Rajshahi University of engineering & Technology

Department of Glass and Ceramic Engineering

INDUSTRIAL TRAINING REPORT

AKIJBASHIR GLASS

Submitted by

Name	: MILTON CHANDRA ROY
Roll	: 2106041
Reg no	: 885
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AGIL Industrial Attachment

Introduction

Akij Group was established in 1940.The founder of Akij group was Sheikh Akij Uddin. Akij Glass was established as a part of this group to provide high quality glass on June 2023. It is situated in Madhabpur upazila, Habiganj. It is one of the largest glass maker industries in Asia having 2000 workers and more than 500 Engineers. The industry produces standard quality Float glasses. It was named as Akij Bashir Glass Industry in 6 March,2023. Akij Bashir Glass, a subsidiary of the AkijBashir Group, is a Bangladeshi company that manufactures high-end float glass, aiming to meet the growing demand in the construction industry with a daily capacity of 600 ton. Investment for this industry is around 2200 core (BDT). European standard float glass, including clear, colored, reflective and other specialized types glasses are manufactured by this industry. The plant operates on 51% renewable energy. It aims to be a key player in the rapidly growing glass market industry in Bangladesh. AkijBashir Group, led by Bashir, son of the group's founder Sheikh Akij Uddin, has diversified into glass production to meet the rising demand for building materials in Bangladesh.

The company has invested in a state-of-the-art manufacturing plant in Madhabpur, Habiganj, to produce high-quality glass. The factory is equipped with sophisticated machinery and equipment imported from Europe to ensure quality. The group also includes other brands like Akij Ceramics, Akij Board, Akij Tableware, Rosa, Akij Door, Akij ceramics, Akij Steel, Akij Polymer. Akij Group has been split into five portions, one of which is Akij Bashir Group.

Glass

Glass is an amorphous solid and transparent materials That is cooled from liquidous melt to a rigid condition without Crystallization. Though it has a liquid like structure, shows nature of solid. Glasses are a unique range of ceramic materials defined principally by their atomic structure.

Glasses do not exhibit the ordered crystalline structure of most other ceramics but instead have a highly disordered amorphous structure. This gives them very different properties to other crystalline ceramics. The most widely used glasses are silicate glasses, formed from silica, SiO_2. Silica consists of a 3D network of tetrahedra where every corner oxygen atom is shared with the adjacent tetrahedron. This SiO_2 tetrahedral unit is also incorporated into chains and sheets (clays), forming different ceramics.

Pure silica can be made to exist as a glass, and is called fused silica. A glass is a material that has hardened and become rigid without crystallizing, making it amorphous. Silicate glasses are the most widely used glasses.

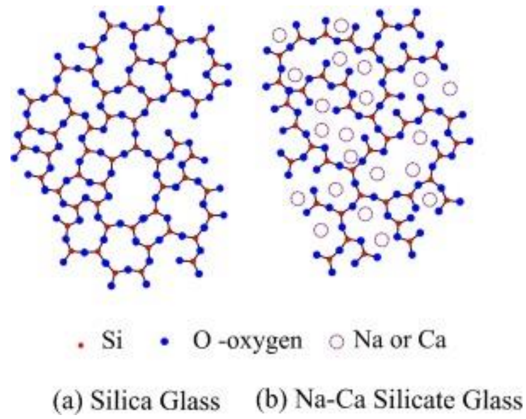
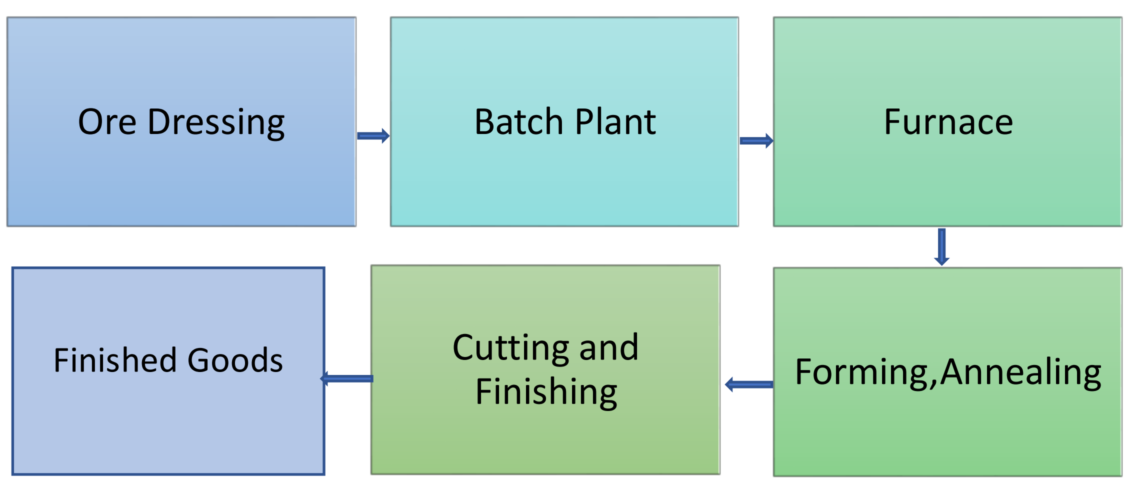


Fig: Glass structure

All of the most important glasses are based on silica SiO2. Two glasses of special interest are soda-lime glass, used in windows and bottles, with composition $70SiO_2.10CaO.15Na_2O$, and borosilicate glass, used in cooking and chemical glassware, with composition $80SiO_2.15B_2O_3.5Na_2O$.

The ability of an oxide to form a glass upon cooling, an amorphous structure, depends on the structural relationship between the oxygen atoms and the cations of the oxide compound. In order to achieve a glass structure, the oxide cations will bind with the oxygen atoms to form a tetrahedral network. Oxides that form glasses are known as network formers. Common examples are SiO_2, B_2O_3, GeO_2, and P_2O_5.Certain other oxides can be added to substitute for Si atoms in the tetrahedral structure. These oxides become part of the network and act as a stabilizer. The oxides are known as intermediates and, in a similar manner to network modifiers, lower the melting point and viscosity of the glass, thereby allowing it to be worked at lower temperatures.

Production Process



Safety in the Glass Industry:

Safety in the glass industry is crucial due to the high risk of injuries from sharp edges, heavy equipment, and extreme temperatures. Key safety considerations include:

Personal Protective Equipment (PPE): Workers should wear cut-resistant gloves, safety goggles, face shields, and heat-resistant clothing to protect against cuts, burns, and flying shards.

Proper Handling: Glass sheets must be lifted and transported with appropriate tools like suction lifters, glass carriers, or cranes to reduce manual handling risks.

Machine Safety: Regular maintenance of cutting, grinding, and polishing machines prevents malfunctions. Emergency stop buttons and proper guarding are essential.

Training and Awareness: Employees must be trained on handling procedures, equipment operation, and emergency response to minimize accidents.

Safe Storage: Glass should be stored vertically in racks with adequate spacing to prevent tipping or falling.

Workplace Environment: Maintaining clean floors, proper lighting, and clear walkways reduces slip, trip, and fall hazards.

Health Precautions: Adequate ventilation prevents inhalation of glass dust, and frequent breaks reduce fatigue in physically demanding tasks.

A strong safety culture with regular audits, incident reporting, and continuous improvement ensures a safer workplace.

Incident Vs Accident:

An incident can be happened or not, but an accident happens and causes hazards. In the glass industry, incidents and accidents are managed under various safety acts and regulations to ensure worker safety and prevent hazards. An incident refers to a near miss or unexpected event that could have caused harm but didn’t, while an accident results in injury, property damage, or environmental impact. Key regulations include the Occupational Safety and Health Act (OSHA), which mandates safe working conditions, hazard communication, PPE usage, and regular inspections. The Factories Act ensures workplace safety through proper ventilation, machine guarding, and accident reporting. The Environmental Protection Act regulates the safe handling of chemicals and waste to prevent environmental damage, while the Hazardous Waste Management Rules oversee the disposal of hazardous materials such as glass dust and chemicals. Additionally, the Workmen's Compensation Act provides compensation for work-related injuries or fatalities. Ensuring compliance through proper training, risk assessment, and regular safety audits is essential for maintaining a safe working environment in the glass industry.

Fire Triangle:

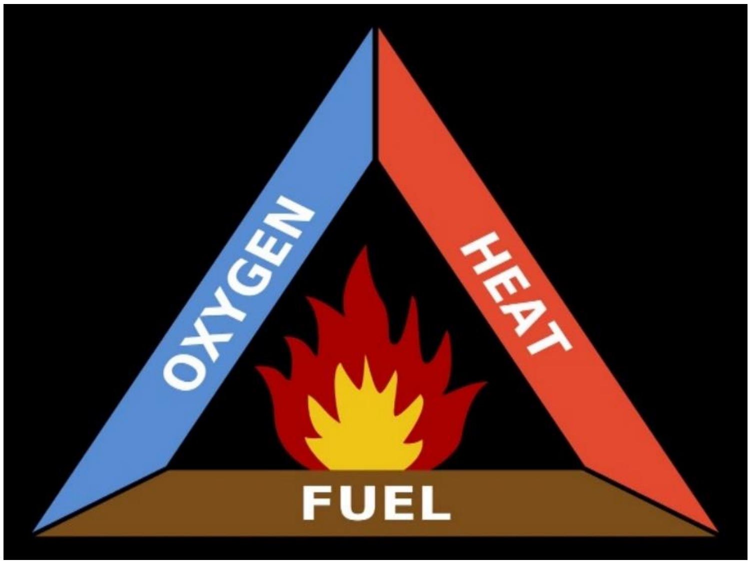


Fig: Fire Triangle

The "fire triangle" is a simple model that illustrates the three elements needed for a fire to ignite and sustain itself: fuel, heat, and oxygen.

Fuel:

This refers to any combustible material, like wood, paper, gas, or plastic.

Heat:

This is the energy needed to raise the fuel to its ignition temperature, the point at which it will catch fire.

Oxygen:

Air contains oxygen, which is essential for the combustion process to occur.The fire triangle is essential in the glass industry because it helps workers understand and prevent fires by identifying the three key elements needed for a fire — fuel, oxygen, and heat. Glass manufacturing involves high temperatures, combustible materials (like packaging or lubricants), and oxygen-rich environments, making the risk of fire significant. By understanding the fire triangle, workers can focus on eliminating or controlling at least one of these elements to prevent fires. For example, proper ventilation reduces oxygen buildup, maintaining equipment prevents overheating, and safe storage of flammable materials limits fuel sources. This awareness is crucial for ensuring safety and protecting both workers and equipment.

How to Properly Use a Fire Extinguisher: PASS

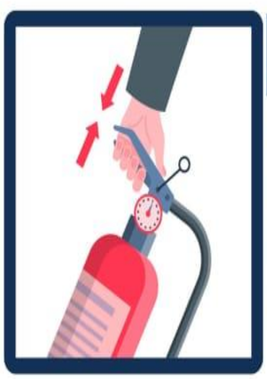
Before you fight a fire, stand 6-8 feet away and position yourself with your **back to an exit**. That way you will be able to exit quickly in case something unexpected happens.

1. PULL

Pull the pin on the fire extinguisher.

2. AIM

Aim low. Point the extinguisher at the base of the fire.



3. SQUEEZE

Squeeze the handle or lever to discharge the extinguisher.

4. SWEEP

Sweep from side to side until the fire is completely out. Make sure you continue to watch in case the fire re-ignites.

LAFORCE

PPE (Personal Protective Equipment):

Working in the glass industry presents a variety of safety hazards, making appropriate Personal Protective Equipment (PPE) essential. Here's a breakdown of key PPE items:

Essential PPE:

Eye Protection:

Safety glasses with side shields are crucial to protect against flying glass fragments.

Face shields may be necessary for tasks involving grinding, cutting, or working with molten glass.

Hand Protection:

Cut-resistant gloves are vital to prevent lacerations from sharp glass edges. The level of cut resistance needed will vary depending on the specific tasks. Heat-resistant gloves are necessary when handling hot glass.

Foot Protection:

Steel-toed safety boots protect against falling glass and other heavy objects.

Body Protection:

Long-sleeved clothing and aprons made of cut-resistant and/or heat-resistant materials provide additional protection.

Hearing Protection:

Earplugs or earmuffs are necessary in areas with high noise levels from machinery.

Respiratory Protection:

Depending on the specific processes, respirators or masks may be required to protect against dust, fumes, or other airborne particles.

Key Considerations:

Hazard Assessment: A thorough hazard assessment should be conducted to determine the specific PPE requirements for each task.

Proper Fit: PPE must fit properly to provide adequate protection.

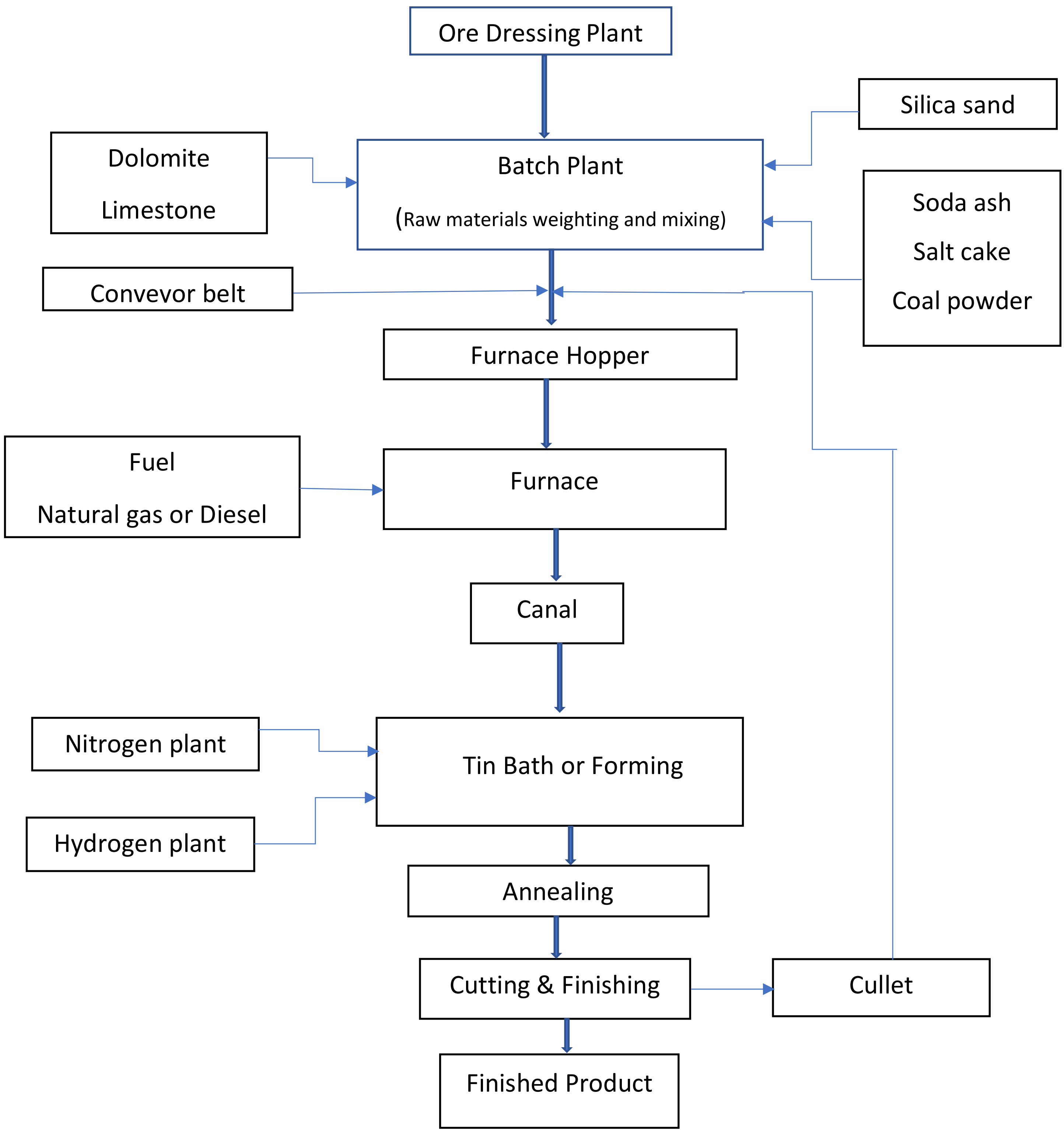
Regular Inspection: PPE should be regularly inspected for damage and replaced as needed.

Training: Workers should be trained on the proper use, care, and maintenance of PPE.

Resources from safety organizations like SafeWork NSW, and Manufacturers of PPE such as Magid glove, and Ansell, offer detailed information on the correct PPE for the glass industry.

By using the appropriate PPE and following safety procedures, workers in the glass industry can significantly reduce their risk of injury. In the glass industry, Personal Protective Equipment (PPE) is essential for ensuring worker safety due to the risks of high temperatures, sharp materials, and hazardous substances. Beyond standard protection, additional PPE enhances safety in specific environments. Head protection includes hard hats for overhead hazards and heat-resistant helmets for high-temperature areas. Eye and face protection can be improved with anti-fog and UV-resistant lenses for visibility in heat and welding shields for intense light. Hand and arm protection can include extended cuffs for forearm coverage and vibration-dampening gloves for machinery operation. Body protection may involve full body suits made of heat-reflective materials for extreme heat or disposable coveralls to prevent skin irritation. Foot protection enhancements include metatarsal guards for falling heavy glass and slip-resistant soles for wet surfaces. Other safety considerations include emergency showers and eye wash stations for chemical exposure, climate control PPE to reduce heat stress, and reflective clothing for visibility in low-light areas. Advanced technology, such as smart PPE with sensors to monitor temperature, noise, or gas exposure, further improves workplace safety. By continuously assessing hazards and integrating advanced PPE solutions, the glass industry can maintain a safer work environment and reduce the risk of injuries.

