separator)

   The compressed air, mixed with lubricant oil, enters a vessel (oil separator) to separate the oil from the air. The oil is recirculated back to the compressor, while the purified compressed air moves forward.

5. Storage Tank

   The dry compressed air is stored in a storage tank, which acts as a buffer to manage pressure fluctuations and demand variations.

6. Drier

   The compressed air passes through a drier to remove residual moisture.Dry air prevents corrosion and enhances efficiency in downstream applications.

7. Solenoid Valves & Burners

   The compressed air is then distributed to different applications such as pneumatic valves and burners, which use air pressure for operation. At last compressed air main line pressure is 0.6MPa.

4.3 Oxygen gas production process

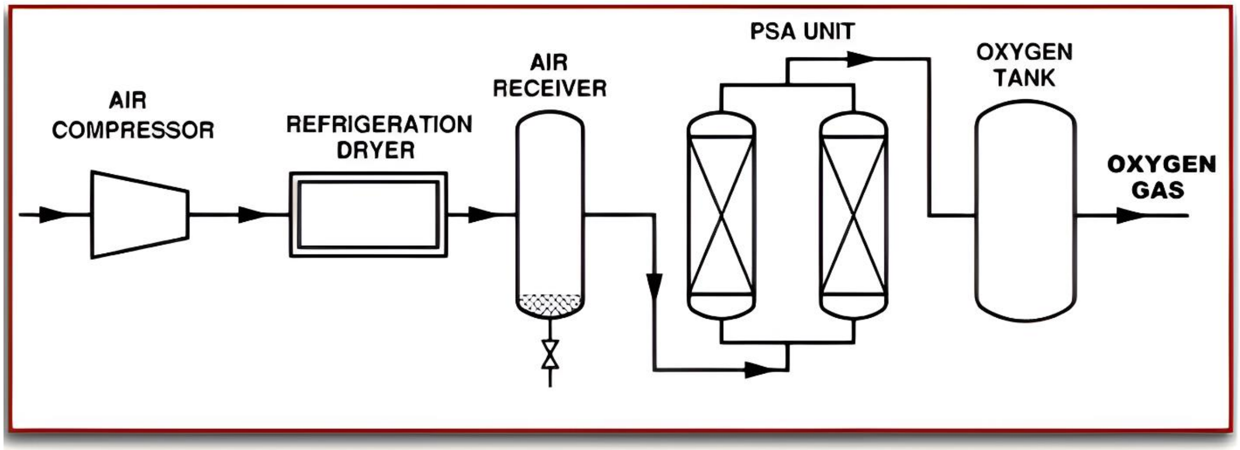


Fig 4.3: Oxygen gas production process

1. Air Intake & Filtration:

Ambient air is drawn into the system through intake filters. Also dust, moisture, and other large particles are removed. Here temperature almost (25°C - 35°C) and Pressure of Atmospheric almost 1 bar.

2. Compression of Air:

The filtered air is compressed using a multi-stage air compressor. The compression increases the pressure to facilitate the separation process. Here temperature almost 150°C - 200°C (after compression) and pressure almost (5 – 8) bar

3. Cooling & Pre-Purification:

The compressed air is cooled in an aftercooler to remove excess heat. Moisture, carbon dioxide (CO_2), and hydrocarbons are removed using molecular sieves or activated carbon filters to prevent freezing in later stages. Here temperature is almost 5°C and pressure (5 – 8) bar

4. Cryogenic Cooling & Liquefaction:

The purified air is further cooled using heat exchangers and expansion turbines to reach cryogenic temperatures. At, -190°C most of the air components liquefy except for neon and helium.

5. Distillation & Separation:

The liquefied air enters a fractional distillation column. Since oxygen has a higher boiling point (-183°C) than nitrogen (-196°C), nitrogen evaporates first. Oxygen is collected as a liquid at the bottom of the column. Here temperature is almost -183°C (for oxygen collection) and pressure 6 bar

6. Oxygen Gas Collection:

The liquid oxygen is vaporized and converted back to gas if required. The oxygen gas is compressed and stored in high-pressure cylinders or transported via pipelines. Here temperature is almost (25°C).

4.4 Gas control room

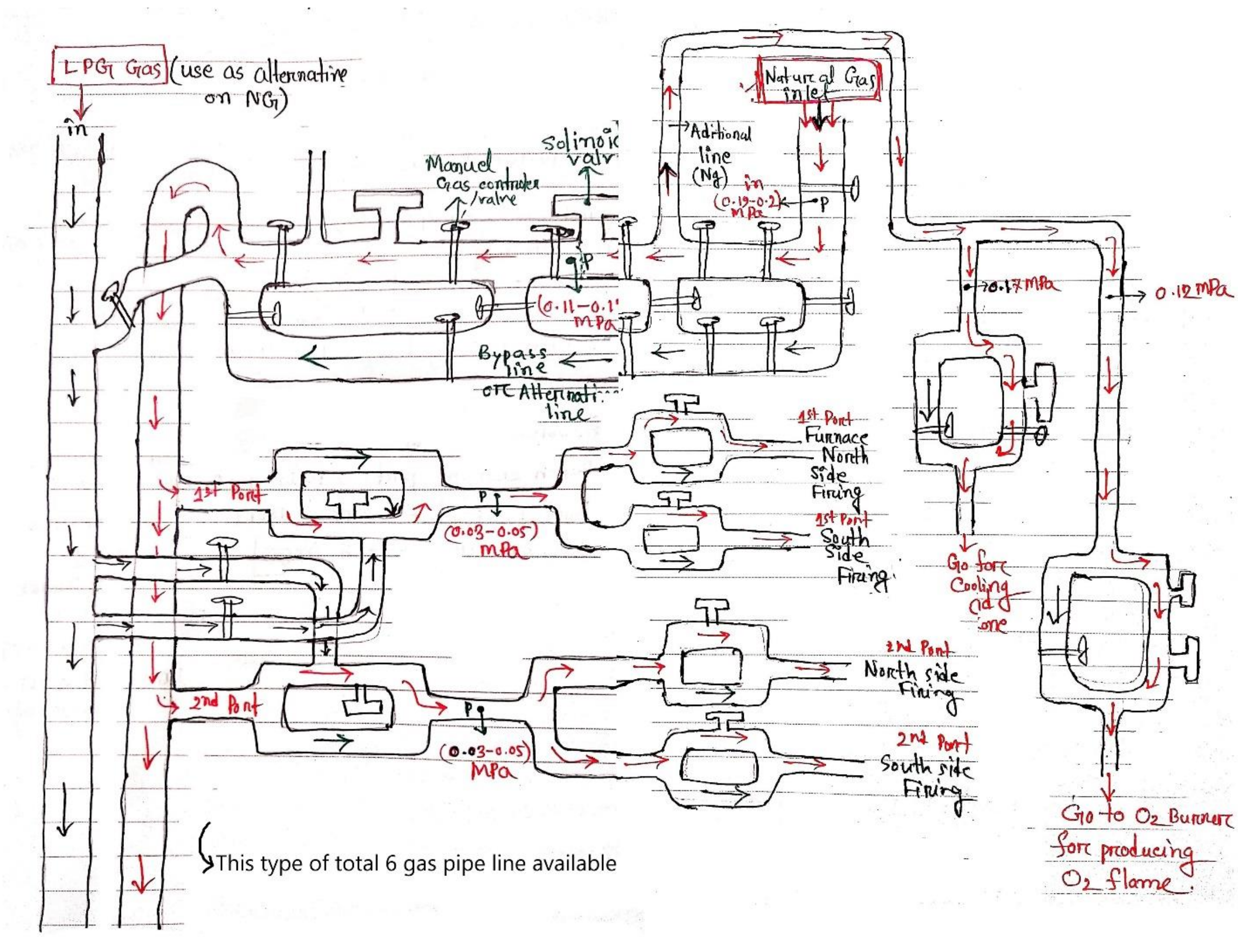


Fig 4.4: Gas control room

Natural gas enters the pressure of (0.19-0.2) MPa on the system from the main Natural Gas Line. Every natural gas pipe line has two line, one is main line of natural gas and other is bypass gas line of natural gas. This bypass gas line is used when technical any type of error creates of main gas line, then this alternative or bypass gas line used for continuous gas flowing. Because our furnace could not be closed at any cost. When natural gas enters firstly then main solenoidal valve reduce this gas pressure and create new pressure o.11-0.12 MPa.

Due to any situation create that natural gas supply is some of day closed then we can use LPG gas for producing burner flame. So, each type of system of furnace have their alternative way. This upcoming natural gas divide up to 6 gas pipe line, here also have bypass gas line system. Every one gas line divide two line, one is going for furnace north side firing and other is going for furnace south side firing. In this gas flow system, those gas line gone to port 1 to 5, this gas line pressure is generally (600-900) Nm3/hr.

Its depending up to which port need more heat. On the other hand port no 6 gas pressure generally rang of (80-200) Nm3/hr. Those port need more heat then, this port gas line gas pressure we control by CCR (Central Control Room). If when, CCR room to gas pressure control may not be happened then, er go to gas control room and check which type of problem is created, and then manually gas pressure controlled with helped by manual gas control valve. Port no (1 to 5) gas one side line divide on 3 gas burner but only 6 no port, one side gas line divide 2 gas burner. So total gas burner line of furnace north side is 17, and south side is 17.

4.5 Oxygen control room

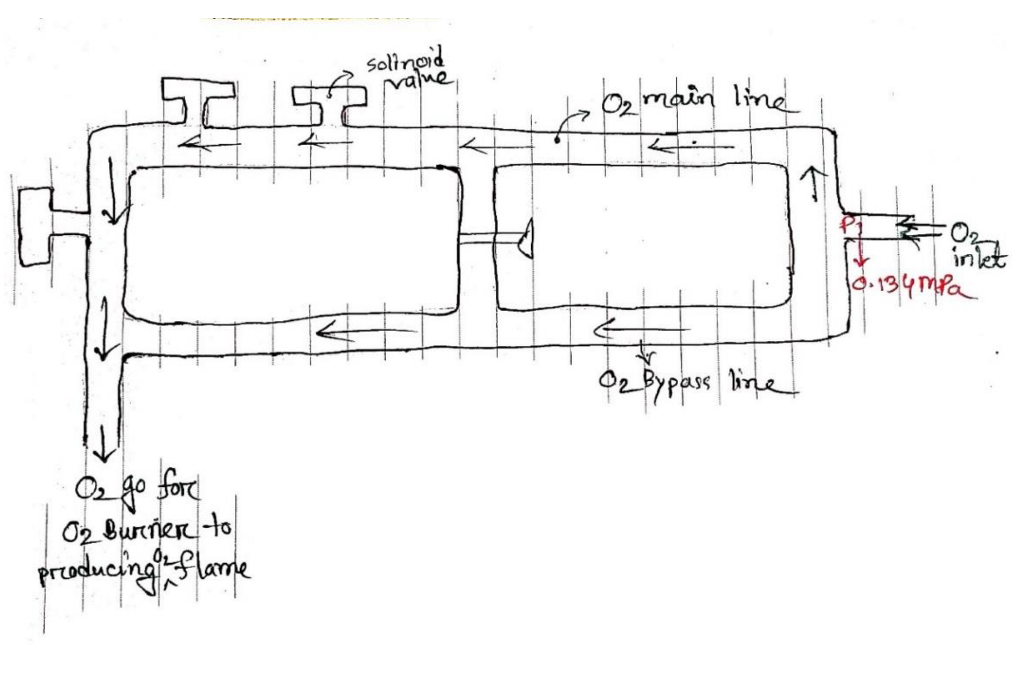


Fig 4.5: 4.5 Oxygen control room

1. Oxygen Inlet & Initial Pressure Control:

   Oxygen gas enters the system through the O_2 inlet at a pressure of 0.134 MPa.

2. Oxygen Main Line Distribution:

   The oxygen is directed into the O_2 main line, which distributes the gas to different parts of the system.

   The flow is controlled through a solenoid valve, which can be opened or closed automatically to regulate supply.

3. Bypass Line for Pressure Regulation:

   A portion of the oxygen flow is directed into an O_2 bypass line to maintain proper pressure balance.

   This helps in controlling excess pressure and ensuring a continuous supply without fluctuations.

4. Final Oxygen Supply to Burner:

   The regulated oxygen from the main line is then directed towards the O_2 burner.

   This oxygen is used for producing an oxygen-enriched flame, which improves combustion efficiency and increases furnace temperature.

4.6 Diesel/HFO control room

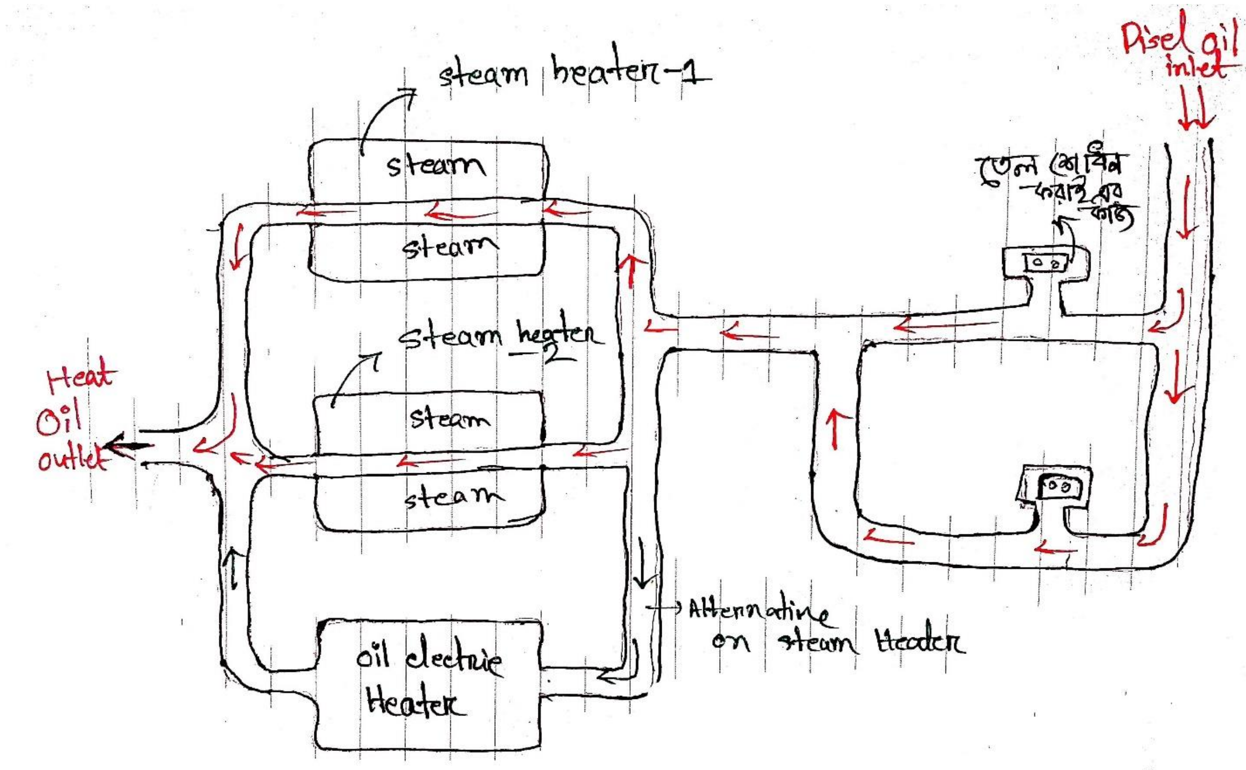


Fig 4.6: Diesel/HFO control room

1. Diesel Oil Inlet:

   Diesel oil enters the system from the "Diesel oil inlet" located on the right side of the diagram. It passes through a pipeline and reaches the oil pumping system where it is regulated and directed towards the heating system.

2. Initial Flow Towards Heating System:

   The oil moves through pipelines, following the arrows towards heating units. The system allows oil to be heated using steam heaters or an electric heater as an alternative.

3. Primary Heating – Steam Heater 1:

   The first heating stage involves "Steam Heater 1." Steam flows through the heater, transferring heat to the diesel oil to increase its temperature. Heated oil continues to flow towards the second stage.

4. Secondary Heating – Steam Heater 2:

   The oil further passes through "Steam Heater 2" for additional heating. This ensures that the oil reaches the required viscosity and temperature before being used in the furnace.

5. Alternative Heating – Oil Electric Heater:

   If steam heating is unavailable, the system allows switching to an "Oil Electric Heater." This provides an alternative heating source using electricity instead of steam.

   The oil passes through this heater to achieve the desired temperature.

6. Final Heated Oil Outlet:

   After passing through the heating system, the oil reaches the "Heat Oil Outlet." At this stage, the oil is at the appropriate temperature and viscosity. The heated oil is then supplied to the glass furnace port burners for combustion.

4.7 Introduction of basic machineries

1) Solenoid valve

2) Thermocouple (K-type)

3) Pyrometer

4.7.1 Solenoid valve

Fig 4.7.1: Solenoid valve

A solenoid valve is an electromechanically operated valve used to control the flow of liquids or gases in various industrial applications. It consists of a coil (solenoid), a plunger, and a valve body. When an electrical current passes through the coil, it generates a magnetic field that moves the plunger, opening or closing the valve. Solenoid valves are widely used in industries due to their fast response time, reliability, and automation capabilities.

Solenoid valves function based on the principle of electromagnetic induction. When the coil is energized, a magnetic field is generated, attracting the plunger and altering the valve's state (open or closed). These valves are categorized into:

1. Normally Closed (NC): The valve remains closed when de-energized and opens when powered.
2. Normally Open (NO): The valve stays open when de-energized and closes when powered.
3. Bi-Stable (Latching): The valve retains its position even after the power is turned off, requiring a pulse to switch states.

4.7.2 Thermocouple (K-type)

Fig 4.7.2: Thermocouple (K-type)

A K-type thermocouple is one of the most widely used temperature sensors in industrial applications due to its durability, wide temperature range, and cost-effectiveness. It consists of two different metal wires—Chromel (90% Nickel, 10% Chromium) and Alumel (95% Nickel, 2% Manganese, 2% Aluminum, 1% Silicon)—joined at one end to form a sensing junction. When exposed to temperature variations, it generates a voltage proportional to the temperature difference, which can be measured and converted into temperature readings.

Used in furnaces and kilns to monitor and control high-temperature processes. Essential for achieving precise temperature control during sintering, melting, and annealing. Helps in ensuring product consistency and preventing thermal shock.

4.7.3 Pyrometer

Fig 4.7.3: Pyrometer

A pyrometer is a non-contact temperature measurement device used extensively in industrial applications. It operates on the principle of detecting infrared radiation emitted by an object to determine its temperature. Pyrometers are essential in industries where high temperatures make direct contact measurement impractical or impossible.

A pyrometer measures temperature without touching the object. It works by detecting the infrared radiation (heat energy) emitted by the object.

- Heat Radiation Detection: The object emits infrared radiation based on its temperature.
- Focusing the Radiation: A lens or sensor captures this radiation.
- Signal Conversion: The radiation is converted into an electrical signal.
- Temperature Calculation: A microprocessor processes the signal and calculates the temperature.
- Display & Output: The temperature is shown on a screen or sent to a control system for monitoring.

4.8 Blower type and application

In furnace total 5 type of blower is contain, also their application is different places. But each of this blower work on supply natural air to the furnace. This 5 type of blower is given bellow:

1) Combustion Blower

2) Tank Cooling Blower

3) Steel Skewback Blower

4) Dilution Blower

5) L-suspended Blower

4.8.1 Combustion Blower

A combustion blower is an essential component in glass manufacturing furnaces, for supplying the required air for fuel combustion. Proper air-fuel mixing ensures efficient heating, stable furnace operation, and consistent glass quality. There are 2 combustion blower here, each of blower power consume 90 KW. At the same time 1 blower is working and other is reserving for furnace combustion blower system.

The combustion blower begins by drawing in air from the surrounding environment. This air passes through filters to remove dust, dirt, and other impurities. Clean air is essential for efficient combustion because contaminants can affect the burning process and lead to incomplete combustion, increasing fuel consumption and emissions. Once the air is collected, the blower compresses it and directs it towards the burners at high pressure.

This pressurization ensures a steady and controlled flow of oxygen-rich air, which is necessary for maintaining a consistent and stable combustion process. Proper air pressure regulation helps achieve uniform heat distribution inside the furnace. The compressed air is then sent to the burners, where it mixes with fuel, such as natural gas, oil, or other combustible materials. Maintaining the correct air-to-fuel ratio is critical because an imbalance can lead to inefficient combustion. Too much air can cool the furnace, wasting energy, while too little air can cause incomplete combustion, leading to increased carbon monoxide production and reduced thermal efficiency.

4.8.2 Tank Cooling Blower

Tank cooling blowers are very important components of the furnace system, specifically used to regulate the temperature within the furnace. These blowers are designed to cool specific parts of the furnace, such as the tank where molten glass is stored, ensuring that the glass is melted and processed at the ideal temperature. There are 4 tank cooling blower here, each of blower power consume 200 KW. At the same time 2 blower is working and other is reserved for furnace tank cooling system. This tank cooling blower pipe is extensive furnace dog house to neck zone.

The tank cooling blower draws in ambient air from the surrounding environment. Since there is no filtration system, the air entering the blower may contain some dust or impurities. However, in this case, the blower's main focus is to provide a steady flow of air for cooling purposes, rather than air quality or cleanliness. Once the air is drawn in, the blower compresses it and directs it toward the specific areas of the furnace that need cooling, such as the furnace walls or the tank where the molten glass is stored. This helps to prevent the furnace from overheating, particularly the tank area, which must be kept at an optimal temperature to maintain the quality of the molten glass. The air is blown directly into the furnace or tank, cooling down the areas with excessive heat. By doing so, it helps absorb and dissipate the heat from the furnace structure and the molten glass. Cooling is crucial because high temperatures, if left unchecked, can damage furnace components and affect the consistency of the glass production process. The cooling ensures that the furnace does not overheat and that the glass melts at the correct viscosity.

4.8.3 Steel Skewback Blower

The Steel Skewback Blower is used to cool down the corner blocks of the furnace, ensuring that the overall furnace temperature and heat distribution remain balanced. There are 2 steel skewback blower here, each of blower power consume 70 KW. At the same time 1 blower is working and other is reserved for furnace steel skewback blower system. This steel skewback blower is extensive on furnace, pre-melting zone, melting zone and post melting/pre-refining zone top corner side.

The steel skewback blower is to cool down the corner blocks of the furnace. These blocks can become overly heated or experience uneven temperature distribution, especially when the top block is not melting as efficiently as required. The directed airflow ensures that these corners receive adequate cooling, preventing overheating and ensuring the structural integrity of the furnace. Cooling the corner blocks helps in maintaining the overall furnace balance and prevents potential damage caused by excessive heat buildup in localized areas.

4.8.4 Dilution Blower

Dilution Blower is essential for cooling the "cooling end zone" of the furnace, where the molten glass begins to cool before being formed into its final shape. The cooling of this area must be carefully controlled to prevent temperature fluctuations that could cause defects in the glass. There are 2 dilution blower here, each of blower power consume 15 KW. At the same time 1 blower is working and other is reserved. This dilution blower is extensive of cooling end zone 6 dilution pipe.

The Dilution Blower first pulls in ambient air from the surrounding environment. This air passes through filters to remove dust, dirt, and other impurities, ensuring that clean air enters the system. Clean air is crucial for proper cooling and to prevent contamination of the molten glass. Once the air is filtered, the Dilution Blower compresses the air and directs it into the cool end zone of the furnace. The blower provides a controlled volume of air that helps reduce the temperature of the molten glass. The amount of air delivered is carefully controlled to avoid cooling the glass too quickly, which can lead to stresses or cracks. The main function of the dilution blower is to maintain a stable and controlled cooling process in the cool end zone of the furnace. As the molten glass moves toward this cooler region, the blower releases a regulated amount of air to absorb and remove the excess heat from the glass. This cooling must be gradual and uniform to ensure the glass solidifies properly and doesn’t develop thermal stresses or distortions.

4.8.5 L-suspended Blower

L-suspended blower main principle is to cool the L-suspended wall, to prevent the brick wall damaged. By supplying controlled airflow to these walls, the blower helps maintain the structural integrity of the furnace, ensuring a longer lifespan and consistent performance. There are 2 L-suspended blower here, each of blower power consume 55 KW. At the same time 1 blower is working and other is reserved.

This L-suspended wall is critical in the furnace, as it is exposed to extremely high temperatures due to the combustion and heat generation. The L-suspended blower helps to channel a high volume of cool air directly onto the wall to prevent it from overheating. The primary function of the L-suspended blower is to provide consistent airflow to cool down the L-suspended wall, which is typically made of refractory bricks. Without proper cooling, the intense heat inside the furnace could cause the wall to melt or degrade, compromising the structural integrity of the furnace. The controlled airflow from the blower ensures that the wall remains within a safe temperature range, extending the life of the furnace and preventing costly repairs.

4.9 Combustion air exchanger

When combustion blower is produce combustion air, then this air need to divide furnace north side and south side due to firing side is different. So then must need to air exchanger because at the same time will not be happened two side firing. This firing side is to change after 20 minutes, as a result combustion air side need to change at the same time of changing firing side. We divide this air exchanger to type for understanding. This two type of combustion air exchanger is given bellow:

1) When left side firing

2) When right side firing

4.9.1 When left side firing

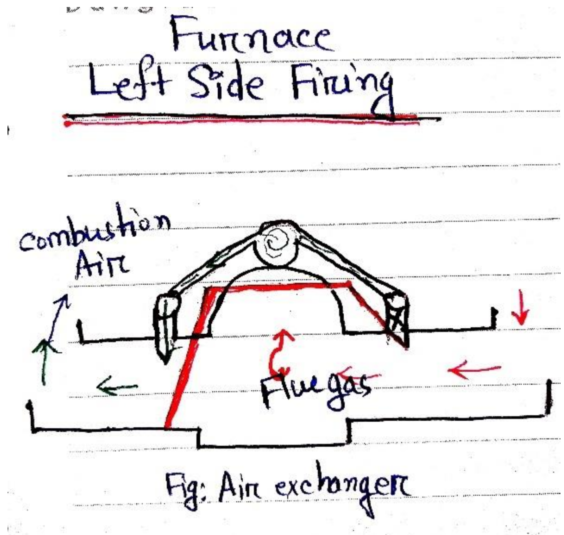


Fig 4.9.1: when left side firing

When left side will firing, then combustion air need to left side. So its need to combustion air prevent to go for right side, this work is to done by gate valve. When left side combustion air flow path is to open and flue gas line is closed, at the same time right side will be happened this opposite, because then right side firing is off. So right side combustion air flow is closed and flue gas line flow is open. This process again change after 20 minutes when right side will be firing.

4.9.2 When right side firing

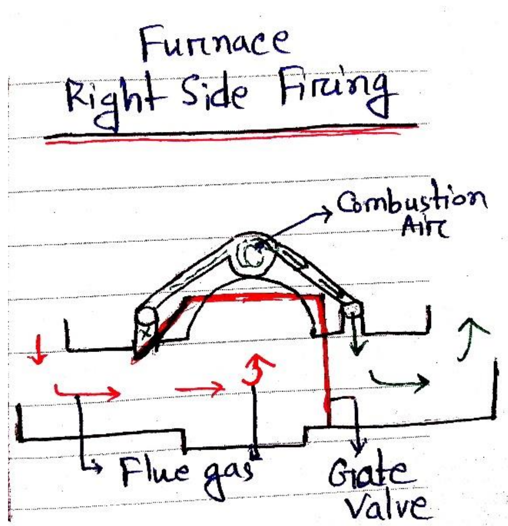


Fig 4.9.2: when right side firing

When right side will firing, then combustion air need to right side. So its need to combustion air prevent to go for left side, this work is to done by gate valve. When right side combustion air flow path is to open and flue gas line is closed, at the same time left side will be happened this opposite, because then left side firing is off. So left side combustion air flow is closed and flue gas line flow is open. This process again change after 20 minutes when left side will be firing.

4.10 Brick type and their basic composition

Generally we use 9 type of brick in different place of furnace. They are given bellow:

1. Silica brick
2. Silica brick (95-99% silica)
3. Alpha-Bita Alumina brick
4. Sinter AZS brick
5. Zirconia brick
6. Sinter zirconite brick
7. (Magnesia + Chrome magnesia) brick
8. (Magnesia + Calsium Oxaid + Zirconia) brick
9. Mullite brick (Insulation brick)

Here’s a brief composition overview of each type of brick used in glass manufacturing furnaces:

1. Silica Brick

Composition: Primarily composed of silica (SiO_2), usually 93-97% silica.

Properties: High thermal stability, excellent resistance to thermal shock, and good refractoriness. It is ideal for high-temperature applications like glass furnaces.

2. Silica Brick (95-99% Silica)

Composition: 95-99% silica with small amounts of impurities like alumina or iron oxide.

Properties: Offers high resistance to thermal shock and excellent refractoriness. It’s used in glass melting furnaces, especially for areas exposed to high heat.

3. Alpha-Beta Alumina Brick

Composition: Predominantly alumina (Al_2O_3) with a mixture of alpha and beta phases of alumina.

Properties: Excellent resistance to thermal shock, high mechanical strength, and good resistance to alkali attack. These bricks are typically used in high-temperature zones of furnaces.

4. Sintered AZS Brick

Composition: A mixture of alumina (Al_2O_3), zirconia (ZrO_2), and silica (SiO_2). Typically contains 70-90% alumina, 5-25% zirconia, and silica content varies. Properties: Known for superior resistance to corrosion, especially in contact with molten glass. It’s highly resistant to thermal shock and has high mechanical strength.

5. Zirconia Brick

Composition: Mainly composed of zirconia (ZrO_2), often with small amounts of silica or other stabilizing oxides.

Properties: Excellent high-temperature stability and resistance to molten glass. It’s used in areas of the furnace exposed to extreme temperatures and molten glass attack.

6. Sintered Zirconite Brick

Composition: Zirconium silicate ($ZrSiO_4$) is the primary component.

Properties: Offers high thermal shock resistance and good resistance to molten glass. It has good mechanical strength at high temperatures, used in furnace walls and other critical areas.

7. (Magnesia + Chrome Magnesia) Brick

Composition: A combination of magnesia (MgO) and chrome magnesia ($MgO\text{-}Cr_2O_3$). The exact percentage can vary, typically 70-90% magnesia with chrome content.

Properties: Excellent resistance to high temperatures and thermal shock, as well as good resistance to basic slags and molten metal. It is used in the furnace's structure where high temperatures and aggressive conditions are present.

8. (Magnesia + Calcium Oxide + Zirconia) Brick

Composition: A mixture of magnesia (MgO), calcium oxide (CaO), and zirconia (ZrO_2), typically in a ratio of 60-80% magnesia, 10-20% calcium oxide, and 10-20% zirconia.

Properties: High resistance to corrosion, especially against alkaline and basic slags. It offers enhanced thermal stability and is used in environments exposed to high temperatures and molten glass.

9. Mullite Brick

Composition: Primarily composed of mullite ($3Al_2O_3 \cdot 2SiO_2$), along with small amounts of alumina and silica.

Properties: Excellent thermal shock resistance and mechanical strength at high temperatures. These bricks are used in furnace structures that require both refractoriness and resistance to mechanical stresses.

1) Furnace and cooling zone arch/top is made by silica brick (95-99% silica)

2) Cooling zone side wall is made by silica brick

3) Cooling tank/block is made by Alpha-Bita Alumina

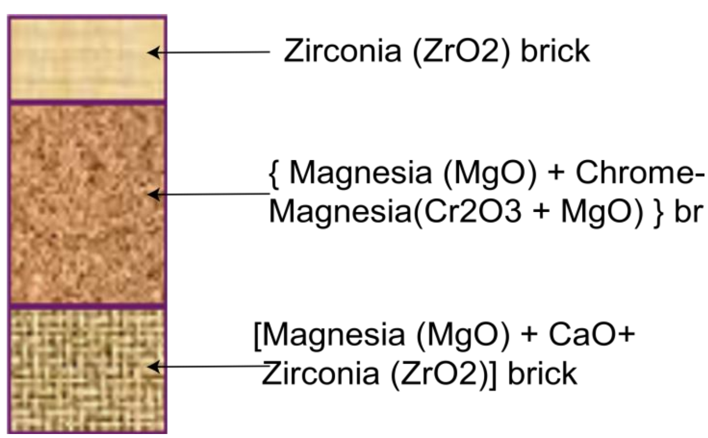
4) Furnace tank (high alumina + low porosity insulation brick) is made by sintered AZS.

Here, A is Alumina (50-55%), Z is Zirconia (30-40%) and S is Silica (10-15%).

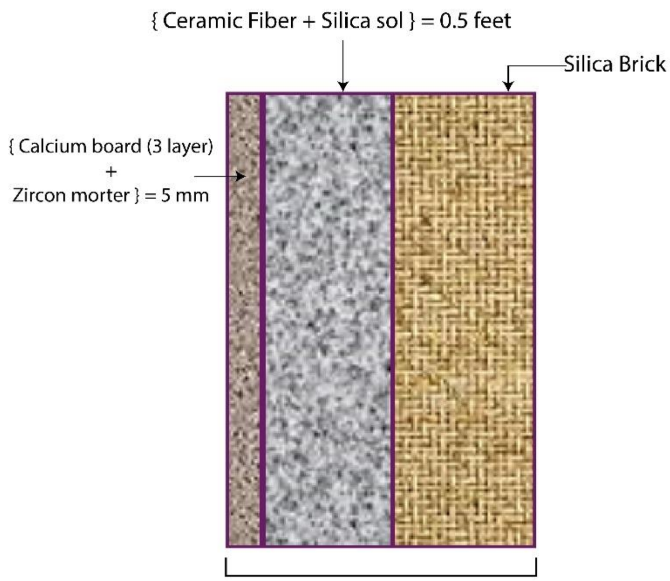
5) Furnace port is made by (AZS + Zirconia) brick

6) Port side wall is made by Sintered Zirconite

7) Regenerator inside and side wall brick:



8) Furnace side wall and top view with insulation:



Furnace side wall or
Furnace top Layer view

4.11 Furnace front side view

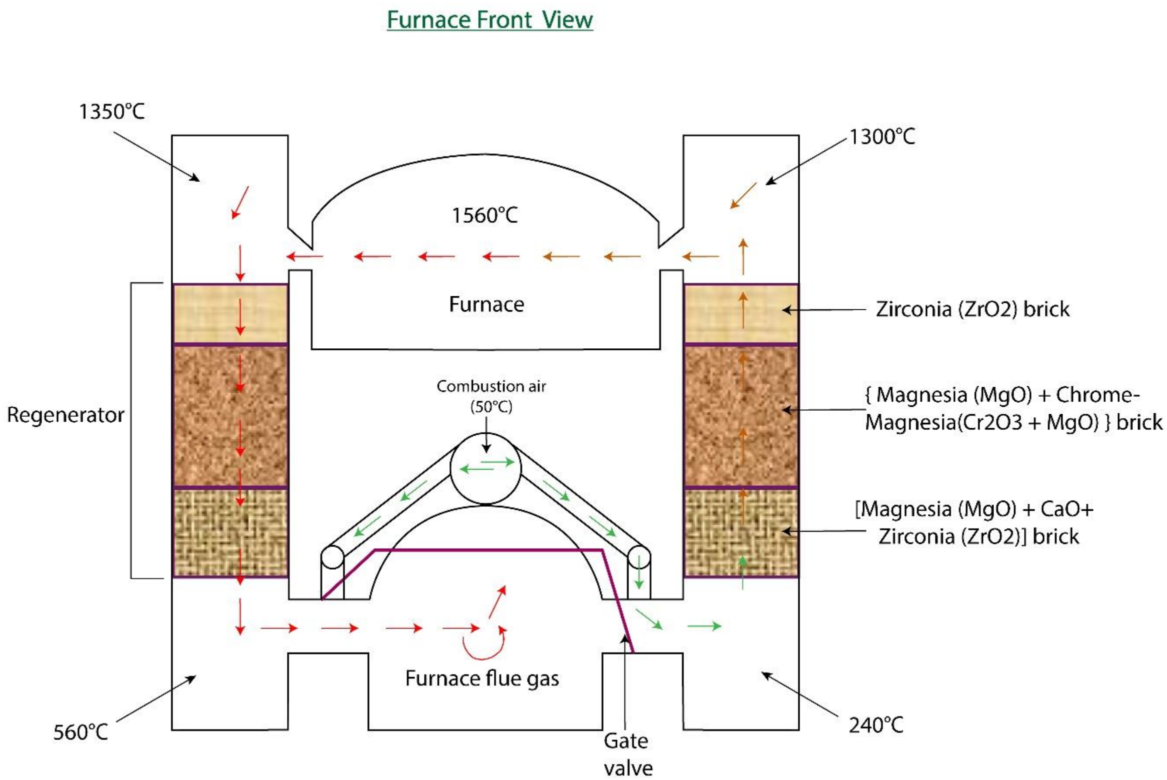


Fig 4.1.1: Furnace Front View

Regenerative Combustion Process in a Glass Furnace:

In glass manufacturing, high temperatures are required to melt raw materials into liquid glass. To maintain efficiency and reduce fuel consumption, regenerative furnaces are used. These furnaces work by recycling heat through special chambers called regenerators. The system switches sides every 20 minutes, ensuring that one side is always firing while the other side is absorbing heat for the next cycle.