Process Flow Chart



Ore Dressing

Introduction:

An ore dressing plant in the glass industry is responsible for processing raw materials like silica sand to meet the required purity and composition for glass manufacturing. The quality of these raw materials directly affects the transparency, strength, and durability of the final glass products.

1. Raw Material Preparation:

Raw materials such as silica sand, feldspar, and limestone are mined and transported to the ore dressing plant. These materials contain impurities like iron oxides, clay, and organic matter, which must be removed to ensure high-quality glass production.

2. Crushing and Grinding

Large chunks of raw materials are crushed using jaw crushers, cone crushers, or impact crushers. The crushed materials are further ground using ball mills or roller mills to achieve the required particle size for glass melting.

3. Screening and Classification

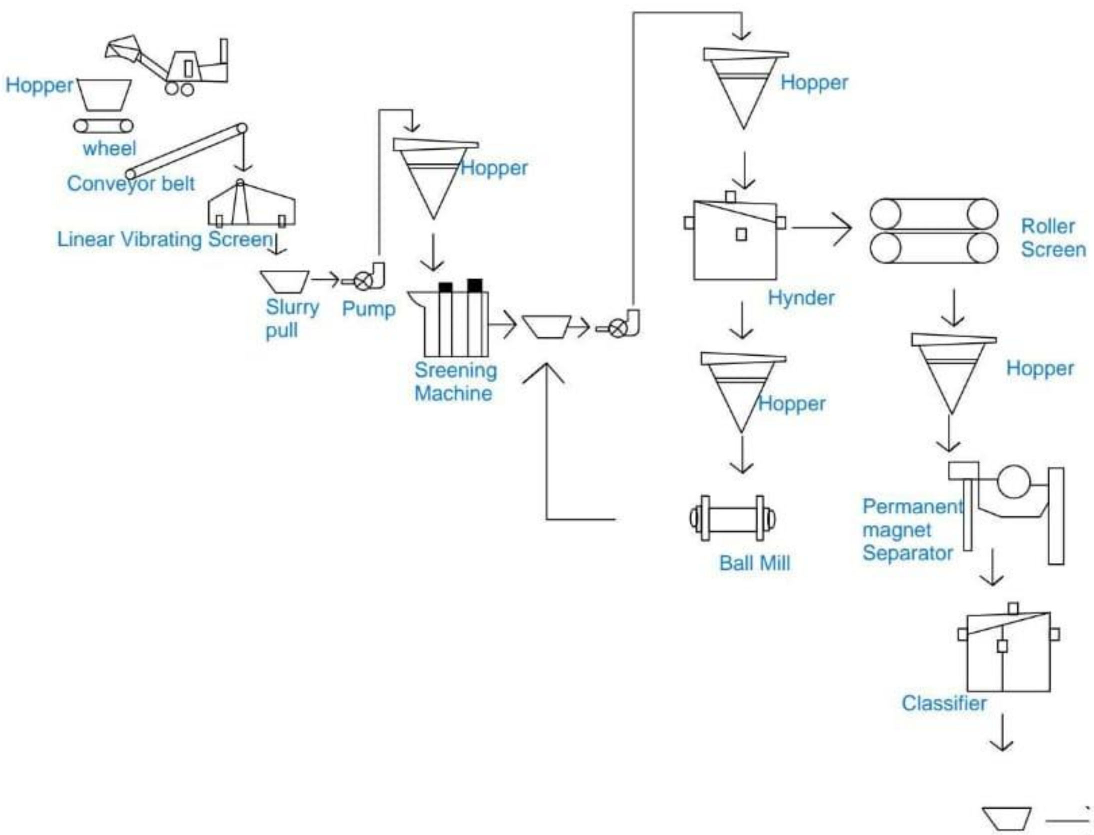
The ground materials pass through vibrating screens and classifiers to separate fine particles from coarse ones. Proper particle size distribution is essential for smooth melting and glass formation.

4. Washing and Purification

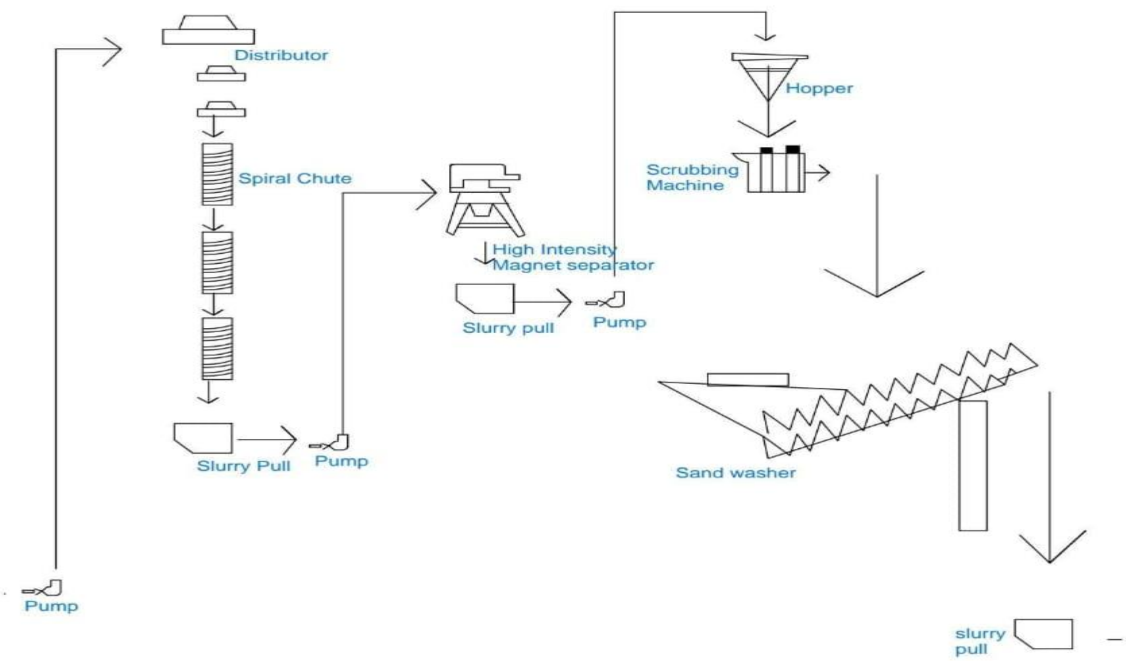
Silica sand, the primary raw material in glass, undergoes washing to remove clay, silt, and other impurities. This step improves the clarity and quality of the final glass product. Washing is a crucial step in ore dressing to remove clay, dust, and other soluble impurities from the raw material, such as silica sand. The process typically involves using water and mechanical equipment like trommels or scrubbers to wash the sand. Purification further refines the material by removing harmful minerals like iron oxides and other trace elements.

5. Magnetic Separation and Flotation

Iron impurities affect the color and quality of glass. Magnetic separators remove iron particles, while flotation techniques help separate unwanted minerals from silica sand and feldspar. Magnetic separation is commonly used to remove iron-bearing impurities from sand and other raw materials. Magnetic separators use powerful magnets to attract and separate magnetic materials, such as iron particles, from non-magnetic minerals like silica. This process is essential because even small amounts of iron can negatively impact the clarity and color of the glass. The separation ensures that the silica sand used in glass production is free from magnetic impurities, resulting in a cleaner and more consistent raw material for glass melting.



Hopper
wheel
Conveyor belt
Linear Vibrating Screen
Slurry
pull
Pump
Hopper
Sreening
Machine
Hopper
Hynder
Roller
Screen
Hopper
Hopper
Ball Mill
Permanent
magnet
Separator
Classifier



Distributor
Spiral Chute
Slurry Pull
Pump
Pump
High Intensity
Magnet separator
Slurry pull
Pump
Hopper
Scrubbing
Machine
Sand washer
slurry
pull

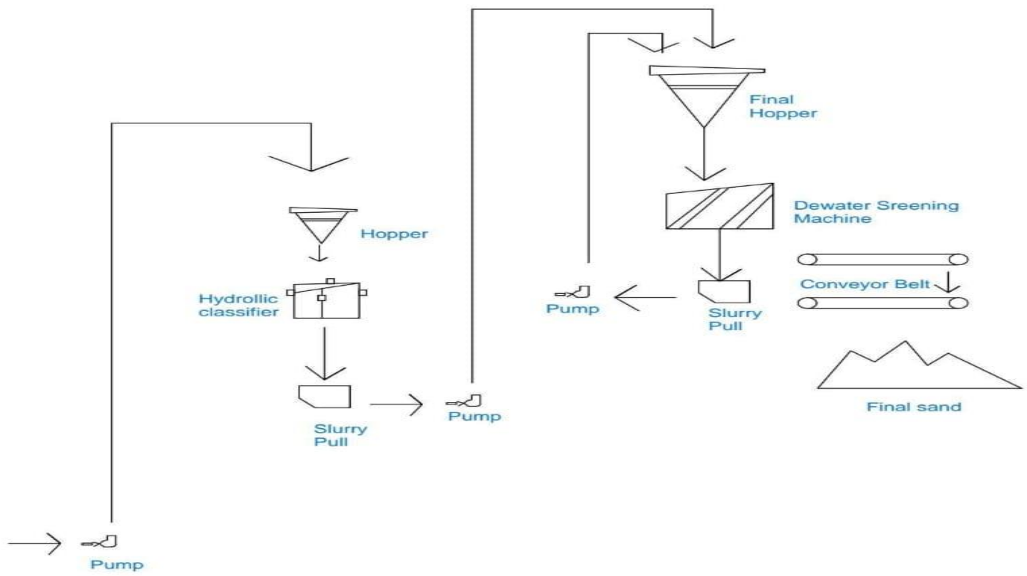


Fig: Ore Dressing Plant

6. Chemical Treatment

Some materials undergo chemical treatments like acid leaching to further purify silica sand by removing iron and other trace elements that could affect glass transparency.

7. Storage and Transportation

After processing, purified raw materials are stored in silos and transported to the glass manufacturing plant, where they are mixed and melted to produce glass products like bottles, windows, and fibreglass.

Objective:

The motive of Ore Dressing Plant is to wash ore silica sand and collect sand with silica about greater than 95%. Also remove iron from the ore. The objective of Ore Dressing or Mineral Dressing in the glass industry is to process and prepare raw materials (such as sand, feldspar, limestone, and other minerals) by separating impurities and undesirable elements to improve the quality of raw materials before they are used in the production of glass. Here are some key objectives:

1. Purification: Removing impurities like clay, iron, and other unwanted materials from the ores to get a higher-quality raw material. This is important as impurities can affect the clarity and color of the glass.

2. Particle Size Reduction: Reducing the size of the ore particles to a manageable level for easier handling, transportation, and mixing with other raw materials.

3. Improvement of Material Properties: Enhancing the physical properties of the raw materials such as hardness, melting point, and chemical composition, to ensure that the final glass product meets the required specifications.

4. Cost Efficiency: By removing impurities and improving the quality of raw materials, the overall cost of production can be reduced, ensuring that only the necessary amounts of high-quality materials are used in the glass-making process.

5. Increase Efficiency in Glass Production: The purification of raw materials ensures better flow during melting and consistency in the glass-forming process, which ultimately increases the efficiency of production and the quality of the finished glass product.

process:

The ore sand from Chittagong and Habiganj are mostly used in Ore Dressing Plant. After the laboratory allow the ore sand on the basis of the Percentage of Iron and silica it is then collected in the sand yard beside the ore plant. The Overall process has been given below:

1.Firstly, Ore sand is filled into a cave with a wheel belt by a Bulldozer and then stored in a slurry pull moving over a conveyor belt.

2. Then the sand passes through a linear vibrating screen which vibrates along a Horizontal direction to remove wood particle, stone and other unnecessary particles primarily.

3. Then the sand particle moves into slurry pull -2 and transfers wet sand into Hopper-1 in which fine particle with water flows over the Hopper and sand with the expected size moves downwards.

4. then mixing is performed by Screw bar and send the moving sand into slurry pull 3, using pump-2 moving sand reaches at hopper-2. This hopper is also used to remove fine particles and extract expected particle from the sand.

5.Next, the sand particles are allowed to pass through a Hinder machine which separates particles size less than 0.1 and also greater than 0.6nm. the sand with a size less than 0.6 sent to Hopper-3 -3 and the particles with a size greater than 0.6nm again come to the Hinder machine by completing a cycle. In Hopper 3, the fine particle flows over the Hopper with water and the expected particle moves downward.

6. To ensure the crushing process, Ball milling machines are uses to get a homogeneous size of particle and after crushing, sand is washed by rotatory roller screen which is able to rotating itself and remove dust particle from it and then moves to Hopper -4.

7. **Iron removal process:**

(i)Permanent magnet separator: It is a very useful process of removing iron and also the preliminary process of iron removal. This process uses a permanent magnet separator that attracts all iron particle towards it from the ore sand.

(ii)Spiral chute Separator: The Hydraulic classifier is used to separate fine particles from the expected particle (0.1-0.6nm) and stored in another slurry pull. The particles are then transfer into a storage at the roof using pump 3. Distribution of Particle occurs with 48 spiral chute allows sand particles to moves downwards rotating with the help of centrifugal force that removes iron particles. The iron and sand particle moves around centerline of the spiral chute ensuring that iron particles are nearer to the centre and separated by another pipeline and remove out.

(iii) High Intensity Machine Separator: Pump-4 helps to the moving sand particles to reach the high intensity machine which is nothing but a powerful electromagnet separator. It highly attracts the iron particles from the ore sand. Passing through this device ppm Value of iron of sand particle becomes lower(700-800ppm) and is then stored in the slurry pull.

Fig: Ore Dressing Machines

(iv) Acid Mixing: The last step of iron removing is mixing acid generally high PH sulfuric acid (10%) to the sand. After Passing Through High Intensity machine, The collected sand are transferred into Hopper-5 in which necessary amount of acid is mixed with sand and then passing through screw bar and then sand washer. Some particles need not mixing with acid and directly passes to the slurry storage bucket along the pipe line. Also sands washes with acid moves into the same destination.

8.Below the final Hopper a dewatering screen is connected and removes water as well as moisture from the sand and this cycle may happen few many times to provide sand of negligible moisture and then the final washed sand moving by conveyor belt stored into the final sand yard.

Mud Water management and ETP system:

Muddy water from Ore dressing plant is collected in a large canal and PAC (Poly-aluminum chloride) and PAM (Poly-acrylamide) are used to form solid mud and agglomerate at the bottom of the canal. Mud particles enter into the molecules of PAC and PAM and form solid mud. Then solid mud can separate from the water and collected in another section.

In an ore dressing plant, water plays a crucial role in various processes like grinding, washing, and separation. However, large amounts of water are consumed, and it becomes necessary to recycle water to reduce environmental impact and improve efficiency. Here's an overview of the water recycling system in an ore dressing plant:

Purpose of Water Recycling:

Conservation: Reduces the dependency on external water sources.

Cost Efficiency: Minimizes the cost of fresh water intake.

Environmental Protection: Reduces waste discharge and ensures compliance with environmental regulations.

Water Recycling Process:

Water Collection: Water used in different processes, like flotation or washing, is collected and stored in sedimentation ponds or sumps.

Filtration and Treatment: The collected water is often treated to remove suspended solids and impurities. In an ore dressing plant, particularly in the glass industry, the water recycling process often uses PAC (Poly-aluminum Chloride) and PAM (Polyacrylamide) to treat and recycle water effectively. Here's a brief explanation:

1. PAC (Poly-aluminum Chloride): It is used as a coagulant to remove suspended particles from the water. PAC helps in agglomerating fine particles and impurities into larger clusters, which can then settle out of the water, making it easier to separate solids from liquids.

2. PAM (Polyacrylamide): PAM acts as a flocculant, helping to bind the coagulated particles together, forming larger flocs. These flocs can then be easily removed through sedimentation or filtration, allowing the water to be reused in the plant.

Process:

PAC is first added to the water to coagulate the fine particles. After coagulation, PAM is added to facilitate flocculation, forming larger flocs that settle at the bottom. The treated, clarified water is then recycled back into the plant for reuse in various processes like grinding, washing, and flotation.

Recycling and Reuse: Once treated, the water is pumped back into the plant for reuse in various operations like grinding, flotation, or washing. This reduces the need for fresh water.

Water Management System: A closed-loop system is often implemented where water is continuously circulated within the plant. Excess water can be sent for additional treatment or be used for dust suppression in some cases.

Quality Monitoring: The quality of the recycled water is constantly monitored to ensure it meets the necessary standards for use in further operations. This includes checking parameters like pH, turbidity, and chemical content.

Benefits:

Resource Optimization: Maximizes the use of available water resources.

Reduced Waste: Limits water wastage and pollution.

Cost Savings: Reduces water purchase and treatment costs.

In summary, a water recycling system in an ore dressing plant helps conserve water, reduces environmental impact, and ensures continuous and efficient processing of raw materials.

ETP System:

Effluent Treatment Plants (ETP) in the glass industry focus on treating wastewater generated during ore dressing, ensuring environmental protection. The process includes:

1. Preliminary Treatment: Screening and sedimentation remove large particles.

2. Coagulation & Flocculation: Chemicals are added to clump suspended particles, making them easier to remove.

3. Filtration: Sand or membrane filters remove finer particles.

4. Chemical Treatment: Removes harmful metals using chemical agents.

5. Neutralization: Adjusts pH levels of wastewater.

6. Advanced Filtration: Reverse Osmosis (RO) or Ultrafiltration (UF) removes dissolved contaminants.

7. Sludge Treatment: Dewatering to handle waste solids.

8. Final Polishing: Ensures water is free of remaining contaminants.

9. Discharge or Reuse: Treated water is either safely discharged or reused.

This process helps minimize pollution, recover resources, and ensure sustainability in glass manufacturing.

Homogenizing section:

The washed water with nearer 700ppm iron constituents are put into homogenizing section to mix the sand and ensure an average ppm of iron into the sand and then transfer into Batch Plant. The washed sand is collected from and dropped into a hopper. Then it is transferred into homogenizing section using conveyor belt. sand of various ppm mixes and result in a homogeneous mixing of average ppm.