This process helps in saving energy, reducing gas consumption, and maintaining consistent furnace temperatures. Below is a step-by-step explanation of how this system works.

Heating the Combustion Air:

Fresh combustion air is supplied by a combustion blower at a temperature of about 50°C. This air enters the regenerator on the firing side through narrow pipes. The regenerator contains special heat-resistant bricks that were heated in the previous cycle. As the fresh air passes through these bricks, it absorbs heat, increasing its temperature from 240°C to 1300°C. The hot air then enters the main furnace chamber through special openings called ports. Here, it mixes with fuel (natural gas or oil) and burns to produce high temperatures (around 1560°C). This heat is used to melt the raw materials into liquid glass.

Flue Gas Heat Recovery:

On the opposite side of the furnace, flue gases (waste gases) at 1350°C exit through the ports. These gases still contain a lot of heat, which can be reused instead of being wasted. The hot flue gases pass through the cool bricks of the opposite regenerator. As they travel, they transfer heat to the bricks, raising their temperature. After transferring most of their heat, the flue gases cool down to around 560°C. Due to friction in the pipes, their temperature further drops to 400°C before being released. The remaining gases are sent to a boiler, where extra heat is used for other industrial purposes. Finally, the gases exit through a chimney into the atmosphere.

Switching the Firing Side (Every 20 Minutes):

If only one side kept firing, the opposite side's temperature would drop, making the process inefficient. To maintain balance, the system switches sides every 20 minutes. The previously firing side now becomes the exhaust side, where flue gases transfer heat to the bricks. The previous exhaust side now becomes the firing side, using the heat stored in its bricks to preheat new air. This alternating process ensures that one regenerator is always hot, and the other is always absorbing heat for the next cycle. This way, we never waste heat, and the furnace runs continuously without extra fuel consumption.

The Role of Refractory Bricks:

Since the furnace runs at extremely high temperatures, it must be built with special heat-resistant bricks to prevent damage. Different types of refractory bricks are used in different parts of the furnace, depending on their heat exposure.

Zirconia (ZrO_2) Bricks:

- These are highly resistant to extreme heat and chemical attacks.
- Used in areas close to molten glass, where they prevent damage and erosion.

Magnesia (MgO) + Chrome Magnesia ($Cr_2O_3 + MgO$) Bricks:

- These bricks are used in the regenerators where heat exchange happens.
- They withstand frequent temperature changes and chemical corrosion.

Magnesia (MgO) + CaO + Zirconia (ZrO_2) Bricks:

- Used in the lower sections of the regenerator, where temperatures rise slowly.
- Provides a balance between heat resistance and structural strength.

4.12 Furnace top side view with zone details

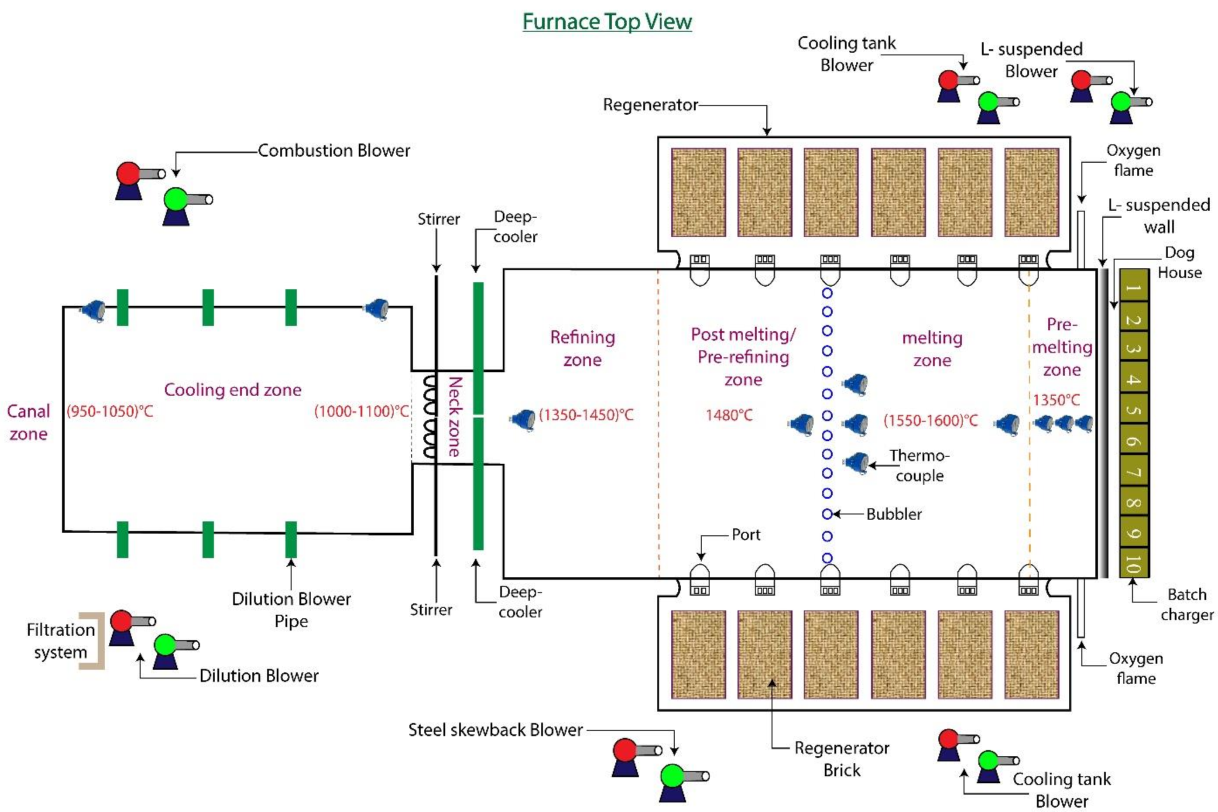


Fig 4.12: Furnace Top view

4.12.1 Batch Charger:

The batch charger is a crucial component in the glass melting process, responsible for feeding raw materials (batch) into the pre-melting zone of the furnace. It ensures a continuous and controlled supply of batch materials, optimizing the melting process and maintaining furnace efficiency.

Batch Distribution and Feeding Process:

The batch plant prepares the raw materials, which include silica sand, soda ash, limestone, feldspar, and cullet (recycled glass). These materials are transported to the furnace hopper, where they accumulate before being fed into the furnace. The hopper is divided into 10 separate zones, ensuring even distribution of the raw materials across the furnace. Each batch charger is responsible for 5 zones, which allows for balanced batch feeding. The batch chargers operate in pairs, meaning that at any given time, two batch chargers are feeding material into the pre-melting zone through the doghouse (the entry point for raw materials). The doghouse prevents heat loss from the furnace while allowing continuous batch charging.

4.12.2 Port:

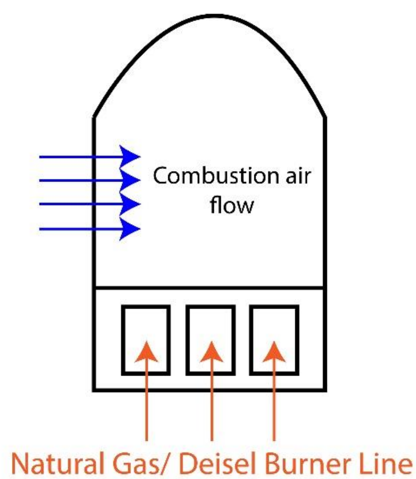


Fig: Port

Furnace Ports play a crucial role in the combustion and heat transfer process. Ports are openings that allow the passage of hot gases and air, facilitating efficient heating of the raw materials inside the furnace. Our furnace is equipped with a total of 12 ports, with 6 ports on the north side of furnace and 6 ports on the south side of furnace. These ports function as entry and exit points for combustion air and flue gases, ensuring optimal thermal efficiency.

Working of Furnace Ports:

Preheated combustion air enters through the ports, ensuring efficient fuel burning and heat distribution. This air is heated by regenerators before entering the furnace, reaching temperatures up to 1300°C to maximize efficiency. The ports help distribute the heat evenly across the furnace, aiding in the melting of batch materials. The placement of ports ensures proper heat balance, preventing localized overheating or cold spots. The hot flue gases generated during combustion exit through the ports on the opposite side. These gases transfer heat to the regenerators before being directed toward the chimney for exhaust.

4.12.3 Gas Burner:

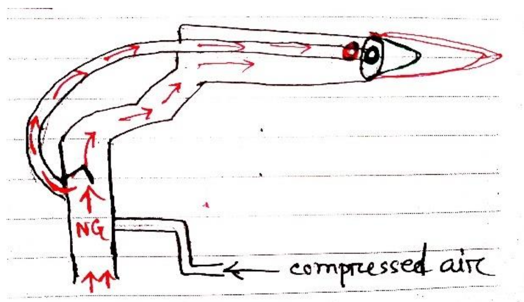


Fig: Gas Burner

the thin pipeline maintains a high pressure, ensuring a steady and controlled flow of gas to the burner. The position of the gas supply significantly affects the size of the flame.

If the gas supply is moved backward (away from the burner nozzle), the gas disperses more before ignition, leading to a larger and more intense flame.

If the gas supply is moved forward (closer to the burner nozzle), the gas concentration increases at the ignition point, resulting in a smaller and more controlled flame.

Additionally, when the burner is not firing, compressed natural air is introduced into the system. This airflow serves a crucial function in cooling down the burner, preventing overheating, and maintaining operational efficiency. This cooling process helps extend the burner's lifespan and ensures safe and stable performance during the next firing cycle.

4.12.4 Oxygen Burner:

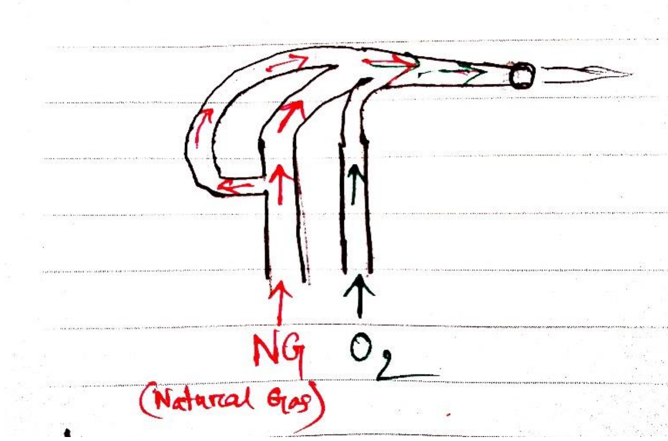


Fig: Oxygen Burner

In the pre-melting zone of the furnace, positioned between the doghouse and Port No. 1, oxygen burners are installed on both sides. These burners play a crucial role in maintaining an adequate oxygen supply within the furnace, ensuring efficient combustion and stable thermal conditions.

These oxygen burners operate continuously, providing a consistent flow of oxygen to support the combustion process. This steady oxygen supply enhances the burning efficiency of natural gas, leading to better heat distribution and improved melting performance.

For optimal combustion, the natural gas-to-oxygen ratio in these burners is precisely maintained at 1:2. This means that for every unit of natural gas, twice the amount of oxygen is supplied. This ratio ensures complete combustion, reducing fuel consumption, minimizing emissions, and maximizing energy efficiency.

By maintaining this controlled oxygen supply and burner operation, the furnace achieves higher melting efficiency, stable thermal conditions, and reduced environmental impact.

4.12.5 HFO/ Diesel Oil Burner:

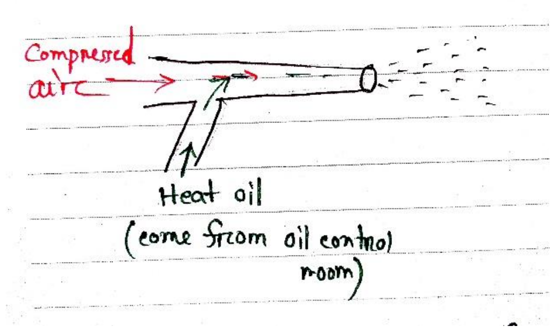


Fig: HFO/ Diesel Oil Burner

This diesel oil need to use this time when natural gas pressure is not enough to continue furnace 6 port firing. But it must be happened that, when we use diesel then total 1 port, that means 3 burner all of line use diesel oil. Its not such like that, 1 port, 2 burner we use natural gas and other 1 burner use diesel oil flow.

4.12.6 Pre-melting zone:

The pre-melting zone is the initial section of the furnace where the batch materials begin their transformation from solid to molten state. It extends up to Port No. 1 and serves as a preparatory stage before the batch enters the main melting zone. This stage is crucial for efficient heat transfer and ensuring uniform melting of the raw materials. In this zone temperature generally 1350°C

Glass formation reaction of this zone:

at 450 °C temperature, water remove from batch.

(550°C - 600°C) temperature, $MgCO_3 \rightarrow MgO + CO_2$

(750°C - 800°C) temperature, chemical reaction is to be initiation.

Here, $Na_2CO_3 + SiO_2 \rightarrow Na_2OSiO_2 + CO_2$

The pre-melting zone consists of ten separate paths, corresponding to the ten zones of the furnace hopper. These zones keep the batch materials organized, preventing cross-mixing and ensuring even distribution across the furnace. At the beginning of the pre-melting zone, two oxygen flames (one on each side) are used. These flames help in oxygen enrichment, which improves fuel combustion efficiency and raises the temperature in this zone. The enhanced combustion process accelerates the heating of batch materials, making the melting process more energy-efficient. Although the solid batch enters from the top, the bottom layer of this zone already contains molten glass from the melting process. As the batch materials fall, they come into direct contact with the molten glass, significantly increasing their temperature. This heat transfer from molten glass to solid batch speeds up the melting process, reducing energy consumption and ensuring a more uniform glass composition.

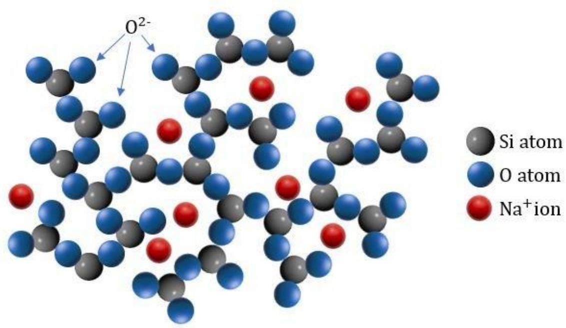
4.12.7 Melting zone:

The melting zone is the most crucial section of the glass furnace, where the batch materials undergo complete melting. It extends from Port No. 1 to Port No. 4 and plays a vital role in ensuring the uniform composition and quality of the glass. In this zone temperature generally (1550°C - 1600°C).

Glass formation reaction of this zone:

$Na_2OSiO_2 \rightarrow Na_2O\ 2\ SiO_3$

$Na_2O\ 2\ SiO_3 \rightarrow Na_2SiO_3$, this is actual glass chemical structure.



Structure: Na_2SiO_3

The batch materials enter from the pre-melting zone, they are fully exposed to high temperatures ranging from 1550°C to 1600°C. The high temperature ensures that all solid particles, including any undissolved raw materials, are completely melted and fully incorporated into the molten glass. To maintain precise temperature control, four thermocouples are installed throughout the melting zone. These thermocouples continuously measure and regulate the furnace temperature, ensuring that the melting process remains stable and efficient. Proper temperature control helps prevent glass defects such as bubbles, streaks, or inhomogeneities. At Port No. 4, a bubbler is introduced into the molten glass. The bubbler releases small gas bubbles into the melt, which helps to enhance heat distribution and promote better mixing within the glass.

4.12.8 Bubbler:

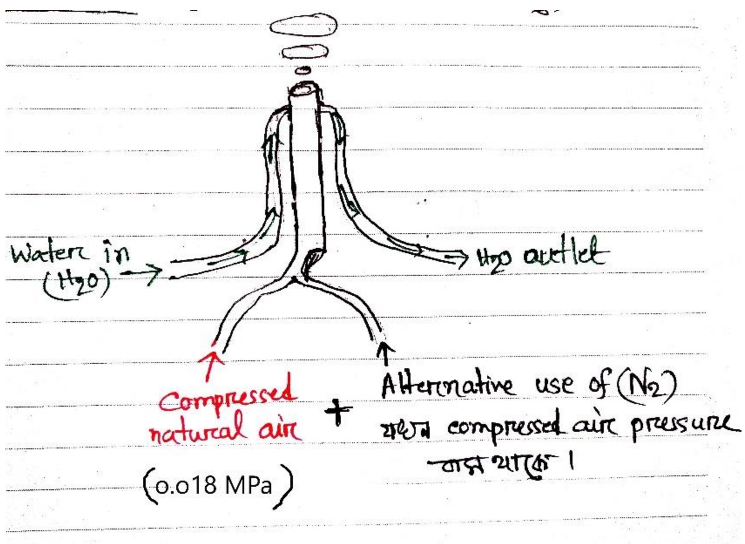


Fig: Bubbler

The bubbler system in a glass furnace plays a crucial role in enhancing the melting process and improving glass quality. It is located at Port No. 4, where 14 bubblers are installed at the bottom of the furnace. These bubblers ensure that the glass melt undergoes proper circulation, heat distribution, and impurity removal, ultimately leading to a homogeneous and defect-free molten glass. The 14 bubblers at Port No. 4 supply approximately 38-40 tons of water per hour to sustain the bubbling effect. Additionally, around 170-180 liters per hour of compressed air is injected into the system to generate consistent and controlled bubbling.

If any unmelted batch material reaches Port No. 4, the bubblers create a barrier that prevents it from moving forward into the next furnace zone. Instead of allowing the unmelted material to pass, the bubbling effect redirects it back into the melting zone, ensuring it undergoes further heating and melting. This helps maintain the consistency and quality of the molten glass by ensuring only completely melted glass moves forward. The bubblers help in stirring and circulating the molten glass inside the furnace. As bubbles rise from the bottom, they push the upper molten glass downward, while simultaneously bringing the lower melt upward. This circulation effect ensures that heat is evenly distributed throughout the melt, preventing temperature variations that could lead to glass defects.

4.12.9 Post-Melting / Pre-Refining Zone:

The Post-Melting / Pre-Refining Zone is a critical stage in the glass melting process. It extends from Port No. 4 to the end of the regenerator section and serves as a transitional phase between the melting zone and the refining zone. This zone ensures that the molten glass is properly conditioned before it enters the final refining stage. In this zone temperature generally 1480°C

Glass formation reaction of this zone:

$Na_2CO_3 \rightarrow Na_2O + CO_2$

By the time the molten glass reaches this zone, all batch materials should be fully melted. Any unmelted batch is redirected by the bubblers in the melting zone to prevent it from entering this stage. One of the key reactions that take place in this zone is the decomposition of sodium carbonate (Na_2CO_3). The release of carbon dioxide (CO_2) lowers the melting temperature, making the process more energy-efficient. The formation of sodium oxide (Na_2O) plays a crucial role in glass formation. Sodium Oxide (Na_2O) acts as a network modifier, which means it adjusts the structure of the glass. It reduces the viscosity of the molten glass, making it easier to refine and shape. This modification helps in achieving the desired properties of the final glass product, such as transparency, strength, and thermal stability.

4.12.10 Refining Zone:

The Refining Zone is a crucial stage in the glass manufacturing process. It extends from the Post-Melting / Pre-Refining Zone to the Neck Zone and is responsible for ensuring that the molten glass is free from trapped gas bubbles and impurities. This stage plays a vital role in achieving high-quality, transparent glass that is suitable for industrial applications. This zone also called bubbler removing zone. In this zone temperature generally (1350°C - 1450°C)

Glass formation reaction of this zone:

$Na_2SO_4 \rightarrow Na_2O + SO_3$

$Na_2O + SO_3 \rightarrow Na_2O + SO_2 + (1/2)O_2$

Carbon (C) is used in this stage to regulate the activity of sodium sulfate (Na_2SO_4). It helps in controlling the refining reactions, ensuring that unwanted gases are removed effectively. However, carbon is not used in the production of colored glass because it may interfere with the coloring agents or lead to unwanted chemical reactions.

One of the main objectives of the refining zone is to eliminate any trapped gas bubbles in the molten glass. As the glass moves through this zone, refining agents facilitate the release of bubbles, making the glass clearer and more uniform. This is a crucial step because any remaining bubbles could weaken the final product or cause visual defects. Several refining agents are automatically formed in this zone due to chemical reactions. These agents include:

Sodium sulfate (Na_2SO_4) – Acts as a surface-active agent, helping gas bubbles rise to the surface.

Arsenic trioxide (As_2O_3) – Aids in bubble elimination by reducing surface tension.

Cc_2O_3 – Plays a role in refining by assisting in gas removal.

Antimony trioxide (Sb_2O_3) – Enhances the refining process by modifying bubble behavior.

4.12.11 Neck zone:

The neck zone is the narrow passage between the refining zone and the working end of the furnace. It helps regulate the flow of molten glass, ensuring a smooth transition while maintaining the required temperature. This zone also plays a role in controlling the glass temperature before it moves to the next stage. In this zone have two basic part, those are play a crucial role in homogenizing and cooling of glass melt. In this zone temperature generally (1100°C - 1350°C)

4.12.11.1 Deep Cooler

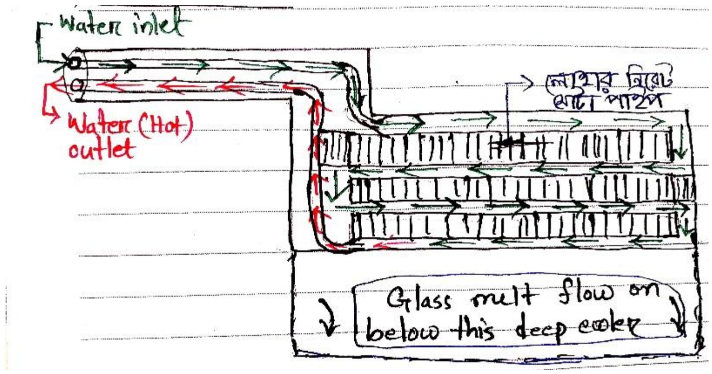


Fig: Deep Cooler

The deep cooler plays a crucial role in rapidly cooling the molten glass. This controlled cooling process helps stabilize the melt before it moves further into the working end. Additionally, the deep cooler aids in removing impurities or unwanted residues from the surface of the molten glass, ensuring a cleaner final product.

4.12.11.2 Stirrer

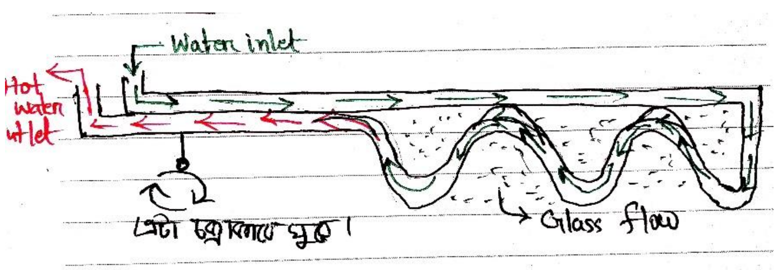


Fig: Stirrer

The stirrer also plays a role in cooling the molten glass and homogenizing it.

By continuously mixing the melt, the stirrer helps in evenly distributing the temperature throughout the molten glass, ensuring consistent heat distribution. It also ensures that the composition of the glass is uniform, preventing any variations in the quality of the final product.

4.12.12 Cooling end zone:

The cooling end zone plays a pivotal role in regulating the temperature of the molten glass as it progresses through the final stages of the furnace. This zone is crucial for preparing the glass to be workable for the next steps in the production process, particularly in the forming and tin bath sections. In this zone enter temperature generally (1000°C - 1100°C) and ending generally (950°C - 1050°C)

As the molten glass exits the refining zone, it enters the cooling end zone, where its temperature is carefully controlled. The temperature in this zone is gradually reduced to make the glass more manageable and suitable for the forming process. The required temperature for the forming or tin bath section is regulated in this zone and then transferred through the canal to the tin bath, where it is further processed.

As the temperature decreases in the cooling end zone, the viscosity of the molten glass increases, which means the glass becomes thicker and more resistant to flow. This increased viscosity leads to higher friction within the molten material, which plays a critical role in ensuring that the glass maintains its shape and consistency as it moves through the production line. This controlled cooling process ensures that the glass is ready to be molded into various forms and maintains the desired properties, such as uniformity and strength, before moving to the next stage of production.

4.13 Melt rotation flow system

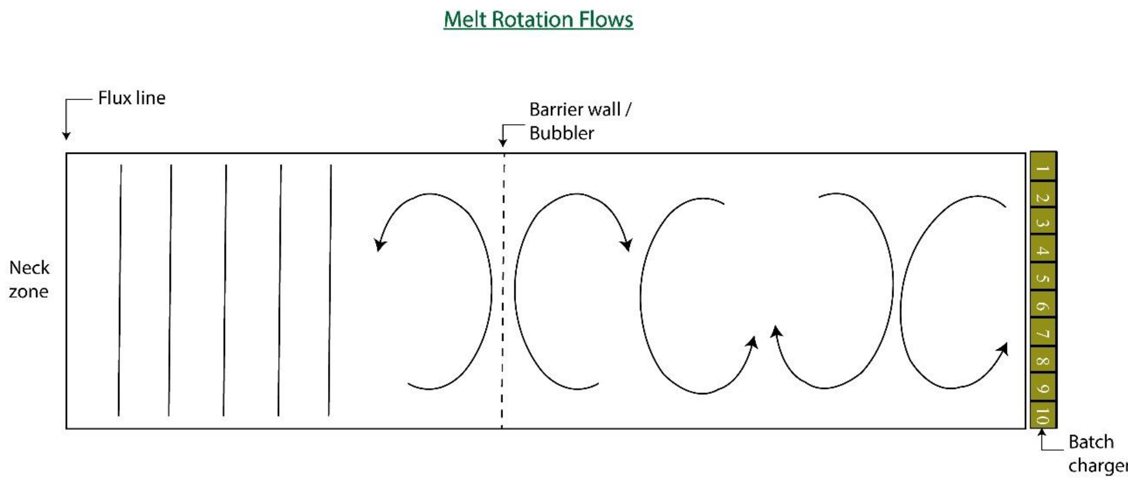


Fig 4.13: Melt rotation flow system

The melt rotation flows within a glass melting furnace, illustrating the movement of molten material during the melting process. On the left side, the neck zone is depicted with vertical flux lines, indicating a more linear flow in this region. A barrier wall or bubbler separates the neck zone from the main melting area, where rotational currents are present. The arrows in the main section represent convection currents, showing how the molten glass circulates within the furnace, which aids in homogenization and refining. On the far right, a batch charger introduces raw materials into the system, initiating the melting process. Additionally, the numbered sections (1–10) likely indicate different zones within the furnace, possibly representing temperature gradients or stages of the melting process. This diagram provides insight into how molten glass moves and interacts within the furnace to ensure a consistent and refined final product.

4.14 Furnace back side view

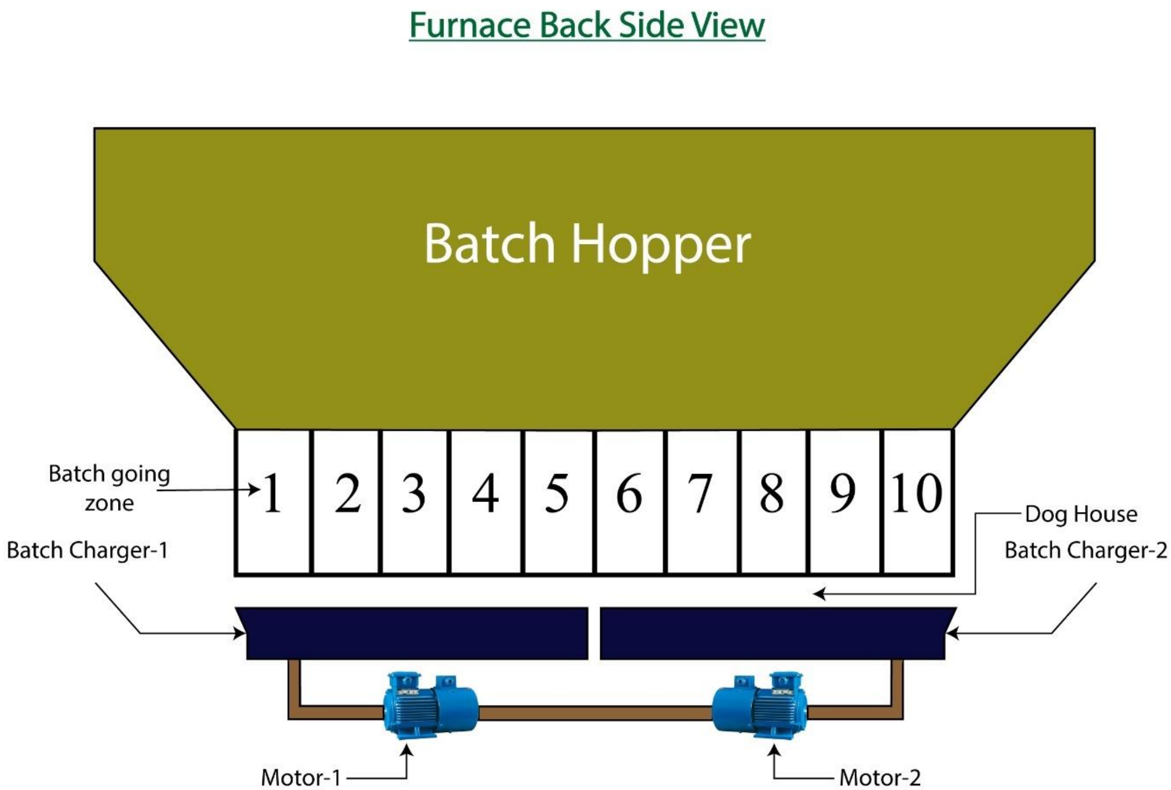


Fig 4.14: Furnace back side view

At the same time one motor is running and other motor is being reserve due to safety. This one motor is to move both batch charger, which through the batch into dog house to furnace pre-melting zone.

4.15 Furnace north side view

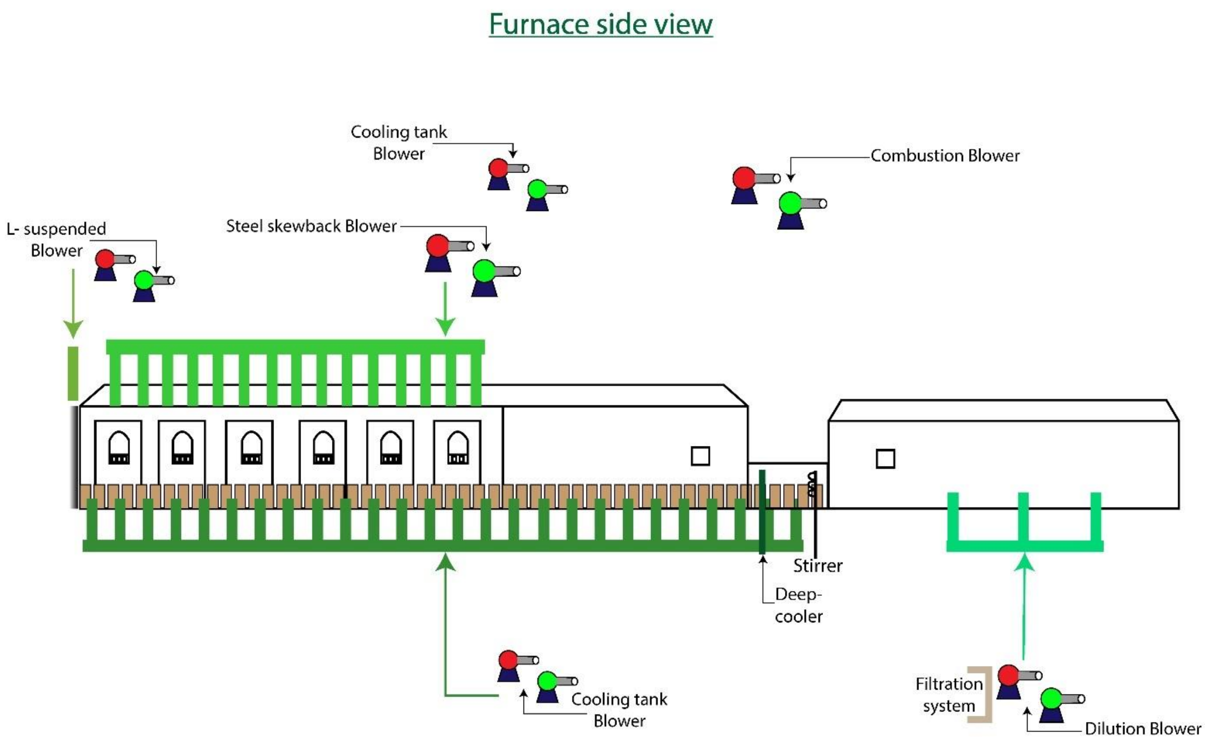


Fig 4.15: Furnace north side view

This cooling tank blower cools the tank block through the tank blower pipe. Dilution blower control the cooling end zone temperature through the dilution pipe line. Steel skewback blower cool the furnace top/arch brick through the skewback blower pipe line.

L suspended blower cool the L suspended wall through the blower pipe line. Combustion blower only use for combustion into the furnace.

Chapter 5: Forming & Annealing

5.1 Introduction

Forming and Annealing are two crucial processes that determine the final shape, strength, and quality of glass products. Forming is the stage where molten glass, at high temperatures, is shaped into desired forms using various methods such as blowing, pressing, drawing, and casting. Common forming techniques include float glass production for flat glass, blow-and-blow or press-and-blow for bottles, and fiber drawing for optical fibers. Once the glass is shaped, it undergoes annealing, a controlled cooling process that relieves internal stresses caused during forming. The glass is passed through an annealing lehr, where the temperature is gradually reduced to prevent cracking or breakage due to thermal stress. Proper annealing enhances the durability and mechanical strength of the glass, ensuring it meets the required specifications for industrial and commercial applications.

In Forming zone, glass temperature enter 1100°C and get out nearly 600°C. Also, annealing zone glass temperature enter 580°C nearly and get out (70 – 80) °C nearly. And next go for cutting and then finishing section.

5.2 Introduction of basic machineries

1.Top Roller

2.Edge Stop Roller

3.Lift Out Roller

4.Carbon Plug Box

5.Chemical Vapor Suspension (CVD)

6.Suspension Water Cooling (SWC)

7.(H_2 + N_2) Line distribution

8.Transformer

5.2.1 Top Roller

Fig 5.2.1: Top Roller

The top roller plays a crucial role in the forming zone, especially in processes like float glass production and rolled glass manufacturing. Positioned above the molten or semi-molten glass ribbon, top rollers help control the thickness, width, and surface quality of the glass as it moves through the forming stage. These rollers apply precise pressure and guide the glass to ensure uniformity and dimensional accuracy. Here total top roller no is 18. Each of roller principle is same.

In float glass production, top rollers are used near the transition from the tin bath to the annealing lehr, helping to maintain the flatness of the glass sheet while preventing distortions. In rolled glass manufacturing, they assist in pattern formation by pressing the molten glass against textured rollers. The materials used for top rollers must withstand high temperatures and have low adhesion to glass to prevent defects. Proper adjustment and maintenance of top rollers are essential to achieve high-quality glass with minimal imperfections.

5.2.2 Edge Stop Roller

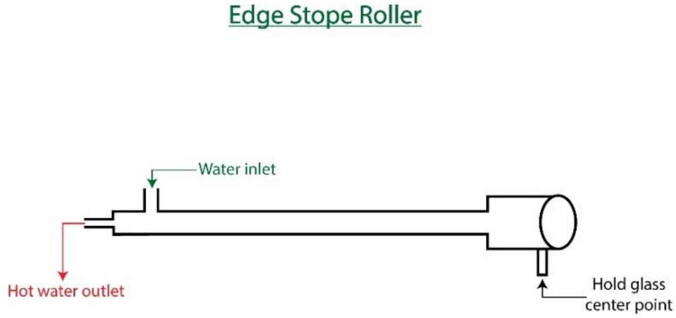


Fig 5.2.2: Edge Stop Roller

The Edge Stop Roller (ESR) is a critical component in the forming zone of glass manufacturing, particularly in the float glass process. Positioned along the edges of the molten glass ribbon as it flows onto the tin bath, the ESR helps control the width of the glass and prevents unwanted lateral movement. These rollers gently touch the edges of the glass ribbon, ensuring uniform thickness and minimizing edge defects. Here total edge stop roller no is 2. Each of roller principle is same.

Made from heat-resistant materials such as ceramics or special metal alloys, ESRs operate in a high-temperature environment and must withstand continuous exposure to molten glass and tin vapor. Proper alignment and control of edge stop rollers are essential to maintaining glass quality, as improper settings can cause edge waviness, thickness variations, or surface defects. Optimizing ESR operation helps achieve precise glass dimensions, reduces material waste, and ensures smooth processing in subsequent stages like annealing and cutting.

5.2.3 Lift Out Roller

Fig 5.2.3: Lift Out Roller

Lift Out Roller (LOR) plays a critical role in shaping and guiding the molten glass as it transitions from the forming process to the next stages, such as annealing. This roller hold out the dust on glass upper surface. Here also use SO_2 as a lubricant for roller, that reduce the corrosion of glass when glass is flowing above its. This roller is strategically positioned to lift or support the glass ribbon, especially in float glass and sheet glass production. It helps control the glass thickness, flatness, and surface quality by preventing defects like waviness or uneven edges. Here total lift out roller no is 3. Each of roller principle is same.