The homogenizing process in the glass industry is essential after ore dressing to ensure that the raw materials are thoroughly mixed and the desired chemical composition is achieved. This process helps in uniform distribution of materials, which is critical for producing high-quality glass. Here's a brief overview:

Purpose: After ore dressing (such as crushing, grinding, and separating), the raw materials like sand, soda ash, and lime are mixed to ensure consistency. This step is critical because even small variations in composition can affect the quality of the final product.

Method: Homogenization is typically done in large rotary or vertical mixers or silos where the materials are continuously mixed over time. This process also helps in breaking down any lumps or aggregates that might have formed during ore dressing.

Outcome: A homogeneous mixture ensures uniform melting in the furnace, which leads to consistent glass quality, color, and clarity. It also improves the melting efficiency by reducing any hot spots in the furnace.

In short, homogenization ensures that raw materials are uniform, which is essential for producing glass with the desired properties.

Batch Plant

Introduction:

In the glass industry, a batch plant is where raw materials like silica sand, soda ash, limestone, and cullet (recycled glass) are stored, weighed, mixed, and prepared before being melted in a furnace. The batch plant ensures precise formulation, consistency, and quality control for glass production. Automated systems are often used to handle material dosing, mixing, and transportation to the furnace, optimizing efficiency and reducing waste. In Batch Plant raw materials for glass production are carefully measured, mixed, and prepared. These raw materials, known as feedstock, are the basic ingredients needed to produce glass. They include both primary materials and refining agents, which help improve the final product's quality.

In the batch plant, materials are combined in precise proportions to ensure proper mixing. The storage system depends on how much material needs to be kept and how often new supplies arrive. Typically, the raw materials used pass through a 12-mesh sieve to ensure consistency.

The plant receives and handles deliveries of raw materials, but the process varies depending on the location and setup of the facility. Dust collectors help maintain a clean working environment by capturing dust from the raw materials.

For glass production, raw materials are categorized into three main groups, ensuring an organized and efficient mixing process before they are sent to the furnace.

Objective

The main objective of a batch plant in the glass industry is to ensure the precise preparation and delivery of raw materials for glass production. It plays a crucial role in maintaining consistency, efficiency, and quality by accurately measuring, mixing, and supplying the right proportions of materials to the furnace.

A well-managed batch plant helps optimize material usage, reduce waste, and improve energy efficiency. It also ensures that refining agents and additives are properly incorporated to enhance the final glass properties. Additionally, dust collectors help maintain a clean environment by minimizing airborne particles. Over all, the batch plant is essential for consistent glass quality, cost-effective production, and smooth manufacturing operations. In the glass industry, a batch plant plays a crucial role in preparing the raw material mixture needed for glass production. Its primary objective is to accurately weigh and blend essential ingredients such as silica sand, soda ash, limestone, and cullet (recycled glass) to ensure consistent glass quality. Precise weighing and homogeneous mixing are critical to preventing defects, bubbles, and inconsistencies in the final product. Batch plants also focus on quality control by monitoring factors like moisture content, particle size, and contamination. Automated handling systems, including conveyors and silos, improve efficiency and reduce labor dependency. Additionally, optimizing batch composition enhances energy efficiency by lowering furnace energy consumption, while incorporating cullet helps reduce emissions and environmental impact. Overall, batch plants ensure cost-effective, sustainable, and high-quality glass production.

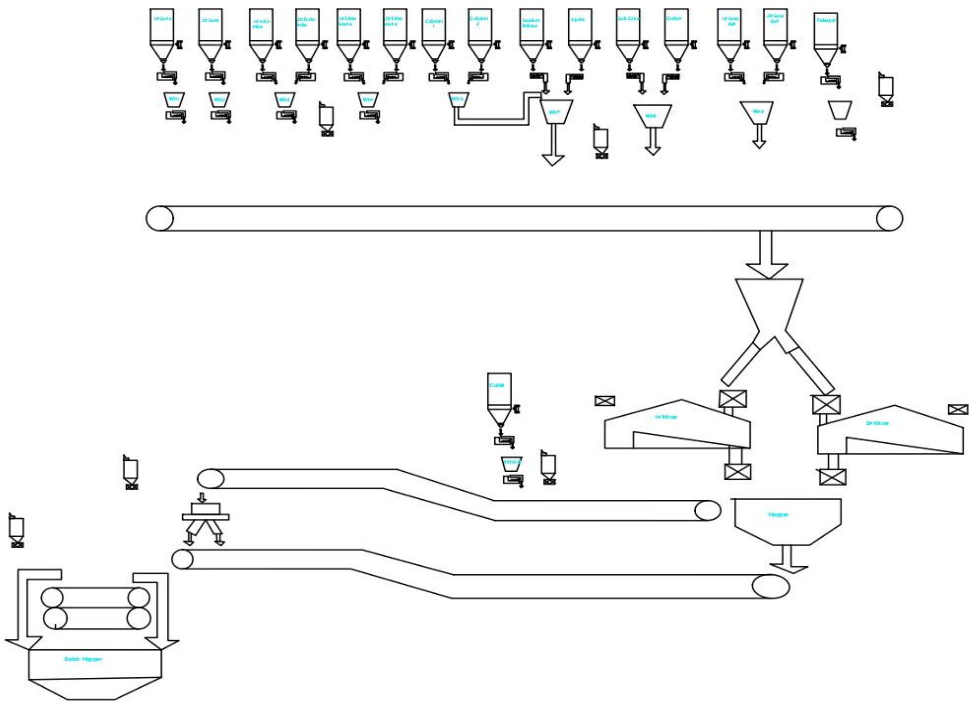


Fig: Batch Plant

Raw materials Used in the Batch Plant:

Silica:

Silica sand is the major ingredient in glass production, serving as the primary component in products like windows and bottles. Often referred to as quartz sand, white sand, or industrial sand, it consists mainly of two elements: silica and oxygen.

Fig : Silica Sand

In particular, silica sand is composed of silicon dioxide (SiO_2). When the sand is extracted, its chemical composition is analyzed using techniques like X-ray fluorescence (XRF), which typically shows that over 96% of the extracted sand is silica.

The melting point of silica is quite high, around 1710°C, making it suitable for the high temperatures required in glassmaking. Apart from silicon dioxide, silica sand also contains trace amounts of other elements like aluminum oxide (Al_2O_3), magnesium oxide (MgO), and ferrous oxide (Fe_2O_3), all of which play a role in influencing the properties of the final glass product. The percentage of the composition has been Given below:

Compound	Percentage
SiO_2	96
Al_2O_3	1.63
Fe_2O3	1.65
MgO	0.145

Limestone:

Limestone is a sedimentary rock primarily composed of calcium carbonate ($CaCO_3$), often in the forms of calcite or aragonite, and it may also contain notable amounts of magnesium carbonate. It plays a vital role in the glass manufacturing process.

Fig: Limestone

The main purpose of limestone in glassmaking is to provide calcium oxide (CaO), which enhances the glass's chemical resistance and durability. Additionally, limestone acts as a flux, helping lower the melting temperature of the glass mixture.It increases hardness of glass and minimize brittleness. The melting point of limestone is around 825°C, which allows it to easily blend with other ingredients.

In terms of composition, limestone is made up of calcium oxide (CaO), aluminum oxide (Al_2O_3), silicon dioxide (SiO_2), and often ferrous oxide (Fe_2O_3), all of which contribute to the overall properties of the glass.

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

Dolomite

Dolomite is an essential raw material in soda-lime glass production. It is an anhydrous carbonate mineral composed of calcium magnesium carbonate ($CaMg(CO_3)_2$) and forms white, tan, gray, or pink crystals. The mineral's structure alternates between calcium and magnesium ions, and calcined dolomite melts at about 2800°C.In glassmaking, dolomite improves the viscosity of the glass melt and enhances scratch and chemical resistance.It minimizes melting temperature

Fig: Dolomite

in furnace and acts as fluxing agent, also hardens glass structure. It also provides magnesium oxide (MgO), which is key for the glass's composition. The main components of dolomite are calcium oxide (CaO) and magnesium oxide (MgO).

Compounds	Percentage (%)
CaO	74.26
MgO	21.42
Al_2O_3	1.09
Fe_2O_3	0.22

Soda Ash:

Soda ash, also known as sodium carbonate (Na_2CO_3), is a key ingredient in glass production. It lowers the melting temperature of sand, the main component in glass, making the process more energy-efficient and reducing CO_2 emissions. This is why glass manufacturing accounts for more than 50% of the total soda ash production. Soda ash is a white, odorless, water-soluble salt that forms a moderately alkaline solution when dissolved in water. Historically, it was derived from the ashes of plants that grew in sodium-rich soils, leading to its name. The melting point of soda ash is around 851°C. While it is used across various industries, its primary application is in the glass industry, where it helps decompose silicates to facilitate glassmaking.

Fig: Soda ash

Salt Cake

Anhydrous sodium sulfate (Na_2SO_4), commonly known as salt cake, is used in small amounts as a refining agent in glass production. Adding up to about 5% of salt cake to the batch helps the glass become bubble-free earlier than in sulfur-free formulations. It also acts as a flux, lowering the melting point and viscosity of the glass, while preventing the formation of scum during the refining process.

Fig: Salt cake

Salt cake is made up of sodium, sulfur, and oxygen, and its composition plays a significant role in improving the glassmaking process by promoting smoother, cleaner melts. The percentages of salt cake compounds has been given below:

Compounds	Percentages(%)
Sodium	32.37
Sulfur	22.57
Oxygen	45.06

Sodium Nitrate:

Sodium nitrate ($NaNO_3$) is used in glass production to act as an oxidizing agent. It helps in the refining process by promoting the removal of bubbles and impurities from the glass melt.

Fig: Sodium Nitrate

Additionally, it enhances the clarity of the glass and speeds up the melting process by lowering the overall viscosity. Sodium nitrate is typically used in small quantities in the batch plant to improve the quality of the final glass product.

Coal Powder:

Coal powder is used in the batch plant in the glass industry primarily as a fuel source to help melt the raw materials in the furnace. Coal powder generally means the presence of carbon in Batch preparation. It acts as an reducing agent and produce CO_2. It provides the necessary heat for the melting process, contributing to energy efficiency. Additionally, coal powder can help reduce the viscosity of the glass melt and promote the refining process by aiding in the removal of bubbles and impurities**.** It can make mixture homogeneous and also can affect in the transparency of glass.

Fig: Coal Powder

Cullet:

Cullet (crushed recycled glass) is added to the batch plant to reduce the melting temperature, lowering energy consumption and CO_2 emissions. It also minimizes the use of colorant.

Fig: Cullet

It improves the homogeneity of the glass melt, speeds up the melting process, and enhances overall glass quality. Using cullet also supports sustainability by recycling waste glass into new production. Clear, Lake Blue, Light bronze, Green, Dark grey, Wash-blue, Dark blue, Osean blue, Dark are various type of cullet are reserved in cullet yard.

Crushing Process:

In the glass industry, the crushing process of batch materials in a batch plant is a crucial step to ensure that raw materials are in the right form for the melting process.

The batch materials used in glass production include ingredients like sand, soda ash, limestone, and various other raw materials. These materials usually Limestone and Dolomite are often large and need to be reduced to a fine, uniform size before they are mixed and sent to the furnace. The crushing process helps in achieving this size reduction, making sure that all particles are small enough to melt efficiently and uniformly. Large chunks of raw materials are first fed into crushers. The type of crusher used depends on the hardness and size of the material, but typically, jaw crushers or impact crushers are used. These crushers break down the large pieces into smaller chunks.

Fig: Jaw Crusher

After crushing, the materials are often screened to ensure that only the properly sized particles are used. Any oversize material is sent back for further crushing. Storage and Transfer: Once the batch materials are crushed to the required size, they are stored in silos or bins until they are mixed with other materials to form the glass batch. The whole process is essential because the finer and more uniformly crushed the raw materials are, the more efficiently they can be melted in the furnace. This not only improves the quality of the glass but also helps in energy efficiency by reducing the time and energy needed to melt the materials.

1. Rock materials like Dolomite and Limestone are poured into Hopper-1, then feed into a jaw crusher with which they are crushed and obtain one-half of the preliminary size.
2. These Crushed materials carried above with Bucket Elevator -1 and reach at 8meter Floor to store in Hopper -2

3. Then a machine named Double roll crusher-1 is used to crushed again. a vibrating feeder fed Dolomite or limestone into the machine. It has two rotating rollers that crush materials between them for better mixing and processing. Size of raw materials becomes more smaller in this device.

Fig: Octagonal Screen

4. These materials are sent to octagonal sceen-1 using Bucket elevator-2. Octagonal screen consists of sieve having 2 mesh per inch holes to separate necessary size of particle. It separates 14.70mm size of particle and oversize particles (>14.70mm) are transferred to Hopper-1 and follow the previous process to obtain
5. Then the optimum size of particle stored into Hopper -3 and then goes to double roll crusher-2 for further crushing to get the final size particle (2.5 mm) and send it into octagonal screen-2 using Bucket elevator-3.
6. Lastly, Octagonal screen -2 ensure further size separation with the sieve. The final size particles then poured into the sailo using Bucket elevator -4

Batch Mixing

The batch mixing process in a glass plant is a critical step that ensures uniformity and consistency in the final glass product. It involves precise weighing, blending, and transporting of raw materials before they are melted in the furnace. Glass is primarily made from a combination of raw materials, each playing a specific role in the final composition.

Each material is stored in separate silos or bins. Automated weighers accurately measure each ingredient based on a specific batch recipe. The precision in weighing is crucial to ensure the right glass composition and quality.

After weighing, the raw materials are fed into a batch mixer. The mixing ensures even distribution of all components, leading to a homogeneous blend. Generally, Drum mixer is used in this process. With the rotation of motor’s shaft the slice rotates to produce a Homogeneous Batch mixing.

Fig: Batch Mixer

Transporting the Mixed Batch

Once mixed, the batch is transported to the furnace, usually through conveyor belts or pneumatic systems. Some plants use pre-heaters to slightly warm the batch before it enters the furnace, improving energy efficiency. In a glass plant, the mixed batch is transported to the furnace using belt conveyors, screw conveyors, pneumatic systems, or bucket elevators. To prevent material segregation, transport speed is controlled, and enclosed systems are used. Some plants store the batch in silos or hoppers before feeding it into the furnace. Batch chargers (oscillating, screw, or pusher types) ensure even feeding for uniform melting, optimizing glass quality and production efficiency.

Importance of Batch Mixing in Glass Production-

Consistency: Ensures uniform composition, preventing defects in the final glass.

Energy Efficiency: Properly mixed batch melts faster, reducing fuel consumption.

Waste Reduction: Correct proportions minimize material wastage.

Product Quality: A homogeneous mix prevents unwanted streaks or bubbles in glass.

The batch mixing process in the glass industry is essential for producing high-quality glass. Accurate weighing, efficient mixing, and proper transportation ensure a consistent and defect-free melt, ultimately improving production efficiency and product quality.

Cullet system

The cullet system in a glass batch plant handles recycled glass, which helps reduce energy consumption and improve glass quality. Cullet melts faster than raw materials, lowering furnace temperatures and cutting CO_2 emissions. It comes from two sources: internal cullet, which includes defective or excess glass from production, and external cullet, which is post-consumer recycled glass like bottles and windows.

The cullet processing system begins with collection and sorting, where contaminants like metals, ceramics, and plastics are removed. It is then crushed into smaller pieces for uniform mixing, cleaned to remove dust and organic residues, and screened to ensure the right size before being

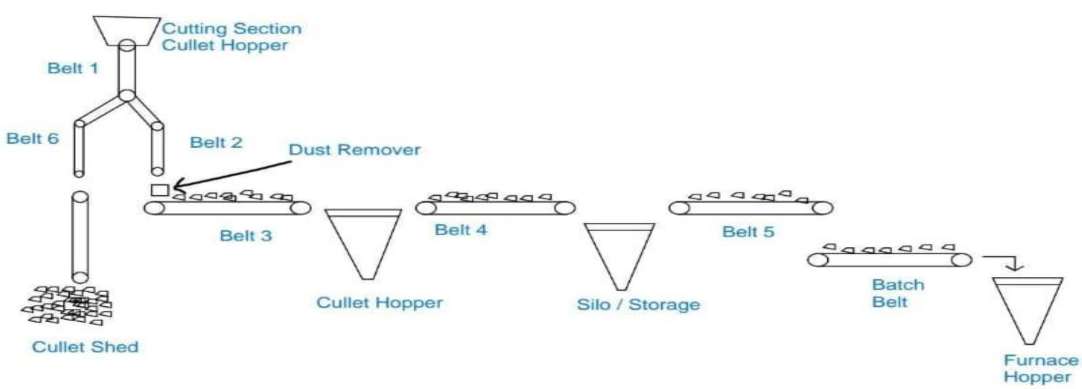


Fig: Cullet System

added to the batch. Once processed, cullet is stored in silos or bins to prevent contamination and is transported via conveyors or pneumatic systems to be mixed with raw materials before entering the furnace.

Cullet Washing Process

In a batch plant, the cullet washing process is crucial for ensuring clean, high-quality recycled glass is ready for melting. Cullet (broken glass) often contains dirt, labels, metals, and other contaminants that can affect the final glass quality.

The process starts with cullet being fed into a washing system where it goes through high-pressure water sprays, scrubbing, and screening. Water helps loosen dirt and separate lighter materials like paper or plastics. Magnets or eddy current separators remove metals. After washing, the cullet passes through drying or dewatering systems to eliminate excess moisture before it's mixed with raw materials for the furnace. Clean cullet melts faster and at lower temperatures, improving energy efficiency and reducing emissions in glass production.