5.2.4 Carbon Plug Box

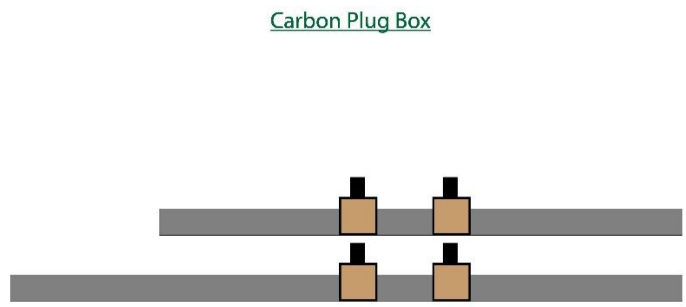


Fig 5.2.4: Carbon Plug Box

The carbon plug box is a crucial component used in the forming zone to regulate airflow and maintain proper pressure conditions during the shaping of molten glass. Typically used in processes like container glass forming, it helps control the gob delivery and shaping of the final product. The carbon plug box is made from high-purity carbon materials, ensuring excellent thermal stability, non-stick properties, and resistance to high temperatures. Here total carbon plug box no is 4. Each of of this principle is same.Its primary function is to prevent unwanted turbulence and oxidation inside the forming area, ensuring a consistent and defect-free surface on the glass. Additionally, the use of carbon reduces contamination risks, as it does not react with molten glass. Proper maintenance and precise control of the carbon plug box are essential for achieving uniform glass thickness, reducing defects, and improving the efficiency of the forming process.

5.2.5 Chemical Vapor Suspension (CVD)

Chemical Vapor Deposition (CVD) is a specialized technique used in the glass industry, particularly for manufacturing high-performance glass with coatings that enhance properties such as strength, durability, optical performance, and thermal resistance. The CVD forming zone is an integral part of the glass production line, where a controlled chemical reaction occurs to deposit thin films or functional coatings onto the glass surface during its formation.

In this process, volatile precursor gases are introduced into a high-temperature zone above the glass ribbon, where they undergo thermal decomposition or chemical reactions, forming a thin, uniform coating on the hot glass surface. The most common application of CVD in glass manufacturing is in the production of low-emissivity (Low-E) glass, which improves energy efficiency by reducing heat transfer while maintaining transparency. Other coatings include anti-reflective, self-cleaning, and conductive layers for specialized applications such as display screens, solar panels, and architectural glazing.

The CVD forming zone is designed to ensure precise deposition conditions, including gas flow rate, temperature, and reaction kinetics, to achieve optimal coating adhesion and performance. Because the coating is applied while the glass is still hot, it forms a strong chemical bond with the surface, enhancing durability and resistance to environmental factors. This technology plays a crucial role in advancing glass products for modern industrial and commercial applications.

5.2.6 Suspension Water Cooling (SWC)

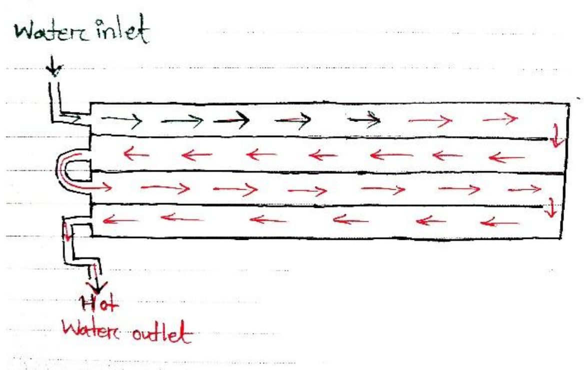


Fig 5.2.6: Suspension Water Cooling (SWC)

Suspension Water Cooling (SWC) is an advanced cooling technique used in the forming zone of glass manufacturing to regulate the temperature of critical components, such as molds, forming rolls, or support structures. In high-temperature glass-forming processes, excessive heat can lead to deformation of equipment, inconsistent glass shaping, and defects in the final product. SWC involves the use of a water-cooled suspension system where water is circulated through specialized channels or nozzles to dissipate heat efficiently. This method ensures uniform cooling, extends the lifespan of forming equipment, and enhances process stability by preventing overheating. SWC is particularly beneficial in processes like float glass production, container glass molding, and fiber drawing, where precise temperature control is essential for maintaining quality and consistency. By optimizing the cooling process, SWC improves glass surface quality, reduces thermal stresses, and enhances overall production efficiency in modern glass manufacturing.

5.2.7 (H_2 + N_2) Line distribution

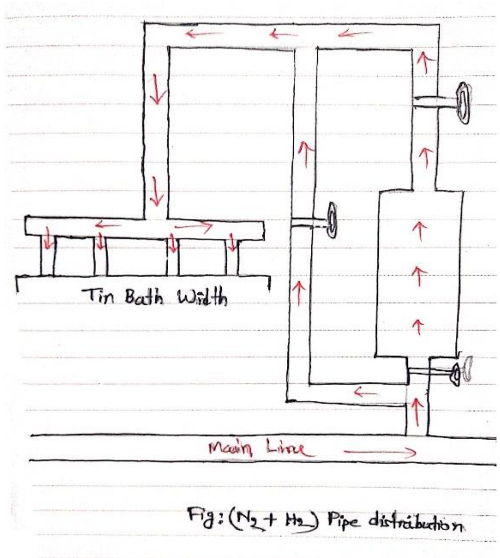


Fig 5.2.7: (H_2 + N_2) Line distribution

Here (90-95)% N_2 + (5-10)% H_2 mixed flow on Tin Bath or Forming zone due to create positive pressure. Total 22 this line have Tin Bath zone.

5.2.8 Transformer

Total 39 transformer in Tin Bath. Wide zone of Tin Bath have 30 transformer, Shoulder zone have 1 transformer, Narrow zone have 8 transformer. Transformers play a crucial role in supplying stable and controlled electrical power to heating elements, which are essential for maintaining precise temperatures in glass shaping processes. The forming zone operates at extremely high temperatures, often exceeding 1000°C, requiring specialized heating systems such as resistance heaters, induction heating, or electrodes for electric boosting.

Transformers in this zone are typically step-down transformers, reducing high-voltage input to lower, controlled voltages suitable for heating applications. They ensure consistent energy supply to maintain uniform heat distribution, preventing defects like thermal stress or uneven thickness in the glass. Special isolation transformers are also used to protect sensitive electronic controls and prevent power fluctuations that could impact glass quality. Efficient transformer operation in the forming zone is critical for optimizing energy consumption, improving process stability, and ensuring high-quality glass production.

5.3 Canal

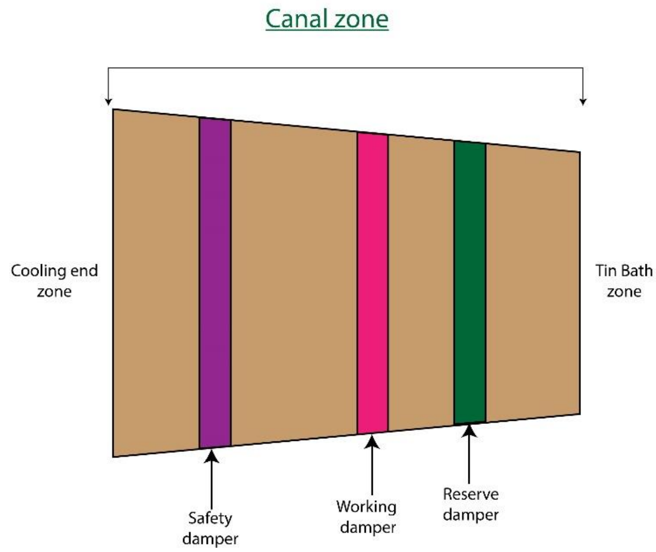


Fig 5.3: Canal

The canal zone is a critical section that connects the cooling end zone of the glass furnace to the tin bath zone, where the molten glass is shaped into a continuous ribbon.

There has three damper:

Safety Damper– This damper is used as a precautionary measure to control or shut off airflow in emergencies, preventing unwanted fluctuations in temperature or pressure.

Working Damper– This is actively used to regulate the temperature and gas flow between the furnace and the tin bath, ensuring a smooth transition of molten glass.

Reserve Damper– It serves as a backup or alternate damper that can be engaged when needed for maintenance or process adjustments.

The canal zone plays a vital role in maintaining the correct temperature gradient and viscosity of the molten glass, preventing contamination, and ensuring a stable flow into the tin bath for uniform thickness and surface quality in float glass production.

5.4 Tin Bath or Forming top view

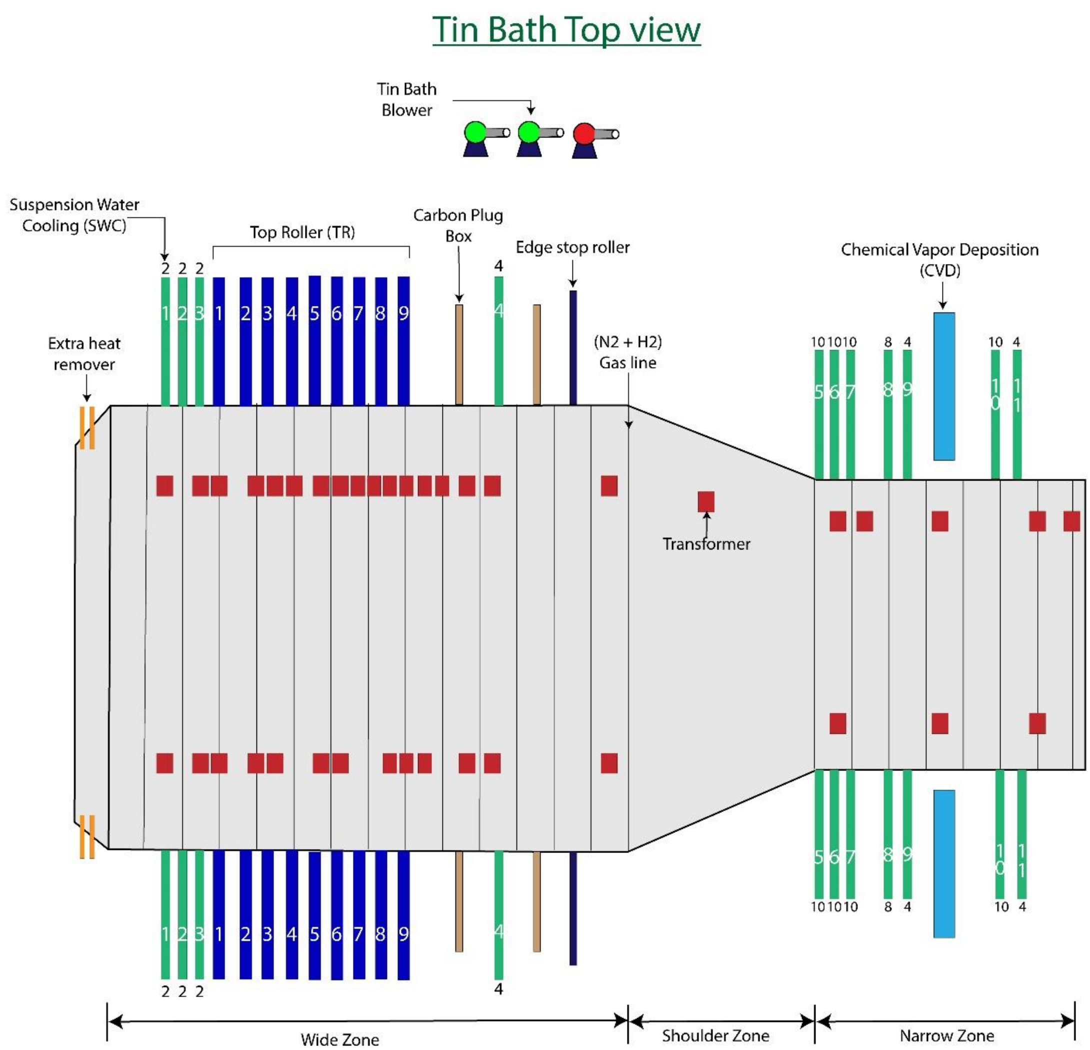


Fig 5.4 Tin Bath or Forming top view

The tin bath, also known as the forming zone, is a critical part of the float glass manufacturing process. This is where molten glass takes its final shape before cooling and solidifying into a continuous ribbon. Below is a broad explanation of what happens in this zone:

Entry of Molten Glass

Molten glass, at a temperature of approximately 1000–1100°C, enters the tin bath from the melting furnace.

The glass floats on a layer of molten tin because tin has a higher density and does not mix with the glass.

The tin bath provides a perfectly flat and smooth surface for the glass to spread and form a uniform thickness.

Shaping and Thickness Control

The thickness of the glass sheet is controlled by top rollers (TR) and the speed of the glass ribbon movement.

Thin glass (e.g., 2mm-4mm): The ribbon is stretched by increasing the pulling speed.

Thick glass (e.g., 10mm+): The ribbon moves slowly, allowing it to spread naturally on the tin surface.

Edge stop rollers and carbon plug boxes help maintain the width and prevent distortions.

Controlled Atmosphere for Quality

The tin bath is filled with a controlled gas mixture of nitrogen (N_2) and hydrogen (H_2).

This prevents oxidation of the molten tin, ensuring that no defects, such as tin oxide layers, form on the glass. Blowers regulate the atmosphere, ensuring uniform conditions across the bath.

Chemical Vapor Deposition (CVD) – Optional Coating Process

Some manufacturers use CVD to apply coatings on the hot glass surface. These coatings improve properties like energy efficiency, UV protection, and scratch resistance. The coatings bond directly with the glass at high temperatures, ensuring durability.

Cooling and Solidification

As the glass moves forward, its temperature gradually drops to around 600°C.

Suspension Water Cooling (SWC) and extra heat removers control the cooling rate, preventing thermal stress. By the time the glass exits the tin bath, it is solid enough to be transferred to the annealing lehr for further cooling.

Exit to the Annealing zone

The now solidified glass ribbon moves towards the annealing lehr, where it undergoes slow cooling to relieve internal stresses.

5.5 Tin Bath or Forming side view

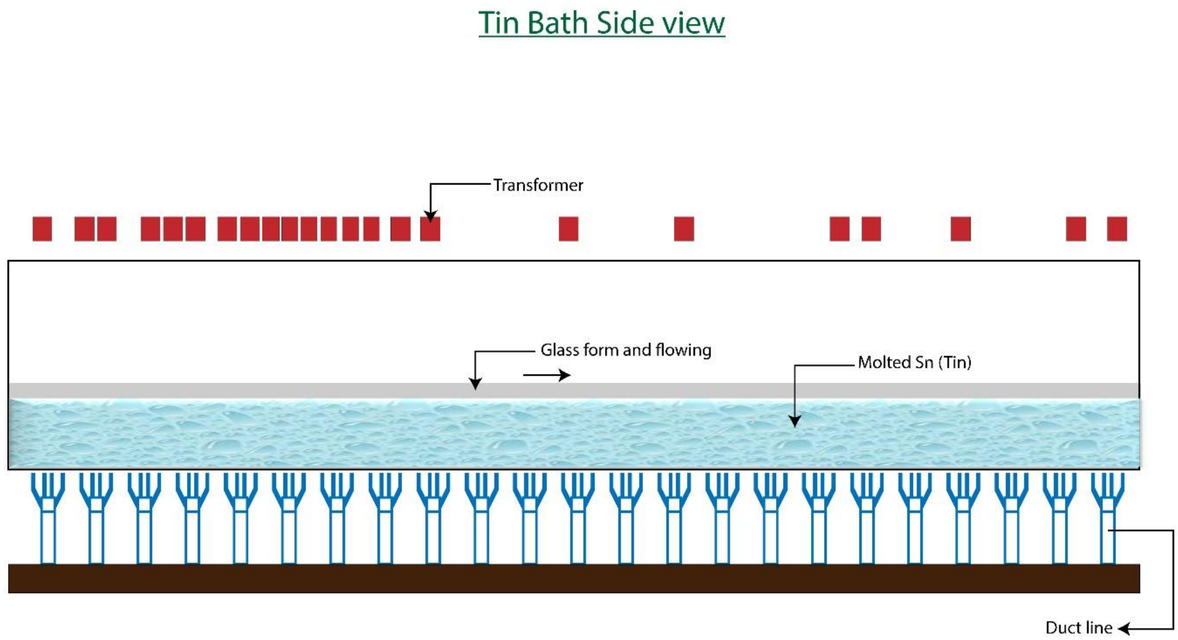


Fig 5.5: Tin Bath or Forming side view

Length of thus Tin Bath is 66 meter. Which contain wide zone, shoulder zone, narrow zone. Also here we see 23 duct line.