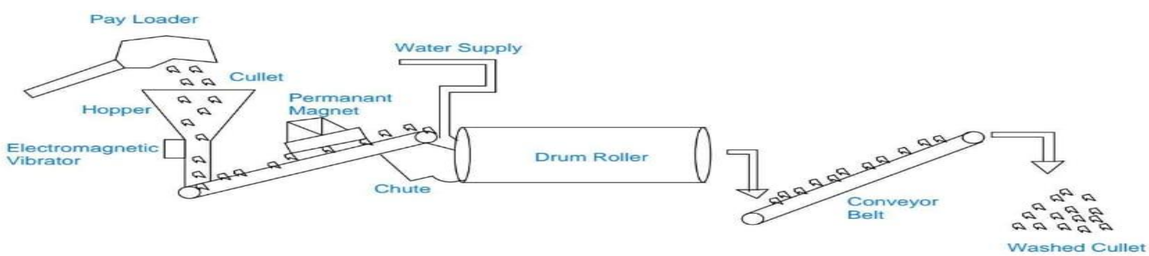


Fig: Cullet Washing Process

Dolomite Washing Process

In a batch plant, the dolomite washing process is essential to ensure the raw material is clean before it's mixed for glass production. Dolomite often contains impurities like dust, clay, and other unwanted particles that can affect glass quality. The process involves feeding raw dolomite into a washing system where it's agitated with water to remove fine particles and dirt. Screens or hydro-cyclones help separate and discard the waste material. After washing, the dolomite is typically dewatered and dried to achieve the right moisture level before it goes into the batch mix. Clean dolomite improves batch consistency and helps maintain the desired chemical composition of the glass.

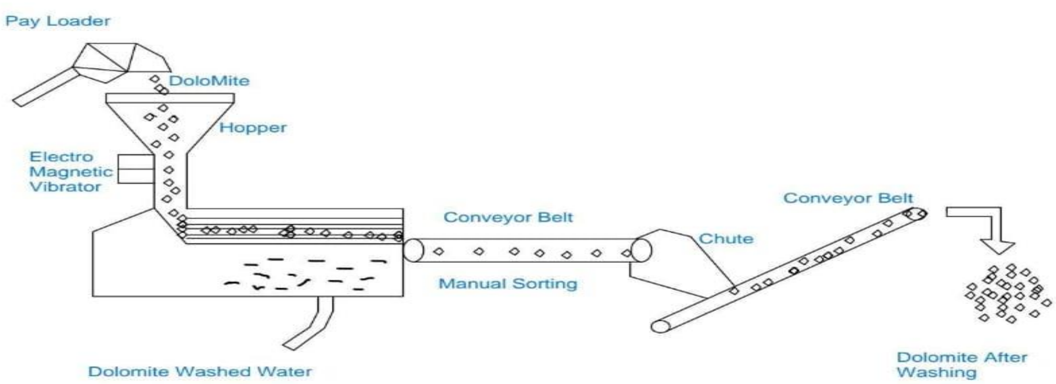


Fig: Dolomite Washing Process

Sedimentary tank Recycling:

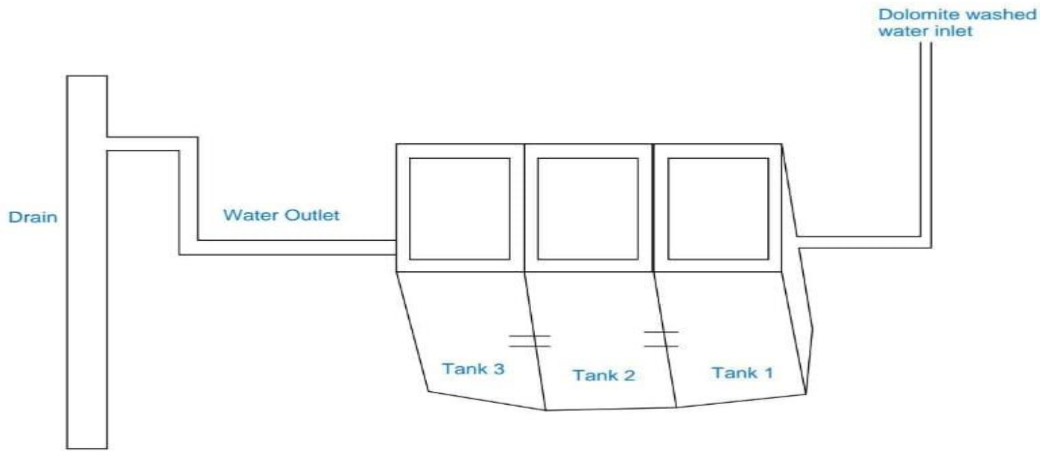


Fig: Sedimentary tank

The sedimentary tank system consists of three tanks where Dolomite mixed water is filled and obtain mud of Dolomite. After washing Dolomite, the dolomite mixed water poured into sedimentary tank-1, the excessive water overflow and fill into tank-2 ensuring the dolomite particles aggregates downwards and fill the tank cavity. Then extra water from tank-2 overflows and fall into tank-3 and coagulation of dolomite particle fill tank-2 cavity. In this way, tank-3 hold a greater amount of water and a less amount of dolomite. By overfilling tank-3, water is drained out and the residual dolomite into the tank is used to fill various cavity present in the in the industry.

Laboratory

The float glass manufacturing process begins with rigorous testing of raw materials to ensure quality and consistency. These materials—local silica, dolomite, limestone, soda ash, coal powder, salt cake, and cullet—are analyzed in a laboratory before production. Their composition, purity, and moisture content (which should be between 4% and 4.5%) are carefully monitored. In a batch plant for the glass industry, the laboratory plays a crucial role in ensuring the raw materials and final batch composition meet quality standards. The process starts with sampling raw materials like silica sand, soda ash, limestone, and cullet. These samples are tested for purity, moisture content, grain size distribution, and chemical composition using techniques like X-ray fluorescence (XRF) and loss on ignition (LOI).

Once the batch is mixed, lab tests confirm homogeneity and chemical consistency. A small melt test may be conducted to check for defects like bubbles or phase separation. Adjustments are made if necessary before sending the batch to the furnace. Throughout production, the lab continues monitoring for variations that could impact glass quality, ensuring consistency in every batch.

(i)Raw Material Testing

The process begins with the careful selection and testing of raw materials such as:

Silica sand (provides the glass structure)

Soda ash (lowers the melting point)

Limestone & dolomite (improves durability)

Cullet (recycled glass) (enhances energy efficiency and sustainability)

Other additives (colorants, refining agents, etc.)

Each material is sampled and tested to verify:

Purity – Using chemical analysis techniques like X-ray fluorescence (XRF) to detect impurities (e.g., iron content in silica).

Moisture content – Measured using loss on ignition (LOI) or drying methods to ensure consistent weight proportions in the batch.

Grain size distribution – Controlled to prevent segregation and ensure uniform melting in the furnace.

Bulk density – Determines the flow characteristics of raw materials for proper mixing.

(ii)Batch Composition and Testing

Once raw materials are approved, they are weighed and mixed according to precise formulations. The laboratory ensures that the batch composition remains consistent by:

Verifying chemical composition – Ensuring the correct ratio of silica, soda ash, and other materials to maintain glass properties.

Homogeneity checks – Ensuring thorough mixing to prevent segregation, which can lead to defects in the final glass.

Melt testing – Small samples may be melted in a lab furnace to check for phase separation, bubbles, or other defects before large-scale production.

(iii)Process Monitoring and Quality Control

As the batch enters the furnace and melts at high temperatures (usually 1,400–1,600°C), the lab monitors:

Melting behavior – Ensuring a smooth, homogeneous melt without crystallization or undissolved particles.

Viscosity measurements – Controlling flow characteristics for forming operations.

Gas analysis – Checking for unwanted gases (e.g., CO_2, O_2) that could cause defects like bubbles in the final product.

Color and transparency checks – Verifying that additives or iron content do not cause unintended discoloration.

(iv)Final Glass Testing

After the molten glass is formed into sheets, bottles, or other products, the lab conducts rigorous tests, including:

Optical clarity – Measuring transparency and detecting inclusions.

Thermal expansion – Ensuring resistance to temperature changes.

Strength testing – Checking mechanical durability (e.g., impact resistance, stress testing).

Chemical durability – Verifying resistance to acids, alkalis, and environmental exposure.

Data from lab tests are used to refine formulations, improve efficiency, and reduce waste. Regular audits and adjustments help maintain product consistency and meet customer specifications.

The laboratory is essential in ensuring that every batch of glass meets the highest quality standards before it moves to production and final use.

Furnace/Melting

Introduction

A furnace is an enclosed structure that generates heat, and a glass melting furnace is specifically designed to melt raw materials into glass. It is a high-temperature oven used to melt raw materials like sand, soda ash, and limestone to make glass. It operates at extremely high temperatures, often exceeding 1700°C (3092°F), to turn these materials into molten glass.

There are different types of glass furnaces, depending on the manufacturing process. Some are continuous, where glass is constantly melted and drawn out, while others are batch-based, melting a set amount at a time. Inside, the furnace is lined with heat-resistant bricks to withstand the intense heat and prevent damage.

Once the glass reaches the right consistency, it can be shaped into windows, bottles, or delicate art pieces. The furnace is the heart of any glass-making operation, keeping the material in a liquid state until it's ready to be formed. Among them, float glass furnaces are the largest in size and production capacity. These furnaces push the limits of construction, typically handling 600 tons per day (t/d), though smaller ones with 250 t/d and larger units up to 1200 t/d also exist. Float glass furnaces are designed for producing soda-lime glass, which requires a much higher quality standard than container glass.

Gas is crucial for furnace operation—it's essentially the "heart" of the system. Most float glass furnaces are cross-fired and use LNG (liquefied natural gas), which is cooled to around -260°C before use. The amount of gas required depends on the raw materials; if they are wet, more gas is needed for efficient melting.

The furnace is built using refractory materials, which can withstand extremely high temperatures. This ensures that both the furnace and its surroundings remain safe. The furnace walls, known as suspended walls, are entirely lined with refractory material for insulation.

In glass production, cross-fired furnaces are common. To monitor the interior, cameras with built-in cooling systems are installed. Thermocouples, typically "S"-type due to their high-temperature tolerance, measure the furnace's heat levels.

Cooling systems are essential because of the intense heat generated. There are two types of cooling systems:

(i)Air cooling

(ii)Water cooling

Blowers are installed in various sections of the furnace to help regulate temperature. They are used to supply air to the Furnace as various part of the furnace are need to be cooled for furnace sustainability and maintenance of temperature throughout the furnace. Generally. 5 types of blowers are used in furnace –

Fig: Blower

Combustion Blower: Combustion Blower is the most useful blower for the Furnace as it circulates air to the furnace as well as regenerator to produce flame and heat. There are two combustion blowers among which one remains active and at the same time another remains off. Combustion air from this blower circulate to the regenerator that produce flame when contact with natural gas or Disel /HFO.

L-Suspension Blower: It is used to cool L-Suspension wall, the hanging wall that provide support to the front wall as the wall is loose and isolated. The number of this blower are two and when one is on, another remains off.

Tank cooling blower: This type of blower is used to cooling the tank block by which glass melt passes. They are four in number among which two remain on when the other two blower is off.

Steel Skewback blower: Furnace has steel skewback portion at the corner part that joint the body with the roof of the furnace. This portion needs to be cooled otherwise the expansion or stretch of the skewback part will cause breakdown of the furnace. So, steel skewback blower circulate air to this portion to be cooled. There are two skewback blowers in which one remain on and another remain off.

Dilution Blower: This blower circulate air at the cooling end to cool rapidly the glass melt. A filter is associated with the blower to circulate clean air to the cooling end to avoid defects in glass. They are also two in number, when one remains off another remain active.

A glass furnace is divided into eight main sections:

1. Regenerator

2. Doghouse & Feeding

3. Pre-melting Zone

4. Melting Zone

5. Refining Zone

6.Neck Zone

7. Cooling End

8. Canal

Each section plays a vital role in the glass-making process, ensuring a continuous and efficient operation.

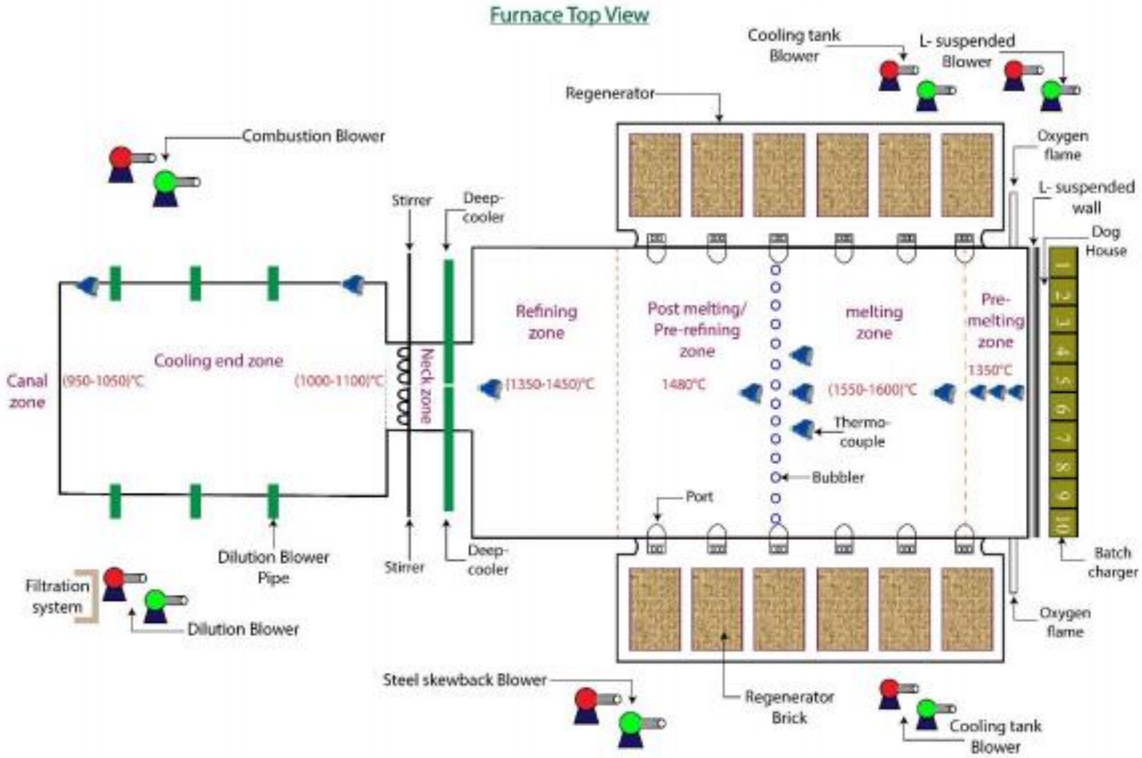
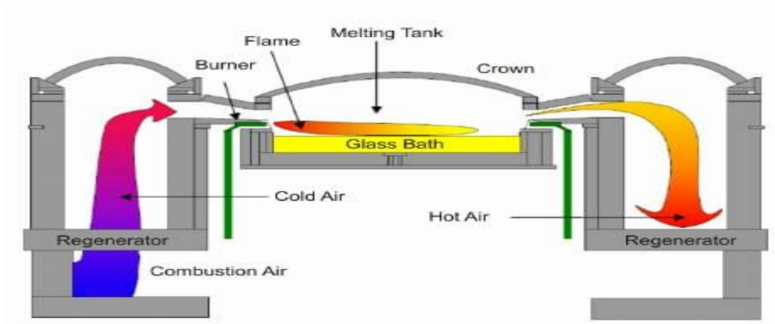


Fig: Furnace

Regenerator and its Working:

Regenerator is a part of furnace which is generally the heat producer element of furnace. In a float glass furnace, regenerators play a crucial role in heat recovery. These are made of refractory materials, their walls absorb and store heat, which is later transferred back to the combustion air.

Furnaces that run on gas or oil typically have a box-shaped regenerator design.



Before burning, Natural gas and compressed air pass through the regenerator, where they get heated. Then, they move through vertical and horizontal channels into the pre-combustion chamber. There, they mix a little and start to burn. This burning mixture is then sent into the

furnace at a set angle and speed, where it

keeps burning. At the same time, the flue gases leave through the opposite port. The port is important because it lets fresh air in and allows exhaust gases to go out.

Port:

The port is an opening that allows compressed air and fuel like natural gas or oil to enter the furnace while also serving as an exit for exhaust gases. It connects the combustion system to the furnace and works with the regenerators to improve heat efficiency. The port helps direct the air-fuel mixture into the furnace for burning and guides the flue gases toward the regenerators and chimney for

Fig: Port

safe release. There are 6 ports in each regenerator that means a glass furnace contains total 12 port for firing. Every 5 ports consist of 3 burners and one port consist of 2 burners, that means a regenerator consist of 17 burners and total 34 burners present in the furnace as a furnace contains two regenerators.

Burners

Burners in a glass furnace are devices that mix fuel and air to create a flame for heating the furnace. They help melt raw materials by producing a high-temperature flame. Burners can use gas, oil, or a mix of both as fuel. Their position and design ensure even heating inside the furnace for smooth glass production. Types of burners:

Oxygen burners:

Oxygen burners in a glass furnace use pure oxygen instead of regular air to burn fuel. It consists of 3 line one is pure oxygen line, another two are natural gas and compressed air respectively.

Fig: Oxygen Burners

This creates a hotter, more efficient flame, which helps melt glass faster and reduces fuel consumption. Oxygen burners are installed besides the pre-melting zone to provide primary heating to the batch materials and prepare for melting.

Gas burners:

Gas burners in a glass furnace are devices that mix fuel gas (like natural gas) with air or oxygen to produce a controlled flame for heating.

Fig: Gas Burners

They help melt raw materials by providing a steady and even heat source.

Gas Supply: Fuel gas flows into the burner.

Air or Oxygen Mixing: The burner mixes the gas with compressed air or pure oxygen.

Ignition: The mixture burns when combustion air circulates with this mixture, creating a high-temperature flame.

Heat Distribution: The flame spreads heat evenly inside the furnace with the help of compressed air to melt glass efficiently.

Oil burners:

Oil burners in a glass furnace use liquid fuel, such as heavy oil or diesel or HFO (High density Fuel Oil), to produce a flame for heating and melting glass materials. The burner sprays the oil into the furnace as a fine mist, which then mixes with air or oxygen and ignites to create a steady, high-temperature flame. This heat ensures even melting of raw materials for smooth glass production.

Fig: Oil Burners

Oil burners are commonly used when gas is not available or when high heat output is needed. They provide strong, consistent heating but require proper maintenance to prevent carbon buildup and ensure efficient combustion.

Firing system

Combustion blower causes the circulation of combustion air to the regenerator. The combustion air pipe line divided by 6 line and each of the 6 line further divided by two lines and 6 lines enters in one regenerator and others 6 lines enters in another regenerator.

Fig: Furnace Firing

There are also 6 air exchangers for each of the regenerator through which the combustion air passes. Air exchanger consists of damper arrangement to block or pass the combustion air and flue gas. When combustion air passes through one regenerator, the passes of this air are blocked for another one. When combustion air lines remain open, flue gas line remains off for the same regenerator and vice-versa. Combustion air passes through the regenerator which combustion air lines is opened and circulate through the hot refractory bricks of the regenerator to gather heat from the brick and mixes with Fuel and compressed air flows through the burners and produce flame. Burning of fuel causes the production of hot flue gas that circulate in a circular motion and passes through another regenerator that make heated to bricks of this regenerator and exhaust out through the main fuel line. The reverse process arises for another regenerator.

Flue System in Float Glass Furnace

The flue is responsible for directing exhaust gases from the furnace to the atmosphere. These gases flow down into the regenerator from the port before being expelled through the chimney. A suction force near the chimney is created naturally to exhaust the flue gas. Necessary amount of flue gas are taken by power plant to run the boiler and the residual amount is extracted out through chimney. The flue system also helps regulate gas flow and pressure using shutters and dampers. Its height contributes to the furnace’s natural draft, overcoming internal resistance and maintaining proper airflow.

In gas- or heavy oil-fired float glass furnaces, the flue layout is relatively simple, with flues positioned inside the regenerators beneath the furnace. The system consists of a main flue and several branch flues, where dampers and combustion air inlets are installed for control. General flues are equipped with rotary dampers to adjust furnace pressure, while an additional damper in the chimney fine-tunes the exhaust power. For gas-fired furnaces, the flue arrangement becomes more complex, as it requires separate air and gas flues. These flues ensure efficient combustion and proper ventilation, preventing heat loss and maintaining furnace stability.

Dog House and Feeder:

Dog house is front part of the furnace through which batch inlets into the pre-melting zone. Batch materials enter to the furnace with the help of batch charger. To reduce the escape of hot gases and dust when raw materials are fed into the doghouse of a glass melting furnace, an enclosure is used. This enclosure has two sections: one is fixed on the side walls of the furnace, covering the doghouse area, and is sealed at the back by the L-suspended wall of the furnace. The second section is mounted on the batch feeder itself.

A feeder delivers raw materials into the furnace, ensuring they enter the pre-melting zone properly. The feeder can be quickly moved away if needed. It is divided by 10 equal parts. Each of the part fed batch materials equally and homogeneously to avoid spread out of the batch and maintain better composition of the batch. The back of the feeder’s enclosure is partially formed by the feed hopper, with the batch material inside acting as a barrier.

A flexible, heat-resistant fabric is attached beneath the feeder's charger plate. This fabric curtain plays a key role in preventing gas and dust from escaping by sealing the space under the charger plate. It is also connected to the ends of the feeder's enclosure section, allowing enough flexibility to maintain an effective seal while the feeder operates.

Pre-melting Zone

The pre-melting zone of a glass furnace is the first stage where raw materials begin to heat up and start melting. When batch materials, like sand, soda ash, and limestone, enter the furnace through the doghouse, they land in this zone. Here, the temperature gradually rises, causing the materials to lose moisture, break down, and react with each other before fully melting. Pre-melting zone use oxygen burner to heat the batch materials. Reaction occurs in pre-melting zone:

$$MgCO_3 \longrightarrow MgO + CO_2$$

This zone is important because it ensures a smooth transition from solid batch to molten glass, preventing sudden temperature shocks that could affect glass quality. It also helps reduce dust and gas emissions by controlling how the batch melts. Proper heating in the pre-melting zone improves overall furnace efficiency and leads to better, more consistent glass production. It is located near the furnace's charging end, just after the doghouse, where the batch materials enter. In this zone, the average temperature of this zone typically 1350 degree Celsius, gradually increasing as the materials move deeper into the furnace.

1. Batch Heating: The raw materials, including silica sand, soda ash, limestone, and other additives, are heated by the furnace's radiant heat.

2. Moisture Evaporation: Any water or volatile compounds in the batch evaporate, reducing the risk of bubbles in the final glass.

3. Chemical Reactions: The ingredients begin to react, forming intermediate compounds that later fuse into molten glass.

4. Softening & Melting: As the temperature rises, the solid particles soften and start melting to the melting zone, preparing them for the high-temperature refining zone.

Prevents Thermal Shock: A gradual temperature increase prevents cracking or uneven melting.

Controls Gas Release: Many raw materials release gases like CO_2 and SO_2. If not managed properly, these gases can create defects in the glass.

Improves Furnace Efficiency: Ensuring proper heat transfer in this zone reduces energy waste and enhances overall melting performance.

Reduces Dust & Material Loss: A well-designed pre-melting zone minimizes raw material carryover, keeping the furnace cleaner.

In modern glass furnaces, advanced technologies like blanket feeders and controlled batch charging help optimize the pre-melting process, ensuring consistent glass quality and efficient production.

Melting zone

Melting zone allows batch materials to totally melt at higher temperature. It is the zone in a glass furnace is where raw materials fully transform into molten glass. After passing through the pre-melting zone, the batch reaches this high-temperature area, typically around 1550-1600 Degree Celsius. Here, the heat is intense enough to break down chemical bonds and completely melt the mixture into a uniform, bubble-free liquid.

Reaction Occurs in melting zone:

$$Na_2CO_3 + SiO_2 \longrightarrow Na_2O.SiO_2 + CO_2$$

$$Na_2SiO_2 \longrightarrow Na_2O.2SiO_3$$

Here, $Na_2O.2SiO_3$ has a glass like structure.

The steps of Melting has been given below:

1. Complete Fusion: The solid batch materials fully melt, forming a consistent liquid.

2. Homogenization: The molten glass is mixed to remove temperature variations and uneven composition.

3. Gas Release: Any remaining gases trapped in the batch escape to prevent bubbles in the final product.

4. Heat Transfer: Burners or electrodes supply heat, ensuring even melting and maintaining furnace efficiency.

Ensures all materials are properly melted for high-quality glass. It Helps remove bubbles and impurities. Maintains a stable temperature for smooth furnace operation. Efficiency of the melting zone directly affects the clarity, strength, and consistency of the final glass product.

Post-melting zone or Pre-refining zone

It is the phase between melting zone and refining zone and arises after melting and before refining. Temperature in this zone becomes 1480 Degree Celsius. Chemical reaction of sodium carbonate occurs in this phase.

$$Na_2CO_3 \longrightarrow Na_2O + CO_2$$

The produced sodium oxide improves the durability and workability of the glass. It also lowers the melting point of silica, making glass production more energy efficient and produced carbon dioxide create bubbles in the melts. A Bubbler is applied to this zone that is the combination of compressed air or nitrogen gas flowing perpendicular to the moving melt. Bubblers create barrier effect for controlling the flowing of melts. Applications of bubbler-

(i)Increases the size of small bubbles and remove out.

(ii) Accelerated the melt flowing

(iii)Return back the unmelt compound to the melting zone.

Bubbler:

A bubbler in a glass furnace is a system used to improve glass quality and furnace efficiency. It works by injecting gas, usually nitrogen or Compressed air, through submerged pipes or porous plugs at the bottom of the furnace. When the gas is released, it creates bubbles that rise through the molten glass. As the bubbles move upward, they stir the glass, promoting better heat distribution and helping to remove impurities and trapped gases. This improves glass clarity and reduces defects. Bubblers also help maintain consistent temperature across the melt, which can extend the furnace's lifespan and improve energy efficiency. They need to be carefully controlled because too much bubbling can cause turbulence, leading to defects or damage to the refractory lining. Main Functions of bubblers:

(i)Bubblers increases the size of smaller bubbles and remove out.

(ii)It accelerates melting process

(iii)It creates a barrier and returns unmelt batch to the melting zone for proper melting.

Fig: Bubbler

Refining Zone

The refining zone of a glass furnace plays a crucial role in ensuring the final product is free from defects. Average temperature of this zone is 1350-1450 Degree Celsius. Glass melt of high temperature passes slowly in this zone. After the raw materials melt in the melting zone, the molten glass moves into the refining zone, where bubbles and impurities are removed. This stage is essential for achieving high-quality glass with the desired clarity and uniformity. Chemical reaction of salt cake or sodium sulphate occurs in this zone and produce Sulphur Dioxide gas that associated with further bubble removing.

$$Na_2SO_4 \longrightarrow Na_2O + SO_2 + O_2$$

Temperature control is critical in this zone. The glass is kept at a high but stable temperature, allowing trapped gases to escape while preventing re-boiling or unwanted reactions. The design of the furnace ensures a smooth flow of molten glass, giving it enough time for refining before it moves to the working end for forming.

In modern glassmaking, refining efficiency is improved using advanced temperature management, special additives, and optimized furnace designs. The goal is always to produce glass that meets strict industry standards while minimizing waste and energy consumption.

Neck Zone

In a float glass furnace, the neck zone is installed for homogenizing the molten glass before it moves to the working end. This area ensures that the glass achieves uniform temperature and composition, which is essential for high-quality production. The two main components of this zone are the deep cooler and the stirrer, both of which contribute to refining and conditioning the molten glass.

Deep Cooler

The deep coolers have a significant impact on both glass homogeneity and the overall thermal efficiency of the furnace. The main functions of deep cooler are cooling glass melts using water supply and also prevent the impurities conveyed by the melts. Their primary functions include: Controlling glass flow by creating a barrier effect, helping in the refinement of the melt. Cooling the surface of the molten glass, which aids in stabilizing temperature variations. Blocking unmolten defect particles to prevent impurities from entering the working end. These coolers are always installed in pairs and are designed for easy manual operation. They consist of rectangular

Fig: Deep Cooler

pipes welded together and mounted on a mobile carriage, allowing for height adjustments and quick insertion or removal. Their simple, ergonomic design ensures fast and easy installation while maintaining efficiency.

Stirrer

The stirrer plays a key role in conditioning the molten glass by ensuring a uniform temperature distribution. As it rotates, it mixes different layers of molten glass, eliminating temperature gradients and improving homogeneity.

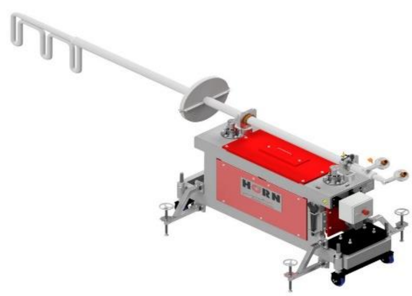


Fig: Stirrer

The stirrer is mounted on a movable wagon, stabilized by four side fixings. It is positioned on the upstream side of the furnace, where it effectively blends the molten glass. Key features of the stirrer include: Placement of sensitive components on the cold side to prevent damage. Easy accessibility for maintenance and adjustments. Adjustable rotation speed and direction for optimal mixing. Variable immersion depth to control the level of homogenization. The entire system operates on a rail mechanism, allowing smooth insertion and removal as needed. Together, the neck cooler and stirrer ensure the glass is properly conditioned before moving further in the process, guaranteeing high-quality float glass production.

Cooling End Zone

The Cooling End zone is an important stage in glass manufacturing, where molten glass is prepared for the forming process. Filtered air from the dilution blower is circulated to this zone for cooling gradually. After leaving the refining zone and neck zone, the glass enters the cooling end zone, where it must reach an optimal forming temperature of approximately 1100°C. This zone typically maintains a temperature of around 1000-1200 Degree Celsius, ensuring the glass remains in a workable state. In float glass production, the working zone plays a key role in conditioning the glass before it moves to the forming section. The glass travels through a canal, gradually cooling to about 950°C as it approaches the forming zone. However, once it reaches the forming section, the temperature rises again, ranging from 950°C to nearly 1100°C. This controlled temperature adjustment ensures the glass achieves the right viscosity for shaping, contributing to the quality and consistency of the final product.

Canal

In a glass furnace, the canal is a critical passage that guides molten glass from the Cooling end zone to the forming section. It serves as a controlled pathway where the glass gradually cools to the right temperature before shaping. The temperature in the canal is carefully regulated to ensure the glass maintains the right viscosity for forming. This zone also maintains the flowing of melt. Canal provides a drain of molten glass flowing with a uniform shape and control melt composition over liquid tin at tin bath. The flowing of melt is controlled by three dampers: Safety Damper, working damper and reserve damper.

As molten glass moves through the canal, it slowly cools from around 1200°C in the working zone to approximately 950°C by the time it reaches the forming section. This controlled cooling is essential for achieving uniform thickness and quality in float glass production. The canal also prevents sudden temperature fluctuations, which could lead to defects in the glass. Its design and temperature regulation play a crucial role in ensuring smooth, consistent flow, ultimately affecting the final product's quality and performance.

Gas Control Room

A gas control room for a glass furnace is where the fuel supply and combustion process are carefully monitored and adjusted to keep the furnace running efficiently. Since glass furnaces rely on high temperatures, the gas control system ensures a steady and precise flow of fuel—usually natural gas or a mix of fuels—into the burners.

Inside the control room, there are pressure regulators, flow meters, and safety valves that help maintain the right balance of gas and air for combustion. Operators constantly monitor these systems using control panels and digital displays to prevent fluctuations that could affect the melting process.

Fuel gas must need to be controlled for the proper working of furnace and melting of the batch materials. Control over fuel gas as well as natural gas can be executed by both manually or solenoid control. Natural gas circulates through the yellow pipe and compressed air circulates through the Sky-Blue pipe. The preliminary pressure of natural gas is 0.2 Mega-Pascal (2kg). The pressure decreases and become 0.1 Mega-Pascal (1kg) using solenoid control. When there is no power supply, gas is controlled manually. The main line of natural gas is separated by 6 lines for supply NG in one regenerator and other 6 line for another regenerator. It produces flame with the contact of compressed air that helps the flame to enlarge. The solenoid valves over the gas pipe are controlled by compressed air. Another Gas control room is for pure oxygen from where oxygen gas is supplied to the oxygen burner to increase fuel efficiency.

Safety is a top priority. Gas leaks or pressure drops can be dangerous, so the room is equipped with detectors and emergency shut-off systems. Proper gas control not only keeps the furnace stable but also improves energy efficiency and reduces emissions. In short, this room is crucial for keeping the glass furnace running smoothly and safely.

Oil Control Room

Oil control room is associated with the flow and proper control on Fuel oil like Diesel or HFO (High Density Fuel Oil). An oil control room for a glass furnace is where the fuel supply is carefully managed to ensure a steady and efficient burning process. Many glass furnaces use heavy fuel oil or diesel as an energy source, and this room is responsible for regulating its flow, pressure, and temperature to maintain optimal combustion. Inside, there are pumps, filters, flow meters, and temperature regulators that ensure the oil is heated to the right viscosity before it reaches the burners. Operators monitor these systems through control panels, making adjustments as needed to keep the furnace running consistently.

Generally, Diesel is mostly used as fuel oil as its density is low, easy to circulate and provide flame. It needs no pre-heating before supply. But the density of HFO is very high and needs to be heated before supply. Superheated steam is used to heat HFO to minimize its density and viscosity and make it increase its fluidity, also flame capacity. An electric heater is also used for heating HFO. There is also two type of control process is used: Manual and solenoid control. The main line of diesel is separated by 12 lines where 6 lines provide oil to one regenerator and other 6 lines circulate air to another regenerator. When the polarity of firing exchanges, the diesel oil return back from the previous regenerator and make a whistle.

Safety is crucial for oil control room. The room is equipped with leak detectors, pressure relief valves, and emergency shut-off systems to prevent hazards like oil spills or pressure surges. Proper oil control not only keeps the furnace stable but also improves efficiency, reduces fuel waste, and ensures a smooth glass production process.

Bricks of Furnace

Different types of bricks are used in a furnace to withstand extreme temperatures, resist corrosion, and provide insulation. The furnace operates continuously at high heat, so the right choice of bricks is essential for durability and efficiency.

Silica Bricks – These are used in the crown (roof) of the furnace because they can handle high temperatures without deforming. They also resist chemical attacks from molten glass. The

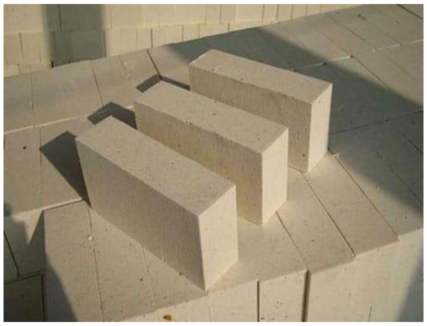


Fig: Silica Brick

percentage of silica in these bricks is 95-99%. They are also used in the sidewall and roof of the cooling end zone.

Alumina Bricks – Found in areas exposed to intense heat and mechanical stress, such as the furnace bottom and sidewalls. Their high alumina content gives them excellent strength and heat resistance. Alpha, Beta Alumina bricks are used in the cooling tank.

Fig: Alumina bricks

Zircon Bricks – Used in parts of the furnace that come in direct contact with molten glass, like the throat and feeder channels. Zircon bricks prevent contamination and erosion, helping maintain glass quality.

Fig: Zircon bricks

Magnesia Bricks – Common in regenerators, where they withstand thermal cycling and resist chemical reactions from furnace gases.

Fig: Magnesia Brick

Insulating Bricks – These lightweight bricks help retain heat inside the furnace, improving energy efficiency. They are often used in less critical areas where direct exposure to molten glass isn't a concern.