5.6 Duct Line front and side view

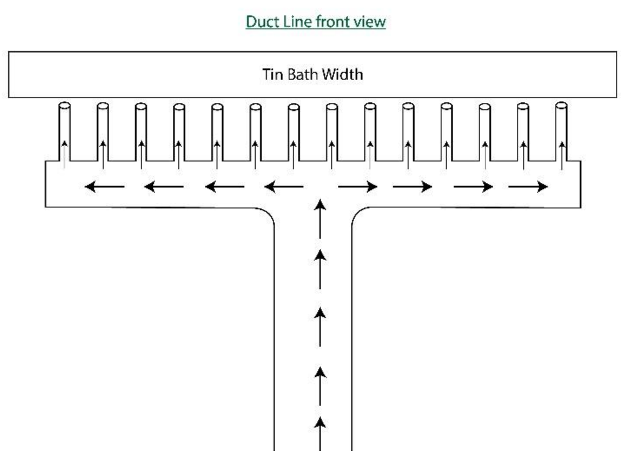


Fig 5.61: Duct line front view

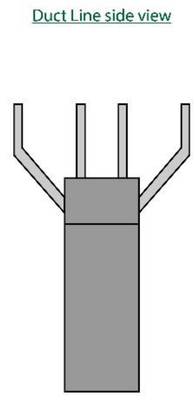


Fig 5.62: Duct line side view

5.7 Annealing section

After forming in the tin bath, the glass enters this zone to undergo controlled cooling to remove internal stresses. In this zone glass glass enter after completing forming, then glass temperature nearly 550 °C. In this zone have total 17 blower, 241 roller, in this 3 roller is lift out roller. That located into entry of this zone. ,

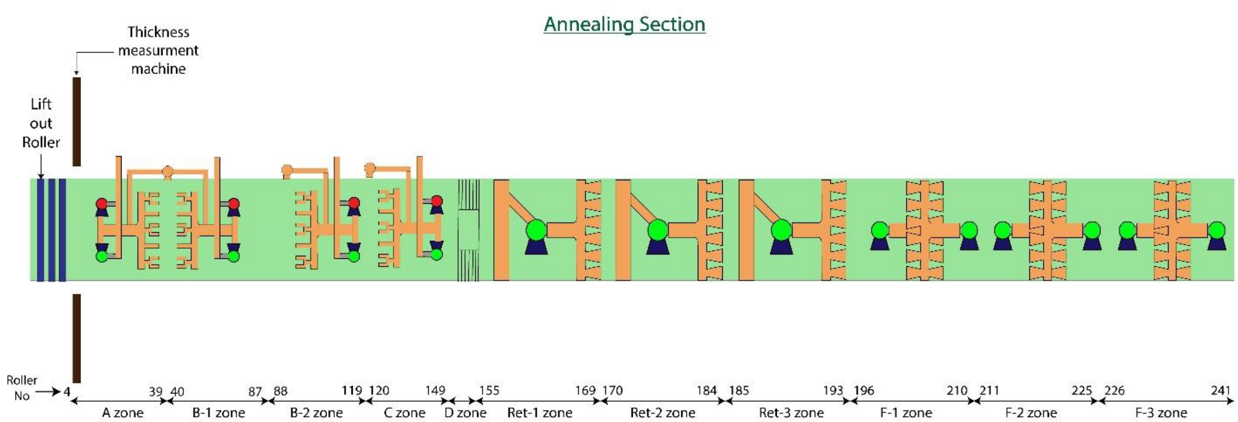


Fig 5.7: Annealing section

This annealing section have 6 zone:

1) A zone
2) B-1 zone
3) B-2 zone
4) C zone
5) Ret zone
    a) Ret-1 zone
    b) Ret-2 zone
    c) Ret-3 zone
6) F zone
    a) F-1 zone
    b) F-2 zone
    c) F-3 zone

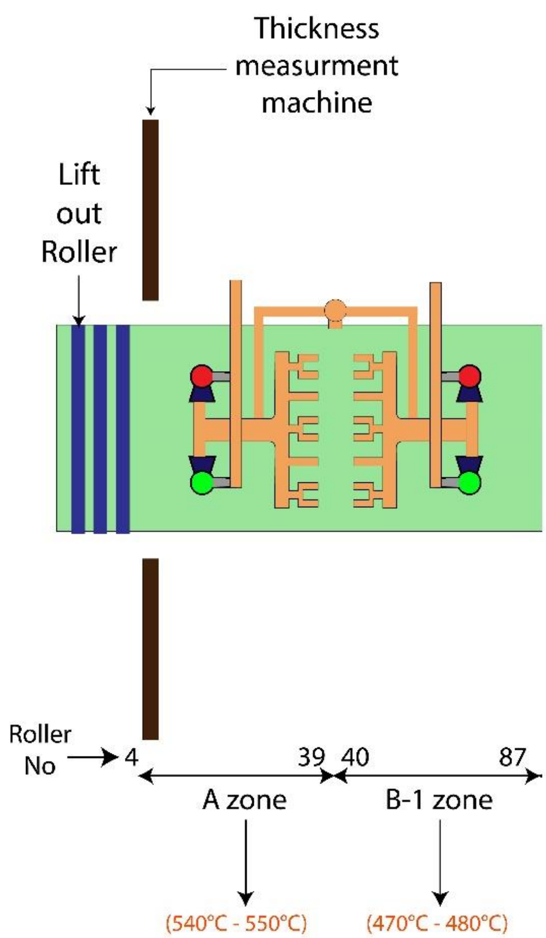


Fig: A zone and B-1 zone

5.71 A zone

In this zone, hot air is primarily absorbed from the inside and expelled outside through blowers. There have 2 blower, one is running and other is reserve. Each of blower is 22 KW. In this zone temperature remain generally (540 °C to 550 °C) . Also this zone is contain of 4 no roller to 39 no roller.

5.72 B-1 zone

In this zone, hot air is primarily absorbed from the inside and expelled outside through blowers. There have 2 blower, one is running and other is reserve. Each of blower is 15KW. In this zone temperature remain generally (470 °C to 480°C). Also this zone is contain of 40 no roller to 87 no roller.

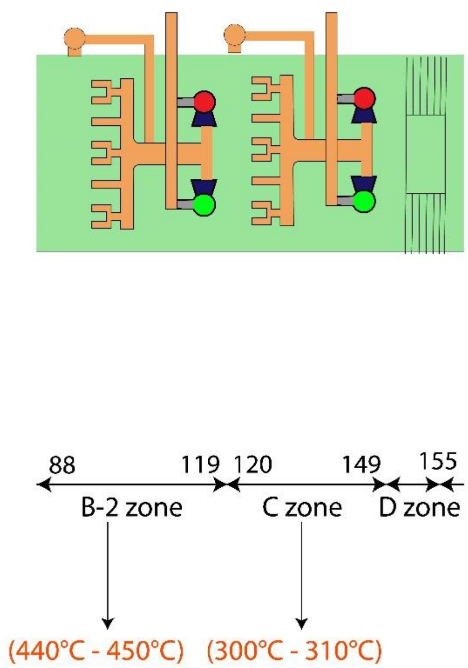


Fig: B-2 zone and C zone

5.73 B-2 zone

In this zone, hot air is primarily absorbed from the inside and expelled outside through blowers. There have 2 blower, one is running and other is reserve. Each of blower is 11

KW. In this zone temperature remain generally (440 °C to 450 °C) . Also this zone is contain of 88 no roller to 119 no roller.

5.74 C zone

In this zone, hot air is primarily absorbed from the inside and expelled outside through blowers. There have 2 blower, one is running and other is reserve. Each of blower is 37KW. In this zone temperature remain generally (300 °C to 310 °C) . Also this zone is contain of 120 no roller to 149 no roller.

5.75 Ret zone

In this zone, the blower primarily absorbs hot air from the inside and brings in cool air from the external environment, mixes them, and then sends the air back into the zone through six blower pipes.

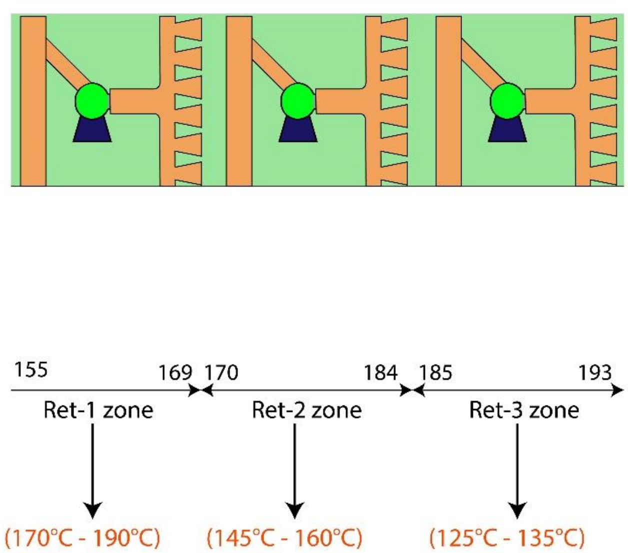


Fig 5.75: Ret zone

Ret-1 zone

In this zone have 1 blower, one is running always. This blower is 45KW. Here, temperature remain generally (170°C to 190°C) . Also this zone is contain of 155 no roller to 169 no roller.

Ret-2 zone

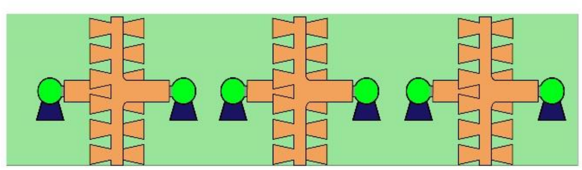
In this zone have 1 blower, one is running always. This blower is 45KW. Here, temperature remain generally (145°C to 160°C) . Also this zone is contain of 170 no roller to 184 no roller.

Ret-3 zone

In this zone have 1 blower, one is running always. This blower is 45KW. Here, temperature remain generally (125°C to 135°C) . Also this zone is contain of 185 no roller to 193 no roller.

5.7.6 F zone

The blower in this zone mainly brings in cool air from the outside environment and sends it back inside this zone through six pipe lines. Here, temperature remain generally (145°C to 75°C)



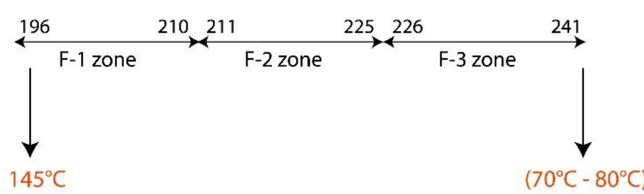


Fig 5.7\.6: F zone

F-1 zone

In this zone have 2 blower, both is running always. This each blower is 37 KW. Also this zone is contain of 196 no roller to 210 no roller.

F-2 zone

In this zone have 2 blower, both is running always. This each blower is 37 KW. Also this zone is contain of 211no roller to 225 no roller.

F-3 zone

In this zone have 2 blower, both is running always. This each blower is 37 KW. Also this zone is contain of 226 no roller to 241 no roller.

Chapter 6: Cutting and Finishing

6.1 Introduction to Cutting and Finishing

The transformation of raw glass sheets into finished products heavily relies on two critical processes: cutting and finishing. Cutting, the first stage, is a precise operation that goes beyond simply dividing a sheet of glass. In traditional methods, a specialized cutter is used to score the surface of the glass, creating a controlled fracture line.
The importance of cutting and finishing goes beyond aesthetics. These processes are essential for ensuring the glass is safe to handle and durable for its intended use. Properly finished edges eliminate the risk of cuts and injuries, while surface treatments increase resistance to scratches and wear. In industrial applications, precise cutting and finishing are crucial to achieving tight tolerances and ensuring that glass components fit and function as intended. Whether producing decorative glass or crafting high-precision optical lenses, the skillful execution of cutting and finishing techniques is key to unlocking the full potential of glass as a versatile and indispensable material.

6.2 Introduction of basic Machineries for Cutting and Finishing

6.2.1 Chips Blower

Fig 6.2.1: Chips Blower

A chips blower is a type of equipment commonly used in industrial settings to blow or transport small particles, such as wood chips, metal chips, plastic pellets, or other debris. These particles are typically a byproduct of manufacturing or processing operations, and the chips blower helps move them efficiently for disposal, recycling, or further processing. The blower operates by generating high-velocity air streams that push the chips through ducts or tubes. In certain industries, such as in wood processing, glass production, or metalworking, chips blowers are essential for maintaining clean and safe work environments. They help clear away the waste material that accumulates during production, preventing the buildup of debris that could disrupt machinery, create hazards, or reduce the efficiency of the operation.

In summary, chips blowers play an important role in keeping manufacturing processes running smoothly by efficiently clearing and moving waste materials, thereby improving safety and operational efficiency.

6.2.2 Liquid Spray machine

Fig 6.2.2: Liquid Spray machine

A liquid spray machine that sprays anti-foaming chemicals and HL-1 (a specific chemical or product code) is designed to apply precise amounts of liquid chemicals in various industrial applications, particularly in processes where foam or unwanted reactions need to be controlled. These machines are typically used in environments like chemical processing, wastewater treatment, or even in the glass and manufacturing industries, where controlling foam is crucial to maintaining process efficiency.

6.2.3 Long Cutting Machine

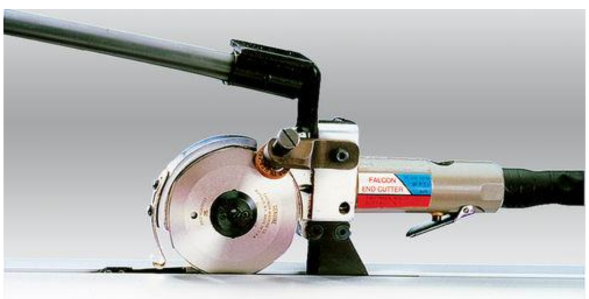


Fig 6.2.3: Long Cutting Machine

In the glass industry, a long cutting machine is crucial for transforming large sheets or panels of glass into smaller, precise pieces. These machines use specialized diamond-tipped cutters or scoring wheels to score the glass surface, followed by controlled pressure to break the glass along the scored lines. Designed to handle the heavy and fragile nature of glass, these machines ensure that each piece is cut accurately to the required dimensions, which is essential for applications like windows, mirrors, and furniture. Many long cutting machines are automated, improving production efficiency and minimizing manual labor. Safety features such as protective barriers and sensors are also incorporated to prevent accidents, while edge finishing capabilities like grinding and polishing ensure smooth, safe, and visually appealing edges. By reducing material waste and increasing cutting precision, long cutting machines play a vital role in enhancing the overall efficiency and quality of glass manufacturing.

6.2.4 Cross Cutting Machine

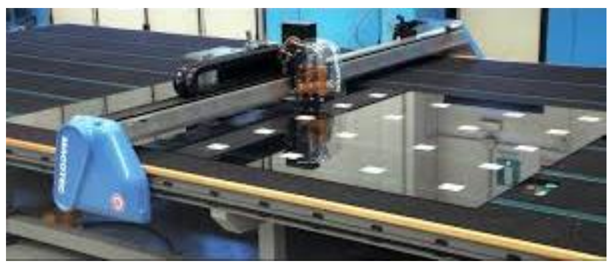


Fig 6.2.4: Cross Cutting Machine

A cross cutting machine for float glass is an essential piece of equipment used in the glass industry to cut large sheets of float glass into smaller, precise sections or pieces, typically at right angles to the length of the glass. Float glass, known for its smooth surface and clarity, is produced in large, continuous sheets, and these sheets often need to be cut into manageable sizes for further processing or for use in windows, doors, mirrors, and other products.

These machines are often automated, with the ability to adjust cutting speeds and dimensions based on specific production needs. Many cross cutting machines also incorporate safety features like protective barriers, sensors, and emergency stop functions to ensure safe operation, especially given the fragile nature of glass. Furthermore, some models come with edge finishing capabilities to smooth or bevel the edges after cutting, ensuring the finished glass is safe to handle and visually appealing.

6.2.5 Defect Detecting Machine

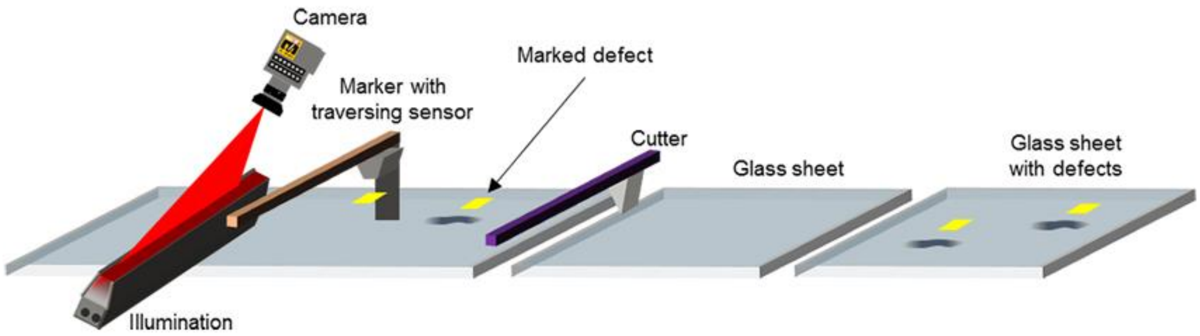


Fig 6.2.5: Defect Detecting Machine

A defect detecting machine is a specialized piece of equipment used in various industries, including glass manufacturing, to identify and assess defects in materials during production. These machines are designed to detect imperfections such as cracks, bubbles, scratches, discoloration, or other structural or visual anomalies that can affect the quality and integrity of the product.

In the glass industry, a defect detecting machine is particularly important because even small imperfections in glass sheets or products can compromise their aesthetic appeal, functionality, or safety. These machines typically use advanced technologies such as machine vision systems, cameras, laser sensors, and infrared sensors to continuously monitor and inspect the surface of the glass as it moves through the production line.

6.2.6 Glass Staking Robot

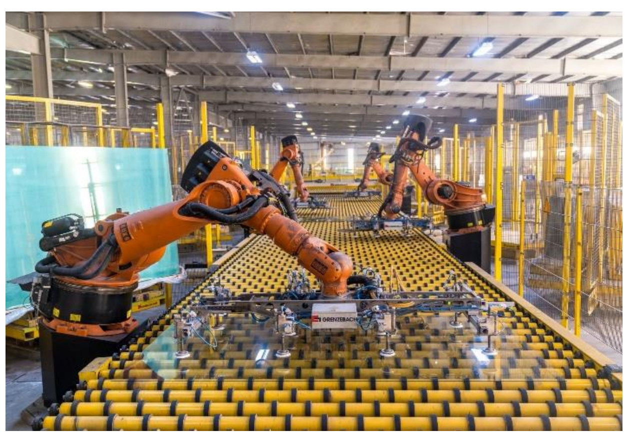
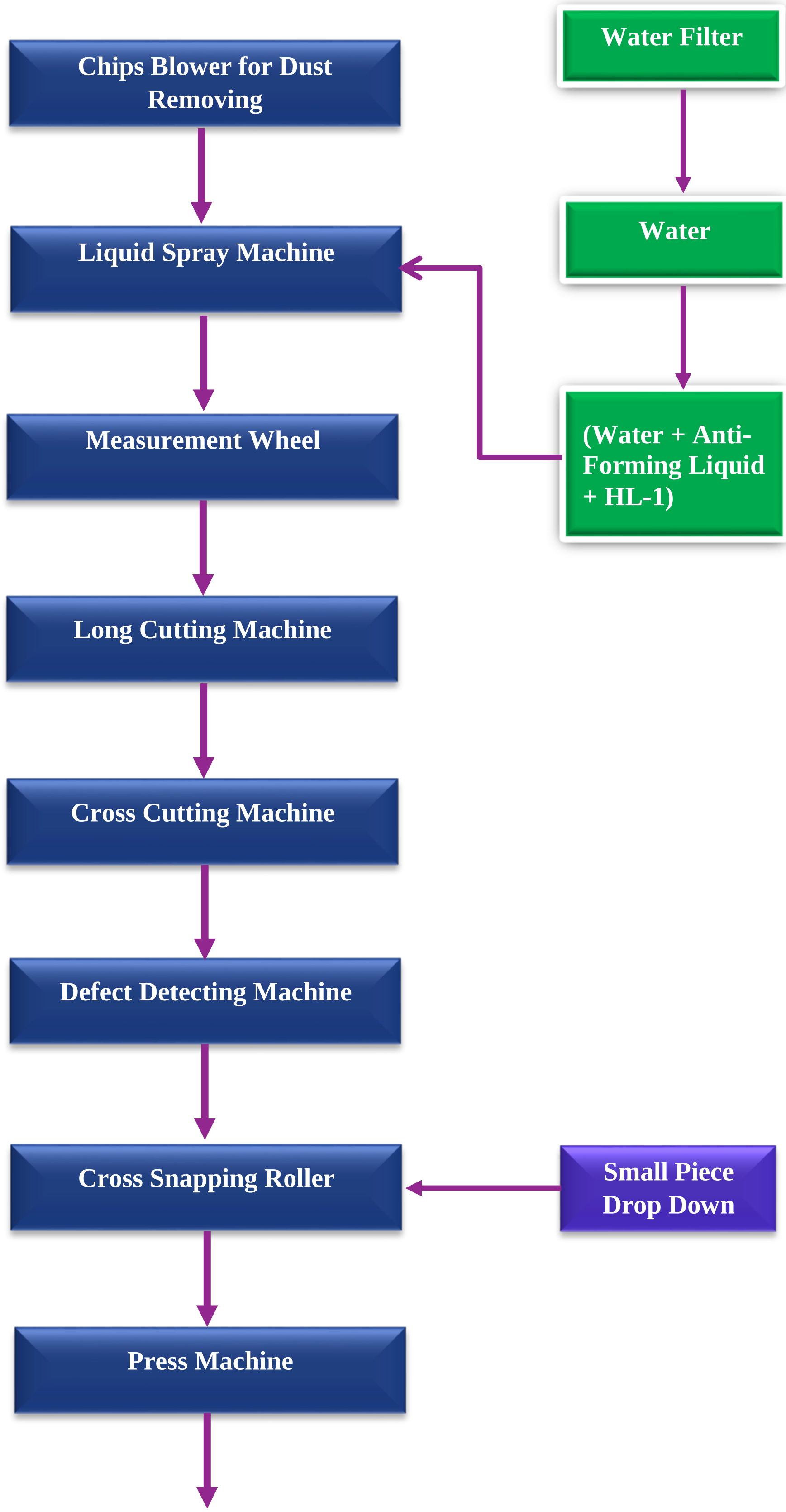