Fig: Insulation bricks

Mullite Bricks: They are white in color and use for insulation of the furnace. Mullite bricks are widely used in glass furnaces due to their excellent thermal shock resistance, high-temperature strength, and good corrosion resistance. Made primarily from alumina (Al_2O_3) and silica (SiO_2), they are ideal for areas exposed to high temperatures but with relatively lower glass corrosion risk. In glass furnaces, mullite bricks are commonly used in the superstructure, crown, and regenerator walls, where they help maintain structural integrity under thermal cycling. Their low thermal conductivity improves energy efficiency by reducing heat loss. Additionally, they resist chemical attack from alkali vapors, contributing to furnace longevity and stable glass production.

Fig: Mullite Brick

AZS bricks

AZS (Alumina Zirconia Silica) bricks are crucial refractory materials used in glass furnaces due to their excellent resistance to glass corrosion, high temperatures, and mechanical wear. They are primarily made from fused alumina (Al_2O_3), zirconia (ZrO_2), and silica (SiO_2), offering superior chemical stability and durability. Percentage of Alumina is 50-55%, Zircon 30-40% and silica 10-15% is these bricks. AZS bricks are commonly used in areas exposed to aggressive molten glass, such as the glass contact zone, superstructure, and throat, where they help prevent glass defects caused by refractory erosion. Their low porosity and high density minimize glass infiltration, reducing the risk of contamination. Overall, AZS bricks enhance furnace longevity, maintain glass purity, and ensure efficient high-temperature performance**.**

Fig: AZS bricks

Tank block of furnace are made of Fused cast AZS and high alumina. Port of furnace are made of AZS and Zirconia brick and sintered Zirconia at port side wall. Each type of brick plays a role in keeping the furnace stable, efficient, and long-lasting. The right combination depends on the specific furnace design and the type of glass being produced.

Forming/Tin Bath

Introduction:

Float glass is made by pouring molten glass onto a bed of molten tin, a process that ensures a smooth, uniform sheet. This method, known as the float process, has been the standard in industrial flat glass manufacturing for decades. The tin bath plays a crucial role, as the molten tin supports the glass while it spreads out and cools. To keep the tin in liquid form, a small amount of heat is applied. Sulfur dioxide (SO_2) is introduced when transferring the glass from the tin bath to the annealing stage. It is uses to remove corrosion between the roller and the glass, also provide a coating over dust and remove dust from the glass surface.

Tin is ideal for this process because it has a high specific gravity, remains cohesive, and doesn't mix with molten glass. However, tin oxidizes in the presence of air, forming tin dioxide (SnO_2), also called dross, which can stick to the glass. While indium (In) could be an alternative, tin is preferred because it is non-toxic, making it a safer option for production.

$$Sn + O_2 \longrightarrow SnO$$

$$SnO + H_2 \longrightarrow Sn + H_2O$$

The float glass process starts with raw materials like silica, lime, and soda, combined with cullet (recycled glass), then heated in a furnace to about 1600°C. The furnace delivers molten glass at 950°C, which is then further heated to

1100°C before entering the tin bath. Inside the tin bath, the temperature never exceeds 1000°C. As the glass moves through, it gradually cools from 1100°C to around 600°C by the time it exits. The tin bath chamber measures 42 meters long and 5 meters wide, with 13 bays controlling the heating process. This section is powered by 30 transformers to maintain precise temperature conditions.

Gases play a key role in production, particularly nitrogen (N_2) and hydrogen (H_2), which resist the penetration of oxygen and help to prevent oxidation of both the glass and the tin. A controlled nitrogen-hydrogen atmosphere minimizes tin contamination in the final glass product. Oxygen and nitrogen flow continuously to maintain optimal conditions.

Under the tin bath, three blowers regulate the internal temperature. Typically, two blowers run at the same time while the another one remains on standby. The air circulates through the duct line that is seen in the Rod Floor.

Fig: Tin Bath

Glass Forming in Tin Bath

The tin bath process consists of three main stages:

1. Spreading

Molten glass from the cooling end zone passing through canal falls over liquid tin at Tin Bath section. Canal zone has three dampers to control the flow of melts and its viscosity. At the start forming stage, the glass temperature is around 1050°C, gradually reducing to 950°C by the end. As the molten glass flows onto the surface of the tin, it spreads out to form a continuous ribbon. The bottom of the glass remains in contact with the molten tin while the top is heated, ensuring an exceptionally smooth and distortion-free surface on both sides.

2. Forming

The forming stage begins at 712°C and rises to 740°C. This molten mixture is then carefully poured onto the tin bath from canal, where it spreads evenly to form a flat, high-quality glass sheet. Canal controls Gravity, surface tension and viscosity of the melt glass. Surface tension prevents the spread of molten glass and shows tendency to spread out due to Gravity by which thickness of glass is maintained. Also glass thickness is controlled mechanically using Capillary Top Roller, Changing its speed and angle. When it creates positive angle to the glass melt, it spreads the melt that causes increase in width and decreases of thickness and vice-versa for the negative angle.

3. Cooling:

Once the glass ribbon is formed, it undergoes controlled cooling while floating on the tin bath. This step starts at 630°C and gradually cools to 600°C by the end. The glass is then transferred to annealing, where it continues to cool down slowly in a controlled process to relieve internal stresses and enhance its strength and durability.

Different type of Rollers

Top Roller

Top rollers are crucial machines in a tin bath, working in pairs to precisely control the width and thickness of molten glass. Each top roller has one capillary roller with 180 notches. Their main function is to adjust the glass thickness as it moves through the process. After leaving the furnace, the molten glass passes through the top rollers before reaching the dross box. There, the lift-out roller guides it into the annealing section. The tin bath has a total of 18 top rollers on both sides, all monitored by cameras.

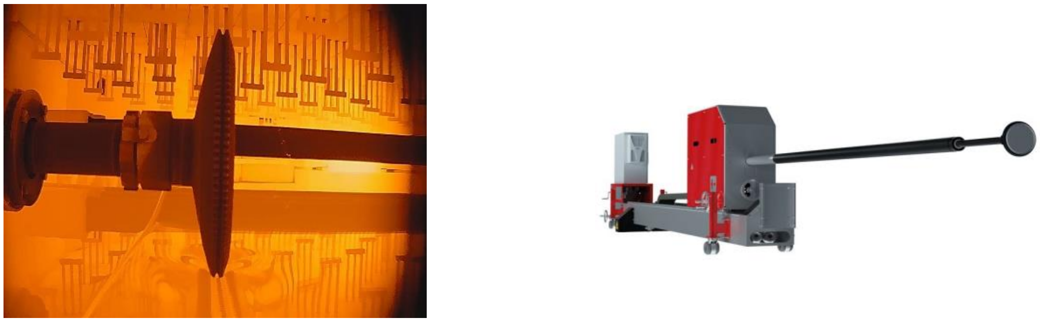


Fig: Top Roller

Typically, the top roller is positioned above the molten glass, exerting controlled pressure to flatten or shape the material as it cools and solidifies. The precise control of the top roller is critical, as it directly impacts the quality and uniformity of the glass product.

Edge Stop Roller

Edge stop roller is also known a as a floating guide in tin bath section. It prevents the swing of glass. The edge stop roller in a tin bath plays a critical role in controlling the width of the molten glass ribbon during the forming process. It is positioned at the edges of the glass sheet, preventing it from spreading too wide while maintaining a consistent width and shape.

As the molten glass flows over the tin surface, the edge stop roller applies controlled pressure to stabilize and guide the ribbon. This helps achieve uniformity in glass thickness and width before it moves further in the production line. Proper functioning of the edge stop roller is essential for maintaining product quality and reducing defects. The edge stop roller is made from durable, heat-resistant materials to withstand the extreme temperatures of molten glass. It's often part of an automated glass forming system, and its precise operation is essential to achieving high-quality, consistent glass products.

Lift Out Roller

Lift out Roller is used to lift the glass slightly and transfer into annealing. Over this roller Sulphur Dioxide (SO_2) is used to remove corrosion between glass and the roller, also create a coating over the roller and resist dust particle. Three lift out roller are used at the end of the forming area. In glass production, the lift-out roller is equally important. After the glass is formed into the desired shape, the lift-out roller helps to lift the container from the forming machine to the annealing lehr or other cooling sections. This is crucial to prevent the glass from breaking or becoming misshapen, ensuring that the final product is durable and perfectly formed.

The lift-out roller is made from heat-resistant and durable materials to withstand the high temperatures of the molten glass. It must be precisely aligned and adjusted regularly to ensure smooth and consistent performance. Proper functioning of the lift-out roller is essential to the efficiency and quality of the glass forming process. Without it, the glass could be mishandled or damaged, leading to defects that affect the final product.

Water Cooler:

In glass manufacturing, a water cooler in the tin bath plays a critical role in maintaining temperature control during the float glass process. The tin bath contains molten tin, where molten glass floats to form a flat, even surface. Precise temperature management is essential to achieve the right glass thickness and quality. There are total 11 water coolers in the tin bath.

Fig: Water Cooler

The water cooler system helps regulate the bath's temperature by circulating cold water through cooling pipes or coils placed strategically in the bath. This prevents overheating, ensures uniform glass formation, and avoids defects like waviness or distortion.

Proper maintenance of the water cooler is vital. Blockages, leaks, or inadequate cooling can lead to inconsistent glass quality or even production downtime. Regular inspections and prompt repairs help maintain efficiency and extend equipment lifespan.

Blowers

In the float glass process, molten glass, heated to over 1000°C, flows continuously from the furnace onto a shallow bath of molten tin. As the glass spreads out and floats on the tin, it gradually cools and forms a smooth, flat surface.

Beneath the tin bath, there are three large cooling fans. Two blowers run continuously, while the other one is kept as a backup. These tin bath cooling fans help regulate the internal temperature, ensuring stable conditions for glass formation.

Dross Box

The dross box serves as the connection point between the tin bath and the annealing lehr, acting as both a passage and a seal. This is where the floating glass is first lifted off the molten tin by three motorized rollers and then transferred to the annealing process.

A key function of the dross box is to maintain an airtight seal for the tin bath. This is achieved with graphite pressing beneath the rollers and protective curtains above the glass. Inside the dross box, the three lift-out rollers—Roller 1, Roller 2, and Roller 3—are responsible for gently raising the glass.

One standout feature of the dross box is its adjustable graphite block pressure and roller height. Instead of being welded, the structure is secured with a clamping system, which is locked in place once the tin bath reaches 620°C. This design accommodates thermal expansion, preventing deformation. It also helps minimize heat loss and ensures a more even heat distribution within the dross box.

Pressure in a Tin Bath

Two types of pressure arise in the tin bath section: Canopy pressure and Tin bath pressure. Always, Canopy pressure remains greater than tin bath pressure. To prevent the penetration of oxygen, the tin bath has a definite pressure. Nitrogen gas is used to provide the gas pressure. When extra pressure is needed to increase the pressure of the canopy space used to maintain higher than the tin bath pressure. If few amounts of oxygen enter into tin bath, it reacts with liquid tin and creates tin oxide, and to prevent this Hydrogen gas is used to react with oxygen and form water.

CVD (Chemical Vapor Deposition process):

The Process CVD includes creates a blur layer over glass and minimizes its reflective properties. Chemical Reaction of Silene or Silicon Di-Hydride (SiH_2) and Ethylene (C_2H_4) deposits Silicon Carbide (SiC) vapor over glass.

$$SiH_2 + C_2H_4 \longrightarrow SiC + H_2$$

The Chemical Vapor Deposition (CVD) process in the tin bath is a crucial step in float glass manufacturing, where thin functional coatings are applied to enhance glass performance. As molten glass floats on a bed of molten tin, reactive gases containing metal precursors are introduced above the glass surface. At high temperatures (around 600–700°C), these gases undergo a chemical reaction, forming a solid thin film that bonds directly to the glass. This process is commonly used to create coatings such as low-emissivity (Low-E) layers for energy efficiency, solar control coatings, and anti-reflective or conductive films. The CVD process ensures durability by making the coating an integral part of the glass surface, providing resistance to scratches and environmental wear. However, maintaining precise control over temperature, gas flow, and deposition rate is critical to achieving uniform thickness and avoiding defects like haze or uneven surfaces. Additionally, the high-heat and reactive environment of the tin bath requires robust equipment to prevent corrosion or clogging. Overall, CVD in the tin bath plays a vital role in producing high-performance glass for the architecture, automotive, and electronics industries.

Heaters and Generators

In the tin bath of the glass forming process, heaters and generators play a crucial role in maintaining precise temperature control.

Heaters are used to keep the molten tin at the right temperature, ensuring the glass remains in a workable state as it floats and spreads into a uniform sheet. They help maintain a stable environment, preventing defects and ensuring consistent glass quality.

Generators provide the electrical power needed for various equipment in the tin bath, including heaters, rollers, and cooling systems. They ensure uninterrupted operation, which is essential for maintaining production efficiency and preventing fluctuations in temperature that could affect glass formation.

Venting system

Venting helps remove volatile tin components from the tin bath, improving overall efficiency. While not mandatory, it plays a key role in preventing defects. As tin vapor cools and turns back into metal in lower-temperature zones, tiny tin droplets can form and contaminate the glass surface. This issue is avoided by controlling the airflow, directing it away from the exit end and toward the venting tubes.

A major advantage of the venting system is its controlled extraction process, which ensures that the delicate pressure balance inside the tin bath remains unaffected.

Protective Gas ($N_2 + H_2$) Room

Gases play a crucial role in the float glass forming process, particularly in the tin bath section, where a controlled atmosphere is essential for maintaining glass quality. The primary gases used are hydrogen (H_2), nitrogen (N_2), and a mixture of both. These two gases come from Nitrogen and Hydrogen plants.

To prevent oxidation, the tin bath chamber is filled with a controlled gas mixture—90% nitrogen and 10% hydrogen. Hydrogen actively reacts with any oxygen present and forms water, preventing it from oxidizing the molten tin. This is essential because tin oxidation can cause defects on the glass surface, affecting its clarity and quality.

Hydrogen acts as a "getter" gas, meaning it helps eliminate any residual oxygen in the chamber, ensuring a pure, oxidation-free environment. This keeps the tin surface clean and allows the glass to form smoothly without imperfections. Nitrogen, on the other hand, is used to maintain a stable atmosphere and assist in the removal of oxides and resists the penetration of oxygen. The controlled nitrogen flow helps sweep away unwanted particles and ensures the glass surface remains flawless.

By carefully managing the gas composition, manufacturers can produce high-quality float glass with a smooth, defect-free surface, which is essential for applications like windows, mirrors, and automotive glass.

Annealing

Introduction

Annealing is a heat treatment process that improves the ductility of glass while reducing its hardness and also removes stress from the glass surface. Essentially, it is a controlled cooling process that gradually lowers the temperature of glass from a high temperature to room temperature.

During annealing, the material is heated above its recrystallization temperature and held there for a specific period before cooling begins. The cooling rate varies depending on the type of metal or glass being treated. If the material undergoes further processing, such as shaping or stamping, additional heat treatments may be needed to maintain the desired properties. By understanding material composition and phase diagrams, heat treatment can help soften metals, improve their workability, and prevent brittleness.An annealing furnace functions by heating the material above its recrystallization temperature and then slowly cooling it. This process allows atoms to move and redistribute, eliminating structural defects and relieving internal stresses. The annealing section measures 90 meters in length and 4.5 meters in width, with a starting temperature of 500°C and an ending temperature of 150°C.

Annealing is necessary to reverse the effects of work hardening, which occurs during processes like bending, cold forming, or drawing. If a material becomes too hard, it can crack or become difficult to work with. By heating it above its recrystallization temperature, annealing restores ductility, making it easier to shape and process. The. The process also helps remove stresses that occur when welds solidify and is commonly used for materials like steel, aluminium, brass, and copper. In metal fabrication, annealing keeps materials workable, ensuring they retain their original properties even after extensive processing. Additionally, certain metals are annealed to improve their electrical conductivity, making the process essential in various industries.

Fig: Annealing zone

Fig: Steel Roller

Stages of Annealing:

Annealing takes place in three stages:

Recovery Stage – The material is heated to relieve internal stresses.

Recrystallization Stage – New grains form as the material is heated above its recrystallization temperature but below its melting point, removing residual stresses.

Grain Growth Stage – Controlled cooling allows new grains to develop, making the material more ductile and easier to work with.

Steel Rollers

Steel rollers play a vital role in the annealing process in glass manufacturing, particularly during the cooling phase. There are 231 steel rollers to carry glass from the annealing to cutting section. Their primary function is to support, guide, and carry the glass products as they pass through the annealing lehr. Here's a simple breakdown of their roles:

1. Support and Stability: Steel rollers provide essential support for the glass as it moves through the lehr, preventing deformation during the cooling process. The rollers ensure that the glass remains in the correct shape and alignment, especially during the temperature fluctuations.

2. Smooth Movement: The rollers allow the glass to move smoothly through the heating and cooling zones of the lehr, which is crucial to prevent any unwanted pressure or stress buildup. This helps maintain the uniformity and quality of the glass.

3. Temperature Control: As the glass moves along the lehr, the steel rollers help in maintaining even temperature distribution by allowing the glass to cool gradually. This is vital because uneven cooling can lead to cracks or warps in the glass.

4. Durability and Strength: Steel is used because of its high strength and resistance to wear, which is essential as the rollers endure constant exposure to heat and weight from the glass products. Steel rollers are durable and can withstand the harsh conditions in the annealing furnace.

Zones of annealing

A-Zone

This zone consists of one blower. The blower passes cool air to the glass for cooling and receives hot air from the zone to remove out. The A-zone is where the glass enters the annealing from the tin bath or forming process. In this zone, the glass is still at a high temperature and is exposed to a controlled heat source to maintain the temperature as the glass moves forward. The primary purpose of the A-zone is to allow the glass to remain at a stable, high temperature to prevent sudden cooling, which could cause stress and imperfections. The glass is typically kept around the annealing temperature, which is just below its softening point, but not so hot that it would deform.

In this zone, the focus is on maintaining temperature consistency. Rapid changes or uneven heat distribution can cause the glass to warp or develop internal stresses. By providing a stable environment, the A-zone ensures that the glass remains flexible enough for the subsequent stages without losing its shape.

B1-Zone

The B1-zone is where the cooling process begins. The zone includes one blower that removes hot air and circulates cool air. As the glass moves through this zone, the temperature gradually starts to drop, but it is still maintained at a level high enough to allow for controlled cooling. The main function of the B1-zone is stress relief—this is where the glass starts to relax after being formed and shaped, and any residual stresses from the forming process are alleviated.

The glass undergoes a controlled cooling process, where the temperature is slowly reduced. The B1-zone is crucial for preventing cracking or breaking, as a rapid drop in temperature would lead to thermal shock. By gradually reducing the temperature, the glass is slowly brought to a uniform state without introducing additional internal stresses.

B2-Zone:

After the B1-zone, the glass enters the B2-zone, where the temperature continues to decrease but at a slightly faster rate. This zone also has a blower and does the same operations as the B1 zone. The zone is designed to further reduce the temperature while ensuring that the cooling process remains uniform across the entire sheet of glass. The glass is kept at a lower but still controlled temperature to allow for additional stress relief and ensure that any remaining thermal stresses are evenly distributed.

In the B2-zone, the cooling rate is adjusted to ensure that the glass does not cool too quickly. The key here is consistency—any variation in temperature within the B2-zone can cause differences in cooling, leading to uneven glass thickness or internal defects like bubbles or streaks. By maintaining a uniform and controlled temperature, this zone ensures the glass continues to cool down evenly without compromising its structure.

C-Zone:

The C-zone is the further cooling zone in the annealing lehr, having one blower, where the glass is cooled to ambient temperature. This is typically the longest zone in the annealing process, as it allows for slow and even cooling to room temperature. The primary role of the C-zone is to stabilize the glass and ensure

that it reaches a state where it is completely solidified and free from any internal stresses.

In the C-zone, the cooling rate is the slowest, ensuring that no thermal shock or sudden temperature changes occur that could lead to cracking or warping. As the glass reaches room temperature, it solidifies and stabilizes, ready for further processing or cutting. The cooling in this zone is so gradual that it allows for the uniform distribution of temperature, ensuring that the glass remains flat and free of defects.

RET-Zone

The RET zone includes three blowers to cool the annealing lehr. It absorbs hot air, mixes with cool air and circulates over the glass surface. In the annealing process of glass forming, the RET zone and F zone are two critical sections of the annealing lehr, each with its specific function in stress relief and uniform cooling of the glass.

The RET zone stands for Relieving Temperature Zone. This zone plays a vital role in ensuring the glass is gradually heated to a point where internal stresses are relieved.

Function:

In this zone, the temperature of the glass is raised slowly to a specific level that allows for the release of any thermal stresses developed during the forming process.

The glass doesn’t undergo significant expansion or contraction in this zone. The goal is to relieve stress and prepare the glass for further heating in the following zones.

Temperature Range:

The temperature in the RET zone typically ranges from around 450°C to 600°C, depending on the type of glass being processed.

F Zone (Final Annealing Zone):

The F zone is also known as the Final Annealing Zone. This is the final stage in the annealing process, where the glass undergoes a controlled cooling phase to ensure uniform temperature and reduce any residual stresses. Force cooling is applied to this zone to minimize the temperature.

Function:

F zone consists of four blowers to circulate air over the glass surface with a definite pressure. In this zone, the glass is held at an optimal temperature for a set amount of time, allowing the molecules of the glass to align in a way that eliminates any remaining internal stresses.

The final annealing process ensures the glass has a uniform thickness and strength across its surface and body.

Temperature Range:

The temperature in the F zone is typically maintained around 550°C to 700°C, but it can vary depending on the specific requirements of the glass.

Together, these zones ensure that the glass is gradually heated and cooled in a way that prevents breakage, cracks, and uneven stress distribution, which is critical for producing high-quality glass products.

Edge Heating and Emergency cutting

Edge Heating and Emergency Cutting are crucial processes during the annealing of glass forming. Let me explain them simply:

Edge Heating:

In glass manufacturing, edge heating is the process of carefully applying heat to the edges of the glass as it moves through the annealing lehr (a controlled heating and cooling furnace). This step is essential for several reasons:

Prevent Cracking: During the cooling phase, glass can become brittle, especially at the edges. By applying heat to the edges, manufacturers can prevent rapid cooling and reduce the risk of cracking or breaking. It also ensures the cutting process efficient.

Maintain Shape: Edge heating ensures that the edges of the glass remain smooth and properly shaped, preventing any unwanted distortion or sharpness.

Uniform Cooling: By controlling the temperature at the edges, edge heating ensures that the entire piece of glass cools uniformly, maintaining its structural integrity.

Emergency Cutting:

Emergency cutting is a critical procedure used when there is an issue with the glass during the annealing process, typically when there is a defect, crack, or if the glass hasn't cooled properly. In such cases, quick action is required to avoid further damage.

Quick Action: If a glass sheet or product has a problem while passing through the annealing lehr, such as a crack that could spread, emergency cutting is done to quickly stop the problem. It may involve cutting the defective part to prevent it from causing further damage to the rest of the glass batch.

Prevent Waste: Emergency cutting helps minimize the loss of material by removing the damaged portion of the glass, which can be recycled or reprocessed.

Quality Control: It ensures that only high-quality glass products proceed to the next stages of production or are sent for packaging.

Hydrogen, Nitrogen and Compressed air Station (Utility)

Hydrogen Plant

In glass manufacturing, hydrogen gas is produced through the electrolysis of water to supply the tin bath, where it serves two critical functions — preventing oxidation of molten tin and cooling the bath. Hydrogen acts like an inert gas, creating a reducing atmosphere that helps maintain the purity of the tin surface. Here's a breakdown of the process and equipment involved:

1. Water Compression

The process begins with normal water passing through a water compressor, which pressurizes the water for further treatment. Proper compression ensures consistent flow and pressure needed for efficient electrolysis.

2. Demineralization (DM) Plant

The compressed water is sent to a Demineralization Plant (DM Plant) to remove mineral salts and impurities such as sodium, calcium, iron, copper, chloride, sulfate, and nitrate ions.

Ion Exchange Process: Water passes through ion exchange resins where impurity ions are replaced by hydrogen (H^+) and hydroxide (OH^-) ions. This ensures the water is pure enough to avoid damage or inefficiency in the electrolysis process.

3. Water Storage Tank

After purification, the demineralized water is stored in a 2-ton capacity water storage tank, ensuring a continuous supply to the electrolysis system.

4. Feed Water Pump

A feed water pump transfers the stored purified water to the Process Frame Machine, maintaining steady water flow and pressure during operation.

5. Process Frame Machine

In the process frame machine Potassium Hydroxide (KOH) is mixed with water in a ratio of 13:5 (13 kg KOH to 5 kg water). KOH acts as an electrolyte, improving the conductivity of water and making it easier to separate hydrogen and oxygen ions.

The KOH concentration range is 400 to 440 g/L, optimized for efficient ion separation.

6. Electrolyzer (Electrolysis Unit)

The Electrolyzer is the heart of the system where the actual production of hydrogen happens. Direct Current (DC) is passed through the electrolyte solution (KOH + water) to break water molecules (H_2O) into hydrogen (H_2) and oxygen (O_2). Rectifier Cabinet: Converts Alternating Current (AC) to Direct Current (DC). DC is used because AC causes energy losses.

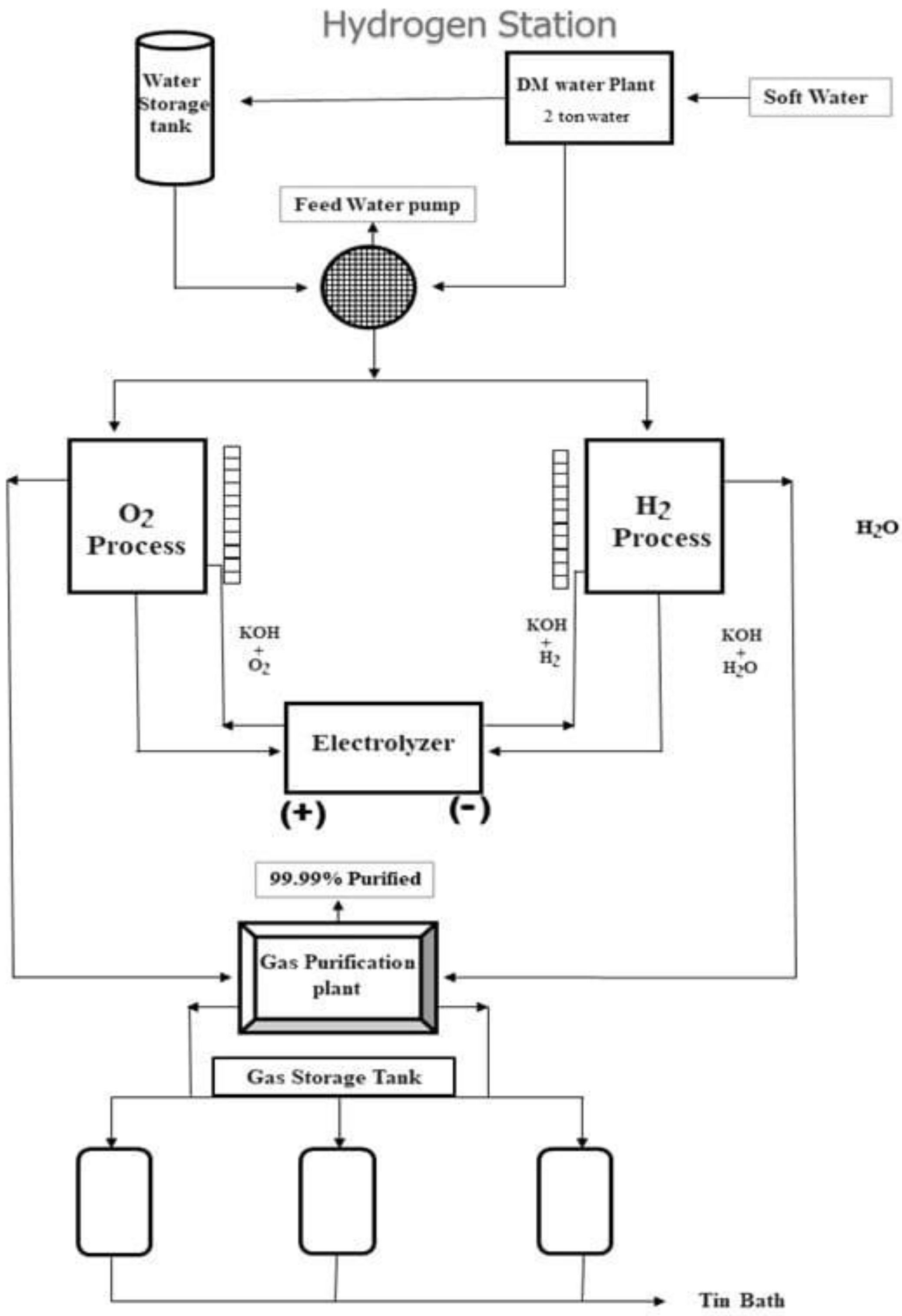


Fig: Hydrogen Station Flowchart

In a hydrogen plant, an electrolyzer splits water (H_2O) into hydrogen (H_2) and oxygen (O_2) using electricity.

Process:

Water flows into the electrolyzer. Electricity passes through two electrodes (anode and cathode) separated by an electrolyte. At the anode (positive electrode), water splits to release oxygen (O_2), electrons, and hydrogen ions (H^+). At the cathode (negative electrode), hydrogen ions combine with electrons to form hydrogen gas (H_2).

Types:

Alkaline Electrolyzers (AEL)

Proton Exchange Membrane (PEM)

Solid Oxide Electrolyzers (SOE)

The produced hydrogen is collected, purified, and stored for various applications.

Operating Parameters:

Voltage: 80V

Current: 3600A

Working Pressure: 1.51 MPa (15.1 bar)

KOH Flow Rate: 4.65 m^3/h

Electrolyzer Blocks:

Two separate blocks handle the gases:

KOH + H_2 Block

KOH + O_2 Block

After separation:

Hydrogen Purity: O_2 content in H_2 is 0.07%

Oxygen Purity: H_2 content in O_2 is 0.01%

7. Gas Separation and Cooling

Once separated, hydrogen and oxygen gases pass through a condenser to cool down the gases and remove residual moisture.

Separator Levels:

H_2 Separator Level: 534 mm

O_2 Separator Level: 533 mm

The gases are then sent to the Gas Purification Plant for further refinement.

8. Gas Purification Plant

The gas purification plant has three key components:

Gas Separator: Further separates trace impurities.

Cooling System: Ensures gas temperature is stable for downstream use.

Driers: Two driers operate in alternating cycles:

One dryer is in the working state, absorbing moisture with molecular sieves.

The other is in the heating state, regenerating the sieves by removing absorbed moisture. This cycle rotates daily for continuous operation.

9. Chiller (Cooling System)

The chiller controls the temperature by circulating cooling water or a heat medium adjusted by the refrigerant cycle. Prevents overheating of the system. Ensures gas quality and consistency.

Applications of Hydrogen in a Tin Bath:

Prevents Oxidation: Hydrogen provides a reducing atmosphere, preventing molten tin from oxidizing.

Cooling Function: Its thermal conductivity helps maintain the right temperature in the tin bath. Efficient hydrogen production ensures glass clarity, surface smoothness, and production stability, making it a vital process in the glass industry.

Hydrogen gas is used in glass forming for:

Protective Atmosphere: Prevents oxidation of metal components in glass furnaces.

Heat Transfer: High thermal conductivity helps achieve uniform temperature distribution.

Reduction Agent: Removes oxygen bubbles and impurities, improving glass clarity.

Cooling Agent: Used in quenching processes for rapid cooling of glass surfaces.

Fuel Source: Combusted with oxygen for high-temperature flames in glass melting.

Compressed Air Station

In this station, natural air is compressed and supplied to operate pneumatic valves and gas or diesel burners. The process involves several key pieces of equipment working together to ensure a continuous and reliable supply of clean, dry air.

Compressors: The station uses five rotary screw-type compressors, categorized by cooling methods — one is air-cooled, and four are water-cooled. Fresh air enters the system through an inlet equipped with a filter to prevent contaminants. Once inside, the air passes to the unloader, which regulates the loading and unloading process. When the air pressure reaches 7 bar, the compressor starts unloading, and when it drops to 6 bar, loading resumes.

The compression process generates heat, so lubricant oil (Mobil RARUS SHCTM 1025) is mixed with the air inside the screw section to cool it down. This oil-air mixture then flows to a separation vessel where the oil is filtered and returned to the screw part, while the compressed air moves to the storage tank. To manage the oil temperature, both air and water cooling systems are used.

The air-cooled compressor has a capacity of 495 ft^3/min with a motor power of 90 kW. Among the four water-cooled compressors, three have a capacity of 17 m^3/min with 90 kW motors, while the largest has a capacity of 26.63 m^3/min with a 180 kW motor.

Storage Tank: The storage tank acts as a buffer to store the compressed air before it moves to the next stage. It helps maintain consistent pressure and ensures a steady supply even during fluctuations in demand.

Driers: To ensure the compressed air is free from moisture, two driers are used. These driers operate alternately to provide continuous drying. When one is drying air, the other is in a heating cycle. Molecular sieve chips inside the driers absorb moisture from the air. Once saturated, the working drier switches to heating mode at a maximum temperature of 150℃ to dry the molecular chips. This cycle ensures uninterrupted drying with each drier resting for one hour before resuming operation. After drying, the compressed air is suitable for operating pneumatic valves and supplying the furnace for gas or diesel burners. This system maintains efficiency by regulating temperature, pressure, and moisture content, ensuring the safe and reliable functioning of industrial processes.