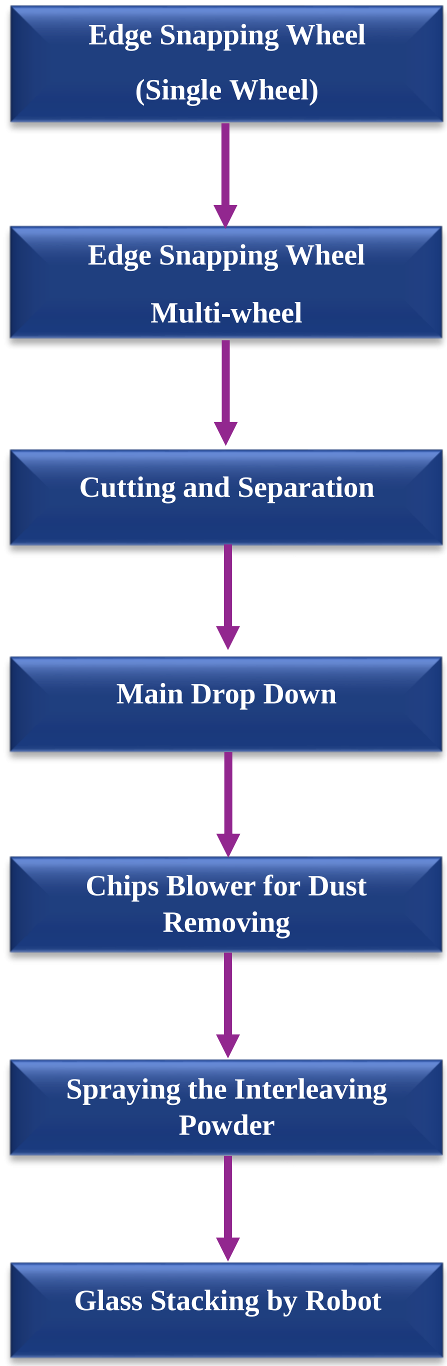
Fig 6.2.6: Glass Staking Robot

A glass stacking robot is an automated system used in the glass industry to handle, organize, and stack glass sheets or products efficiently and safely. These robots are designed to optimize the handling of glass, which is heavy, fragile, and prone to damage during manual handling. By automating the stacking process, glass stacking robots reduce the risk of accidents, improve production efficiency, and maintain high levels of safety and consistency in the production line.

Typically, a glass stacking robot uses robotic arms equipped with specialized vacuum grippers or suction cups to lift and handle glass sheets. These grippers securely attach to the glass surface, allowing the robot to pick up sheets, move them, and stack them in an organized manner without causing any damage. The robot's precise control allows for the glass to be placed in a specific order, often based on size, thickness, or type, ensuring that it is stored properly and can be easily retrieved for further processing.
The glass stacking robot operates through programmed routines or machine vision systems that guide its movements, ensuring the robot accurately picks up and places each piece of glass. These robots can work continuously, handling large volumes of glass sheets quickly and efficiently, which increases the overall throughput of the production process. Additionally, glass stacking robots are often equipped with safety features, such as sensors and automated shutdown mechanisms, to prevent accidents and protect both the machinery and human workers.

6.3 Flow Chart for Cutting and Finishing




Edge Snapping Wheel
(Single Wheel)
Edge Snapping Wheel
Multi-wheel
Cutting and Separation
Main Drop Down
Chips Blower for Dust Removing
Spraying the Interleaving Powder
Glass Stacking by Robot

6.4 Working Procedure of Cutting and Finishing

1. Chips Blower for Dust Removal

Function: The process begins with using a chips blower to remove any dust or small particles from the material or product. This ensures that the product is clean and ready for further processing without contamination.

2. Liquid Spray Machine

Function: The liquid spray machine applies a liquid mixture of water, anti-forming liquid, and HL-1 to the material. The anti-forming liquid helps in preventing any unwanted formation or buildup during the next steps of processing. HL-1 is possibly a specific chemical or agent used for enhancing the quality of the material or product.

Output: The liquid is sprayed over the material to prepare it for the next steps.

3. Water Filter

Function: The water filter is used to purify the water used in the spray machine. It ensures that the water is clean and free of impurities before being sprayed onto the product.

4. Measurement Wheel

Function: The measurement wheel is likely used to measure the dimensions or length of the material, ensuring that it is cut or processed to the correct size.

5. Long Cutting Machine

Function: The long cutting machine is used to cut the material into long pieces, likely according to the measurements determined earlier.

6. Cross Cutting Machine

Function: The cross cutting machine cuts the material into smaller, possibly shorter sections or pieces perpendicular to the previous cuts.

7. Defect Detecting Machine

Function: The defect detecting machine scans the material for any defects, such as cracks, irregularities, or imperfections. It ensures that only the good pieces proceed to the next stages.

8. Cross Snapping Roller

Function: The cross snapping roller likely serves to break or snap the material into the required shape or size based on the previous cuts. Any small or unwanted pieces identified earlier might be discarded.

9. Small Piece Drop Down

Function: After the material is snapped or cut into smaller pieces, the smaller pieces drop down to the next area. These could be removed for further use or sent to another part of the process.

10. Press Machine

Function: The press machine applies pressure to the material, likely to shape it, compress it, or finalize its form. It may be used to ensure consistency and to solidify the shape of the material.

11. Edge Snapping Wheel (Single Wheel)

Function: Finally, the edge snapping wheel works on the edges of the material, ensuring they are shaped properly or that any excess material is removed. It helps in refining the edges to the desired finish.

Chapter 7: Quality Control

7.1 Introduction to the Quality Control

Quality control in glass production is a vital process that ensures the final product meets strict standards and customer expectations. It involves a series of inspections, tests, and procedures implemented at each stage of the production process, from raw material selection to final packaging. This thorough approach is designed to minimize defects, maintain consistency, and enhance the overall quality of the glass. Key factors such as chemical composition, dimensional accuracy, optical clarity, and mechanical strength are carefully monitored throughout production. Techniques like visual inspections, precise dimensional measurements, and advanced testing equipment are used to detect any deviations from the required specifications. By applying rigorous quality control measures, manufacturers can reduce waste, improve production efficiency, and deliver glass products that are both reliable and visually appealing. This ensures that the glass meets both functional and aesthetic standards, helping manufacturers build customer trust and maintain a strong reputation in the industry.

During the production process, a wide range of parameters are closely monitored, including the chemical composition of the raw materials, the dimensional accuracy of the glass, its optical clarity, and its mechanical strength. These factors are critical to ensuring the product's durability, safety, and visual appeal. To achieve this, manufacturers rely on a combination of visual inspections, precise dimensional measurements, and specialized testing equipment to detect any variations or defects that may arise. For example, testing for clarity involves checking for imperfections or distortions, while measurements of thickness and size ensure the glass fits within the specified tolerances.

Moreover, advanced techniques such as statistical process control (SPC) and automated inspection systems are used to continuously monitor and refine the production process. These systems provide real-time data that can quickly identify potential issues, reducing the risk of defects reaching the final product. This results in fewer waste materials, lower production costs, and a more efficient manufacturing process.

7.2 Defects of Glass

Glass, despite its strength and versatility, can suffer from a variety of defects during its production and use. These defects can impact both its functionality and aesthetic appeal, potentially leading to reduced quality, customer dissatisfaction, and increased costs. Below are some of the common defects found in glass:

7.2.1 Cracks and Fractures

Cracks or fractures can occur during the production process, handling, or use of the glass. These defects can compromise the strength of the glass, making it prone to breaking. They may be caused by sudden temperature changes (thermal shock), mechanical stress, or mishandling.

7.2.2 Bubbles and Inclusions

Air bubbles or foreign particles trapped inside the glass during manufacturing are known as inclusions. These imperfections can weaken the glass and detract from its clarity and aesthetic appeal. Bubbles may form if the molten glass is not properly processed, or if impurities are not fully removed during the melting phase.

7.2.3 Surface Scratches

Scratches on the surface of glass can occur during handling, transport, or from contact with rough surfaces. While minor scratches may not affect the function of the glass, they can significantly reduce its aesthetic quality, especially in decorative or transparent glass products.

7.2.4 Distortion

Distortion refers to any irregularities in the glass that cause visual warping or bending. This defect is often seen in flat glass products like windows or mirrors and can be caused by uneven cooling during production or inconsistencies in the thickness of the glass. Distortion can affect both the appearance and functionality, particularly in applications where clarity and precision are essential.

7.2.5 Staining or Discoloration

Glass can sometimes develop stains or discoloration due to impurities in the raw materials, exposure to chemicals, or poor cleaning. These stains can affect the transparency and aesthetic value of the glass. For example, iron oxide impurities may cause a greenish tint in glass.

7.2.6 Uneven Thickness

Glass that has an inconsistent thickness can result from improper handling during the molding or cooling stages. Variations in thickness can weaken the glass, making it less durable and prone to breaking under pressure. It may also affect the optical properties of the glass, especially in applications like lenses or display screens.

7.2.8 Chipping

Chips are small pieces of glass that break off from the edges or corners of a product. They are often caused by mechanical stress or impact during handling, and while they may not compromise the entire glass, they can make it unsuitable for use, particularly in high-strength or decorative applications.

7.2.9 Misshapen or Out-of-Spec Dimensions

Inaccurate measurements or irregular shapes can result from issues in the molding or cutting process. This defect is especially important in the production of glass for industrial or architectural purposes, where precise dimensions are critical for the product's functionality and fit.

7.2.10 Coating Defects

Some glass products, especially those with decorative finishes or functional coatings (e.g., anti-reflective, anti-scratch, or UV coatings), may suffer from coating defects. These defects can include peeling, bubbling, or uneven application, which can affect the durability and appearance of the glass.

7.2.11 Edge Defects

The edges of glass products are particularly susceptible to defects such as roughness, chipping, or improper finishing. These imperfections can be caused by incorrect cutting or grinding processes and can undermine the overall strength of the glass, making it more likely to break or fail under pressure.

To maintain high-quality standards, manufacturers must carefully monitor and address these defects during the production process. Implementing rigorous quality control measures, such as visual inspections, dimensional measurements, and specialized testing, helps detect and correct defects early, ensuring the glass meets the required specifications and performance standards.

7.3 Defect Detecting Tests

7.3.1 Zebra Crossing Test

Zebra Crossing Test is critical for ensuring that the glass has an even and consistent surface, which is particularly important for applications like windows, mirrors, or displays where clarity and precision are essential.

Pattern Application: A grid or stripe pattern, typically in black and white, is placed on a flat surface or projected onto the glass. The alternating stripes create a high-contrast visual pattern that makes distortions or irregularities easier to spot.

Visual Inspection: When the glass is held at a certain angle, the stripes should appear straight and uniform. If the glass has any distortion or waves, the stripes will appear bent, wavy, or irregular, indicating that the glass surface isn't perfectly flat.

Analysis of Distortions: The presence of any bending, distortion, or inconsistencies in the pattern signals that the glass has defects, such as variations in thickness, surface unevenness, or other optical issues that can affect the glass's performance and appearance.

Purpose and Importance:

Optical Clarity: For applications where transparency is critical, such as windows, display panels, or mirrors, any distortion could affect how objects appear through the glass, reducing its optical clarity.

Flatness and Consistency: Glass used in various industries (construction, automotive, electronics, etc.) must have a consistent, even surface. Waves or surface irregularities can impact how the glass fits into its designated application, such as in windows or screens, where precision is key.

Quality Assurance: The wave checking test is a visual method to ensure that the glass meets the required standards for optical and dimensional quality before it moves forward in the production process. This type of testing is often done alongside other quality control processes to ensure that glass products meet the necessary aesthetic and functional criteria before reaching the customer.

7.3.2 Curvature Testing Machine

A Curvature Testing Machine is a specialized device used in the glass industry to measure the curvature of flat or curved glass surfaces, ensuring that the glass meets precise specifications for shape and flatness. This machine is vital for industries where glass must have accurate dimensions and curvature, such as in architectural applications, automotive glass production, and in the manufacturing of mirrors or display screens.

Purpose of a Curvature Testing Machine:

The primary purpose of a curvature testing machine is to assess whether the glass maintains the intended curvature (concave, convex, or flat) and to ensure that any variations fall within acceptable tolerance limits. This is important because slight deviations in curvature can lead to problems such as distortion, optical errors, or difficulties in fitting the glass into its intended frame or structure.

Working Principles of a Curvature Testing Machine:

1. Measurement of Curvature:

The machine uses precise sensors or probes to measure the curvature of the glass surface. For flat glass, the device ensures that the surface is perfectly level. For curved glass, it checks whether the radius of curvature adheres to the required specification.

2. Flatness Testing:

In cases where the glass is supposed to be flat, the machine can also detect any deviations from flatness. These deviations are often referred to as "waves" or "bends" and can be problematic, especially for applications where clarity or smoothness is critical, such as in optical products.

3. Calibration:

The machine is often calibrated with a reference standard or master glass to ensure its accuracy. This ensures that measurements are consistent and precise for every test, contributing to high-quality production.

4. Display and Data Analysis:

Most curvature testing machines are equipped with digital displays that show the measurements and provide data for further analysis. These readings can be used to compare actual curvature with ideal values, helping manufacturers decide whether the glass is within acceptable tolerance levels.

5. Software Integration:

Many modern curvature testing machines come with software that allows for more advanced data analysis, documentation, and reporting. This can include generating graphs or reports for quality control purposes and for tracking deviations over time.

Applications of Curvature Testing:

Architectural Glass: Glass used in facades, windows, or skylights often needs to have precise curvature to fit into frames or achieve a specific aesthetic. The curvature testing machine ensures the glass meets these requirements.

Automotive Glass:

Automotive manufacturers rely on curvature testing for windshields, side windows, and mirrors, where precise curvature ensures proper fit and function.

Mirrors:

For mirrors, especially large ones used in public spaces or vehicles, the curvature needs to be accurate to avoid visual distortions.

Advantages of Using a Curvature Testing Machine:

Precision: These machines provide high levels of accuracy, ensuring that glass products meet the required specifications for curvature or flatness.

Efficiency: The process is automated, allowing for quick and consistent measurements across multiple pieces of glass. This makes it easier to maintain high production rates while ensuring quality.

Quality Control: The machine helps identify defects in the curvature of the glass that could affect its function or appearance. This early detection allows manufacturers to correct problems before the glass moves further down the production line.

Cost Savings: By ensuring that glass meets specifications on the first pass, manufacturers can reduce waste, avoid rework, and improve yield.

Compliance: For industries with stringent quality standards, such as automotive or aerospace, curvature testing machines help ensure that products comply with safety regulations and design requirements.

7.3.3 ISRA Vision Machine for Defect detection

The ISRA machine is designed to perform high-precision, real-time surface inspections to detect a wide range of defects in glass products. This helps manufacturers ensure that the glass meets high-quality standards by identifying imperfections before the glass moves further down the production line or reaches customers.

Types of Defects Detected by ISRA Machines:

Surface Scratches and Marks: ISRA machines can detect even the finest scratches or marks on the glass surface. These can be caused by handling during production or transportation, and the machine helps identify these defects for corrective action.

Bubbles and Inclusions: Air bubbles or foreign particles trapped in the glass during the manufacturing process can weaken the glass and impair its clarity. ISRA machines can identify these imperfections using advanced imaging techniques, including infrared and UV light.

Cracks and Fractures: Cracks or fractures in the glass, often due to stress or thermal shock, can be detected early using the ISRA machine. This helps ensure that defective glass is removed from the production line before it becomes a safety issue.

Color and Transparency Variations: ISRA systems can inspect the glass for inconsistencies in color or transparency, which are crucial for both aesthetic purposes and functional applications (e.g., for optical or architectural glass).

Distortion: The machine can identify areas of distortion, which could result from temperature variations during cooling or improper handling. These distortions can affect the functionality and appearance of the glass, especially in applications like mirrors or display screens.

Dimensional Inconsistencies: ISRA systems are capable of detecting dimensional defects in the glass, such as variations in thickness, which can compromise the strength or fit of the glass in its intended application.

How ISRA Machines Work:

- **High-Resolution Cameras:** The ISRA system employs high-resolution cameras that capture detailed images of the glass surface. These cameras are often capable of using multiple wavelengths of light (visible, UV, infrared) to capture a variety of defects that might not be visible to the naked eye.

- **Machine Vision Software:** The captured images are processed by sophisticated machine vision software that analyzes the surface of the glass for any deviations from the desired quality. The software uses advanced algorithms to detect, classify, and measure defects with high accuracy.

- **Real-Time Detection and Feedback:** The ISRA machine provides real-time feedback, identifying defects and immediately signaling the need for corrective actions. This allows operators to address issues quickly, ensuring minimal waste and higher production efficiency.

- **Automation and Integration:** ISRA machines can be integrated into automated production lines, allowing continuous inspection of glass as it moves through different stages of manufacturing. This automation reduces human error and speeds up the overall inspection process.

- **Data Logging and Reporting:** The system generates data logs and reports, which can be used for tracking defect trends over time, assessing production performance, and providing feedback for process improvements.

Advantages of Using the ISRA Machine for Defect Detection:

- **Enhanced Quality Control:** ISRA machines offer a high level of accuracy in detecting even the smallest defects, helping manufacturers maintain stringent quality standards and reduce the risk of defective glass reaching customers.
- **Increased Efficiency:** With real-time inspection capabilities, ISRA systems allow for faster detection and sorting of defective glass, reducing the time spent on manual inspections and improving the overall production efficiency.
- **Minimized Waste:** By catching defects early in the production process, manufacturers can prevent defective glass from continuing down the line, reducing waste and scrap material costs.
- **Consistent and Reliable Results:** Machine vision systems like ISRA provide consistent, repeatable results, ensuring that each piece of glass is thoroughly inspected and meets the required quality standards, reducing the reliance on human inspectors.
- **Cost Savings:** Early detection of defects allows for more targeted corrections, reducing the need for expensive rework or product recalls and leading to overall cost savings.
- **Continuous Monitoring:** ISRA systems can run continuously, offering real-time monitoring of the glass production process, which helps identify problems immediately and allows for quicker adjustments.

Applications of ISRA Machines:

Flat Glass Manufacturing: ISRA systems are widely used in flat glass production lines (e.g., windows, mirrors, architectural glass) to detect surface imperfections such as scratches, distortion, and inclusions.

- **Automotive Glass:** In the production of automotive windshields and windows, the ISRA machine ensures that the glass is free from defects that could impair visibility, safety, or aesthetics.
- **Optical Glass:** The machine is used in the production of lenses and optical components, where even the slightest defects can compromise performance. It ensures that the glass is clear and free of defects that could affect optical properties.
- **Solar Glass:** ISRA systems are also used to inspect glass intended for solar panels, ensuring that it is free from defects that could affect energy efficiency.

Chapter 8: Mirror Plant

8.1 Introduction to the Mirror Plant

A mirror plant is an industrial facility focused on the production of mirrors, involving several precise and critical stages to ensure the final product meets high-quality standards. The process begins with the reception of raw glass sheets, which undergo a thorough cleaning and preparation to remove any dirt or contaminants. One of the most important steps in this process is the application of a reflective coating, typically made of silver or aluminum, onto the back surface of the glass. This is achieved through techniques like chemical deposition or vacuum metallization, ensuring a smooth and even coating. To protect the reflective layer from corrosion and physical damage, a durable backing paint is applied.

Next, the mirrors undergo cutting and finishing operations to achieve the desired shape and size, with edges carefully smoothed for both safety and aesthetics. After these shaping processes, the mirrors go through stringent quality control measures at each stage to guarantee flawless reflectivity, proper adhesion of the coating, and overall product integrity. Automated systems are often integrated into the production line to increase efficiency and consistency while reducing human error. Additionally, mirror plants must adhere to strict environmental guidelines, especially regarding the use of chemicals and the proper disposal of waste.

The mirrors produced in these plants vary widely in application, from standard household mirrors to specialized optical mirrors used in scientific research and industrial settings. This versatility makes mirror plants a crucial part of the glass industry, providing products that serve a wide range of purposes, each requiring meticulous care and precision in their production.

8.2 Common Machineries of Mirror Plant

8.2.1 Glass Washer

Fig 8.2.1: Glass Washer

A glass washer in a mirror plant is a critical piece of equipment designed to clean raw glass sheets before they undergo the process of reflective coating and other finishing operations. It removes contaminants such as dust, dirt, and oils that can interfere with the adhesion of the reflective coating, ensuring that the glass surface is spotless and free from impurities. The glass washer typically uses a combination of water, cleaning agents, and mechanical scrubbing to thoroughly cleanse the glass, followed by rinsing and drying to prevent moisture from interfering with the coating process. Advanced glass washers may incorporate technologies such as ultrasonic cleaning or high-pressure spray systems to provide a more precise and efficient cleaning process. By ensuring that the glass is impeccably clean, the glass washer plays a vital role in improving the quality of the final mirror product, reducing defects, and ensuring better coating adhesion, ultimately contributing to higher mirror performance and durability.

8.2.2 Painting Machine for Mirror

Fig 8.2.2: Painting Machine for Mirror

A painting machine for mirror glass in a mirror plant is an essential piece of equipment used to apply protective coatings to the back surface of mirrors. This coating, often a layer of paint or lacquer, serves multiple purposes, including protecting the reflective layer (usually silver or aluminum) from moisture, scratches, and corrosion. It also adds durability and enhances the mirror’s overall lifespan.

The painting machine typically operates in a highly controlled environment to ensure uniform coverage and high-quality finishes. The process begins with the glass being fed into the machine, where it is positioned for optimal application of the paint. The machine often uses spray or roller coating methods, ensuring an even, consistent layer is applied to the entire back surface of the mirror. Some advanced painting machines are equipped with automatic sensors to monitor and control the thickness of the paint layer, ensuring precise application without excess buildup. Once the paint is applied, the mirror passes through a curing or drying system, where the coating is baked or air-dried, depending on the type of paint used. This step ensures that the coating bonds securely to the glass and dries properly without affecting the reflective surface.

8.2.3 Laser Printing Machine

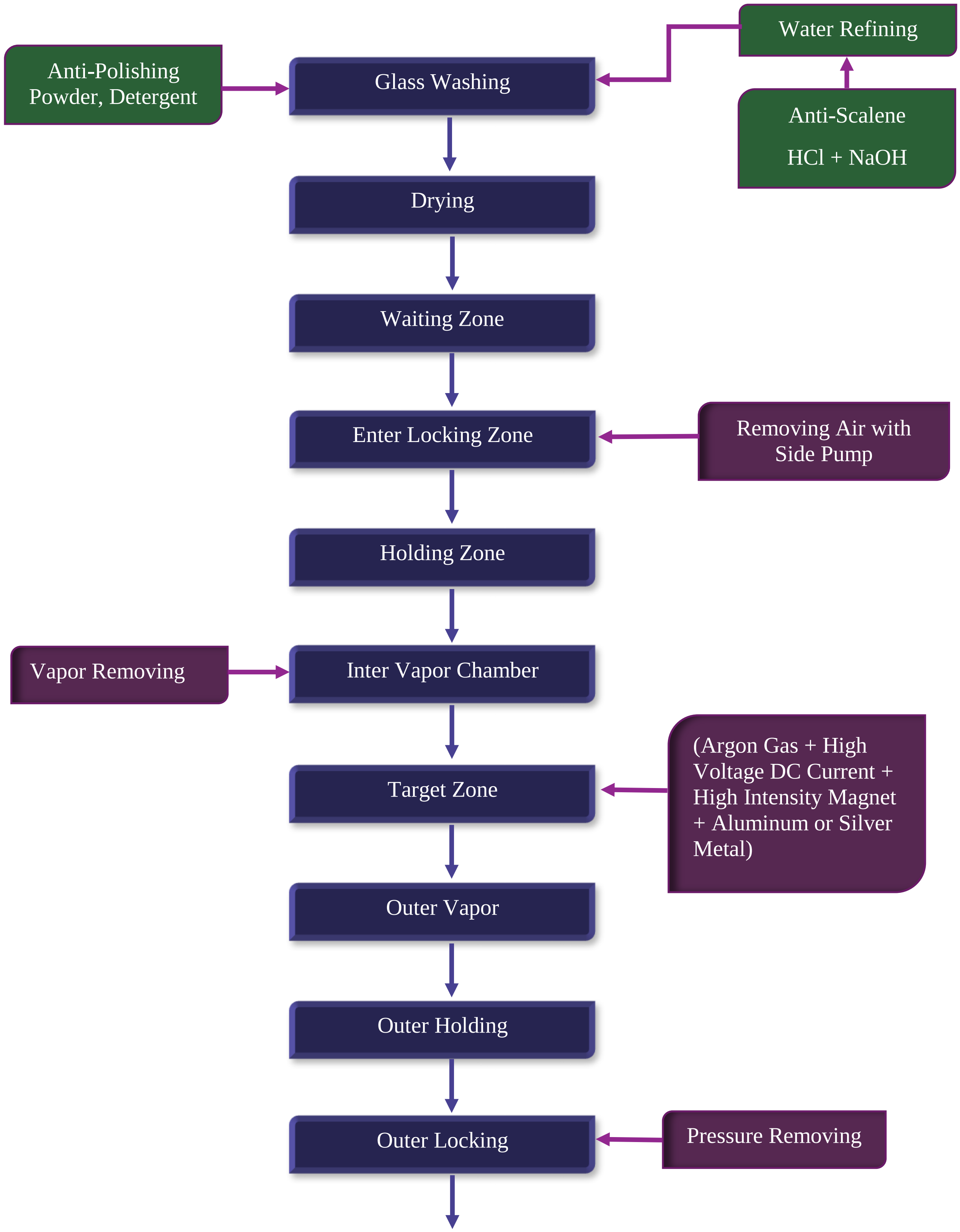
Fig 8.2.3: Laser Printing Machine

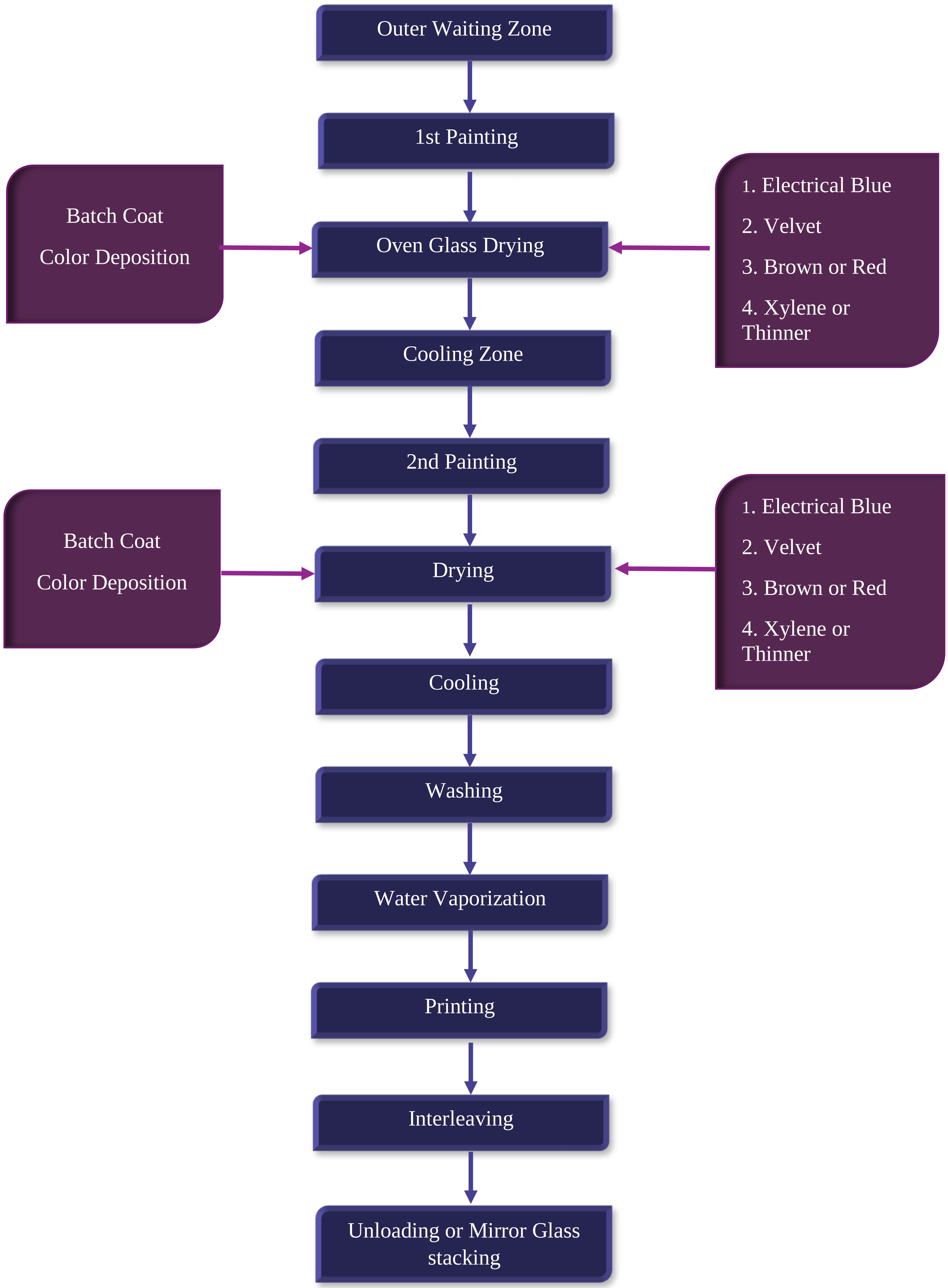
A laser printing machine for glass is a specialized piece of equipment used to apply intricate designs, text, or patterns onto glass surfaces, including mirrors, windows, or decorative glass panels. This technology uses high-powered lasers to etch or engrave precise markings directly onto the glass, offering high resolution and detail that traditional printing methods may struggle to achieve.

In a mirror or glass production plant, the laser printing machine works by directing a focused laser beam onto the surface of the glass. The laser beam heats the glass at specific points, causing the surface to vaporize or change color, creating the desired pattern or design. The process is highly accurate, allowing for custom logos, artwork, barcodes, serial numbers, or even fine details for decorative purposes. One of the key advantages of laser printing is that it does not require any physical contact with the glass, reducing the risk of damaging delicate surfaces during the printing process.

Laser printing machines for glass are highly versatile and can be used for various applications. In the decorative glass industry, they are used to create beautiful patterns and designs, enhancing the aesthetic appeal of glass products. For architectural glass, they can be used to apply branding, logos, or specific markings to glass facades, windows, or doors. In the automotive sector, they are used for marking glass parts with vehicle identification numbers (VINs) or logos.

8.3 Flow Chart for Mirror Plant




Outer Waiting Zone
1st Painting
Batch Coat
Color Deposition
Oven Glass Drying
1. Electrical Blue
2. Velvet
3. Brown or Red
4. Xylene or Thinner
Cooling Zone
2nd Painting
Batch Coat
Color Deposition
Drying
1. Electrical Blue
2. Velvet
3. Brown or Red
4. Xylene or Thinner
Cooling
Washing
Water Vaporization
Printing
Interleaving
Unloading or Mirror Glass stacking

1. Anti-Polishing Powder / Detergent → Glass Washing

- The process starts with washing raw glass sheets.
- To remove dirt, grease, oil, fingerprints, or any polishing powder left from cutting or grinding.
- A mixture of detergent and anti-polishing powder is used with clean water and brushes.
- The goal is to make the surface completely clean so the coating will stick properly.

2. Water Refining (Anti-Scale: HCl + $NaOH$)

- The washing water is treated with chemicals like Hydrochloric acid (HCl) and Sodium hydroxide ($NaOH$).
- These prevent "scaling" a white mineral deposit that forms from hard water.
- This ensures the glass remains clear and no minerals stick to its surface during cleaning.

3. Drying

- After washing, the glass must be completely dried using air blowers or heat.
- Even tiny water drops can create spots or prevent proper metal coating in later steps.

4. Waiting Zone

- The dried glass is moved to a short waiting area before entering the vacuum system.
- This helps organize the flow of glass sheets and keeps them ready for the next stage.

5. Enter Locking Zone

- The glass enters a lock chamber (also called an airlock).
- To prevent air from rushing into the vacuum chamber.
- This small area isolates the vacuum environment from the outside atmosphere.

6. Removing Air with Side Pump

- The side pump removes all air from the lock chamber.
- To create a near-vacuum condition before opening the gate to the next zone.
- This prevents contamination from oxygen, dust, or moisture.

7. Holding Zone

- After air removal, the glass stays in a holding position inside the system.
- It ensures the glass is stable and ready to enter the coating chamber safely.

8. Vapor Removing → Inter Vapor Chamber

- Any unwanted gas or vapor near the glass is taken out using suction or heat.
- To make sure the glass surface stays perfectly clean before metal coating.
- The "inter vapor chamber" works as a transition area between holding and target zones.

9. Inter Vapor Chamber

- This is the middle chamber between the vacuum locks and the main coating zone.
- **Purpose:** It helps maintain a stable vacuum pressure and stops impurities from entering the coating area.

10. Target Zone (Main Coating Stage)

- Here the real mirror coating is made.
- The process uses:
  - **Argon gas** → creates plasma for sputtering.
  - **High Voltage DC Current** → energizes the metal source.
  - **High-Intensity Magnet** → controls the path of charged particles.
  - **Aluminum or Silver Metal** → the coating material that forms the mirror layer.
- **Result:** The metal atoms are vaporized and deposited evenly on the glass surface, forming the reflective layer.

11. Outer Vapor → Outer Holding

- After coating, the chamber removes excess vapor or residual gas.
- The glass moves to the outer holding zone, where pressure is gradually increased.

12. Outer Locking → Pressure Removing

- The final lock system brings the coated glass back to **normal air pressure** carefully.
- Sudden pressure change can damage the coating or the glass itself.

13. Outer Waiting Zone

- The metal-coated mirror waits here before painting starts.
- This keeps production organized and allows inspection before painting.

2. 1st Painting

- A first paint coat (called batch coat) is applied on the back of the mirror.
    - Protects the metal layer from scratches and corrosion.
    - Gives mechanical strength.
- This layer is usually a protective primer.

14. Oven Glass Drying

- The mirror passes through a heated oven to dry the first paint layer.
- Proper drying hardens the paint and ensures good adhesion to the metal.

15. Cooling Zone

- After oven drying, the glass must cool to normal temperature.
- The next coat cannot be applied on hot glass; it may cause bubbles or poor bonding.

16. 2nd Painting

- A second paint layer is applied for extra protection and color.
- **Common paint colors/materials:**
    1. *Electrical Blue*
    2. *Velvet*
    3. *Brown*
    4. *Red*
- **Solvents used:** *Xylene* or *Thinner* help spread the paint smoothly.

17. Drying

- The second coat is dried in air or in another oven.
- To fix the color and make it strong enough to resist scratching or peeling.

18. Cooling

- The mirror cools again after drying.
- Stable temperature avoids cracking or paint damage during handling.

19. Washing

- A gentle wash removes any dust or chemical residue on the mirror's surface.

- To make it clean before final finishing steps.

20. Water Vaporization

- Remaining water or moisture is evaporated using warm air.
- The mirror must be fully dry before printing or packing.

21. Printing

- If required, the company logo, brand name, or production code is printed on the back.
- For identification and quality tracking.

22. Interleaving

- Thin protective paper or plastic sheets are placed between mirrors.
- To prevent scratches, rubbing, or breaking during stacking and transport.

23. Unloading or Mirror Glass Stacking

- Finally, mirrors are unloaded from the line and stacked for packing.
- The finished mirrors are now ready for quality inspection, packaging, and delivery.