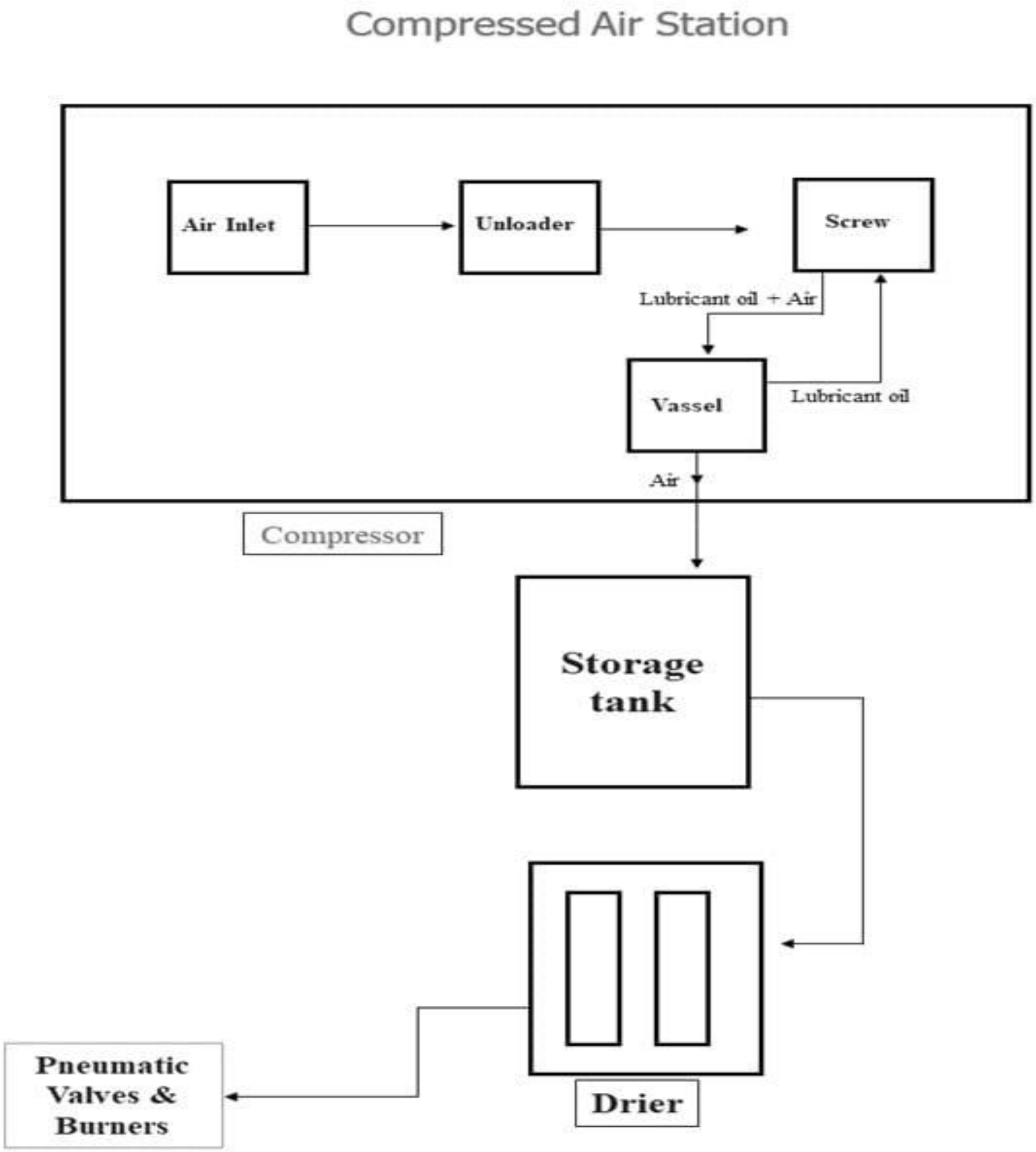


Fig: Compressed Air Station Flowchart

Nitrogen Station

In this station, natural air is processed to produce nitrogen, which is essential for maintaining positive pressure inside the tin bath. Earth's atmosphere consists of approximately 78% nitrogen and 21% oxygen, making air an ideal source for nitrogen extraction. Positive pressure ensures that if any leaks occur, gas will escape outward, preventing outside air from entering the system. This is crucial in the tin bath where nitrogen acts as an inert gas, preventing oxidation or contamination.

Compressor: The system uses a multi-stage reciprocating compressor (piston compressor) to compress natural air. These compressors are ideal for increasing gas pressure by using pistons moving within cylinders. As air enters through the inlet, it undergoes compression, resulting in high pressure (0.7 MPa) and high temperature (140–150°C). This high-pressure air is then passed through various cooling and purification stages.

Secondary Cooler: After compression, the air is extremely hot. The secondary cooler reduces its temperature to 35–40°C while maintaining constant pressure. This cooling stage helps prevent system damage and improves efficiency in the next steps.

Air Receiver Tank: The cooled air is stored temporarily in the air receiver tank, where the temperature remains 35–40°C, and the pressure is still 0.7 MPa. This tank acts as a buffer, ensuring a consistent supply of compressed air for further processing.

Precooler: Before purification, the air passes through a precooler to further lower the temperature to 5–10°C. Lower temperatures improve the efficiency of the subsequent purification process by making moisture and contaminants easier to remove. Pressure remains constant during this stage.

Purifier: The purifier removes unwanted substances from the air, excluding oxygen (O_2) and nitrogen (N_2). It contains molecular chips made of calcium carbonate ($CaCO_3$) that absorb moisture and other impurities. There are two purifier units that operate alternately — one works for 8 hours while the other rests for 8 hours in a process called regeneration. During regeneration, oxygen is used to help remove moisture from the saturated molecular chips.

Cool Box: The cool box is a critical component where the final air separation occurs. It is a sealed vessel with insulation to prevent contamination by water, snow, or dust. Inside, two heat exchangers and two turbo expanders work to drastically lower the temperature to -178 to -180°C while reducing pressure to 0.180–0.192 MPa. As a result of this temperature and pressure drop, air separates based on density — oxygen moves downward, and nitrogen rises upward.

Heat Exchangers: Transfer heat between different mediums, helping achieve the required low temperatures.

Turbo Expanders: Reduce air pressure, which lowers enthalpy and temperature while increasing volume.

At this point, gaseous nitrogen is extracted at a temperature of about 16.7°C and directed to the tin bath. Simultaneously, liquid nitrogen is collected at a rate of 40 L/h and stored in a dedicated

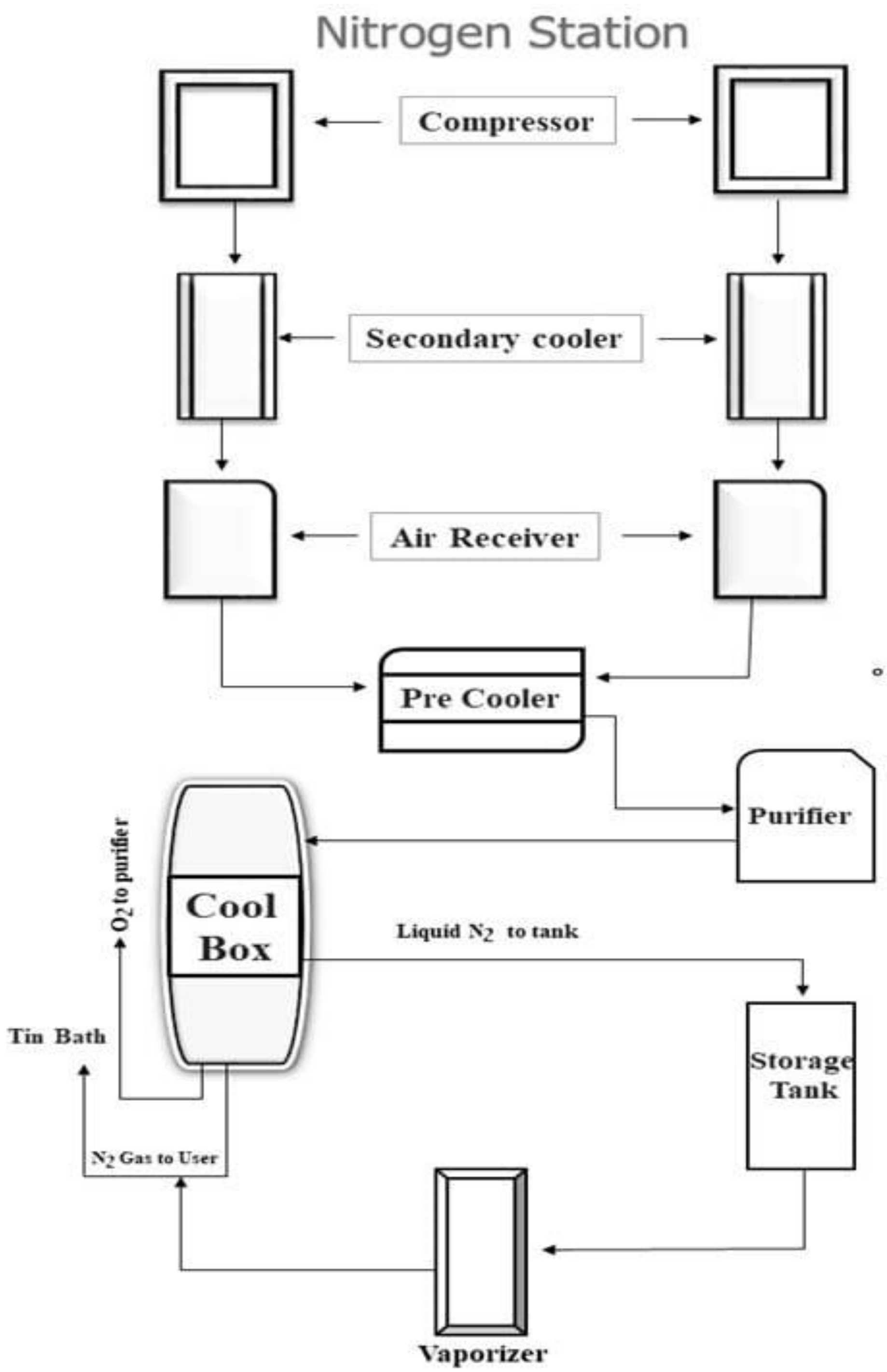


Fig: Nitrogen Station Flowchart

tank. Some oxygen is released into the environment, while a portion is recycled back to the purifier for regeneration.

Cool Box Capacity:

Air capacity: 2300 Nm^3/h

Weight: 19740 kg

Nitrogen output: 1000 Nm^3/h

Liquid nitrogen output: 40 L/h

Nitrogen purity: ≤ 3 ppm (O_2)

Liquid Nitrogen Storage Tank:

Liquid nitrogen is stored in a 20 m^3 tank to ensure a steady supply when needed. Proper insulation keeps the liquid nitrogen stable until it is ready for use.

Vaporizer: The vaporizer converts liquid nitrogen into nitrogen gas, which is also supplied to the tin bath to maintain positive pressure. This dual supply (both gas and liquid nitrogen) ensures continuous operation, preventing any external air from entering the system.

This entire setup ensures a reliable, high-purity nitrogen supply for maintaining ideal conditions in the tin bath.

Cutting And Finishing

Introduction:

The cutting and finishing process in the glass industry involves several precise and automated steps to ensure high-quality output. It begins with longitudinal and cross-scoring machines that create accurate cuts according to specific dimensions, with servo motors and PLC systems ensuring precision. Cross snapping devices and hydraulic roll-edge cutters separate glass sections cleanly, while edge trimming bridges remove excess material. Defective glass is identified by microdefect sensors and diverted through the mainline drop-down system for recycling as cullet. Once the glass is properly shaped, powder spray machines rapidly cool it to prevent stickiness, while air blowers remove dust and moisture for a clear, smooth finish. Glass receiver robots, logo printers, and horizontal striker machines streamline handling, branding, and stacking processes, reducing labour and improving efficiency. Finally, the glass is stored on air-floating tables, where air circulation prevents surface damage, ensuring the product is ready for packaging and distribution.

Glass Cutting & Processing Equipment

Chips Blower: It is a dust remover device that provides air flow to clear dust and unnecessary particles. It is installed at the front part of the cutting zone.

Liquid Spray Machine: It is a spraying arrangement of a liquid over the glass surface consisting of 12 nozzles. Anti-forming chemicals with HL-1 and water are used for spraying to remove bacteria or any other micro-organism.

Measurement Wheel: This wheel is for measuring glass before cutting. It rotates and takes measurement.

Cross Scoring Machine: This machine adjusts the cutter's lifting and lowering positions using signals from a glass scoring machine. It can cut glass sections at angles, typically around 10°, for precise cross-cutting. A motor controls the line speed, working alongside a hydraulic system to maintain a straight length on the rolling line.

Longitudinal Scoring Machine: Equipped with a screw driven by a servo motor and eight cutting tools on each side of its bridge, this machine makes precise longitudinal cuts. Integrated with a PLC system, it applies significant pressure to cut the glass. While one side cuts, the other side tracks based on control signals, ensuring continuous and accurate operation.

Fig: Glass Cutting Device

Cross Snapping Machine: This device uses a ϕ150 rubber roller for snapping glass, with a maximum stroke of 50 mm. It is powered by an air cylinder. For thin glass production, the main snapping roller can be adjusted slightly higher than the roller table surface to ensure delicate handling.

Cutter: Utilizing air pressure and an oil line, this tool applies gentle force to create smooth, precise cuts. A small cloth lightly soaked in oil helps minimize friction, enhancing the cutting process.

Stress-Strain Machine: This device measures glass temperature from the tin bath stage, sending data for 30–60 minutes. It identifies optimal cutting points and transmits signals to the controller based on time initialization.

Encoder: The encoder continuously monitors and records line speed, sending real-time data to the inspector. It ensures the tin bath and cold end maintain consistent speeds and provides step-by-step cutting and quality information.

Roll-edge Cutting Device: This device uses hydraulic pressure on both edges of the glass to separate the excess from the main portion. The separated pieces are collected later and recycled as cullet.

Edge Trimming Bridge: Located on both sides of the production line, this system handles the separated glass pieces from the rolledge device. Rollers guide the glass through the bridge, where the extra portions fall off, leaving finely trimmed glass ready for production.

Mainline Drop Down: Defective or unqualified glass detected by micro defect sensors is diverted to a drop-down line. The roller height adjusts automatically, causing the faulty glass to fall and break into pieces no larger than 50×50 mm, which are later reused as cullet.

Powder Spray Machine: Used in industrial settings, this machine rapidly lowers the glass temperature to a stable minimum, preventing stickiness. This cooling process makes the glass easier to handle and package.

Glow of Device: An air blower cleans the incoming glass by removing dust, oil, moisture, and other contaminants. This ensures the glass remains transparent and smooth, preventing dark spots or blemishes.

Glass Receiver Robot: Designed for high-volume production, these robots handle glass thicknesses of 2.5–6 mm, especially when manpower is limited. They use compressed air to attach and transport glass without scratches, optimizing efficiency.

Logo Printer Machine: Modern glass production facilities use logo printers to brand products instantly. These printed tags last longer than traditional stickers, enhancing brand visibility while saving time and reducing labour costs.

Horizontal Striker Machine: This fully automated, sensor-equipped machine gently handles incoming glass using air suction. It stacks freshly produced glass, reducing the need for manual labour and minimizing the risk of accidents, ultimately saving time and production costs.

Air Floating Table: This table stores stacked glass plates using air circulation to prevent them from sticking. A vacuum device vertically grips the glass, with angle-turning devices, distribution machinery, and glass stacking mechanisms ensuring efficient alignment and handling.

Quality Control

Quality control involves carefully checking glass products at every stage to ensure they meet standards. The process includes:

Raw Material Inspection: Sand, soda ash, limestone, and other raw materials are checked for purity and composition to avoid defects like bubbles or discoloration.

In-Process Inspection: During production, glass is monitored for temperature consistency, thickness, and uniformity. Real-time adjustments are made to prevent warping or uneven surfaces.

Visual Inspection: Trained inspectors or automated systems look for visible defects such as bubbles, cracks, scratches, chips, and surface distortions.

Dimensional Check: Thickness, diameter, and other dimensions are measured to ensure specifications are met.

Stress Testing: Glass is tested for strength, thermal resistance, and impact resistance. Tempered glass undergoes fracture pattern testing.

Optical Testing: Light transmission, clarity, and color consistency are measured for products like automotive or architectural glass.

Defect Classification:

Glass manufacturing often runs into defects that affect both appearance and strength. Some common issues include:

Bubble Defects: These are tiny air pockets trapped in the glass during production. They can be small and harmless or large enough to weaken the structure. Bubbles often form when gases from raw materials or melting processes fail to escape.

Stone Defects: Stones are solid inclusions caused by unmelted raw materials, refractory particles, or contaminants. They create rough spots and can compromise glass strength or cause breakage under stress.

Color-line Defects: These show up as streaks or lines of different colors due to uneven mixing or impurities. They're usually cosmetic but can signal deeper processing issues.

Cold Glass Defects: Cold glass happens when molten glass doesn't fuse properly, often due to temperature drops or poor flow. It results in weak, brittle areas that can easily crack or break.

Pin Hole Defects: These are tiny surface holes that appear when gases escape from the glass too late or due to surface contamination. While often minor, they can affect coatings and overall finish.

Point Defects: These are tiny imperfections at the atomic level, such as vacancies (missing atoms) or foreign atoms disrupting the glass structure. They're usually invisible to the naked eye but can weaken the glass over time, affecting clarity and mechanical strength.

Cracks: Cracks are more obvious and can form due to mechanical stress, thermal shock, or impact. Once a crack starts, it tends to spread, making the glass fragile. Even microscopic cracks can grow under pressure, eventually leading to complete failure.

All defects are warning signs that something went wrong — whether in cooling, handling, or environmental exposure — and managing them is key to producing strong, reliable glass.

Each defect tells a story about what went wrong — from temperature fluctuations to raw material quality — and pinpointing the cause helps maintain glass integrity.

Working of the ISRA machine

The ISRA (Integrated System for Reflective Analysis) machine is a high-tech tool used in glass manufacturing to check quality in real-time. It consists of 6 cameras that inspect glass defects. It uses advanced cameras and sensors to inspect the glass surface as it moves along the production line.

Fig: ISRA VISION Machine

Working

High-Resolution Cameras: The machine captures detailed images of the glass surface.

Lighting Systems: Specialized lighting highlights defects like bubbles, scratches, cracks, and surface distortions.

Software Analysis: The system processes the images instantly, identifying and classifying defects by size, type, and location.

Data Feedback: It provides real-time feedback, helping operators make adjustments quickly.

The ISRA machine is essential because it catches defects early, reducing waste and improving the overall quality of glass products.

. Documentation & Feedback: Records are maintained for traceability, and feedback loops help improve future batches.

The goal is to ensure every piece of glass is safe, functional, and aesthetically acceptable.

In glass quality control, several specialized tests ensure the product meets required standards:

Zebra Angle Test: This test uses striped (zebra) patterns reflected on the glass surface to check for distortions. Any bending or warping in the glass makes the stripes appear wavy or misaligned, indicating surface irregularities. This test allow angle between 50 – 80 Degree.

Fig: Zebra Angle Testing

Outline Detector: This system scans the outer shape of the glass to ensure dimensions and edges match specifications. It's crucial for automotive or architectural glass where precise fitting is required.

Edge Light Detector: This test focuses on the edges, using light to detect chips, cracks, or other defects. Since edges are more prone to damage, this helps maintain glass strength and safety.

Curvature Testing: Curvature tests ensure the glass bends or curves to the correct specifications. It’s essential for windshields and other curved glass products, where even slight deviations can affect performance or aesthetics. Each method targets specific defects, working together to ensure high-quality, reliable glass.

Mirror Plant

A mirror is a reflective object that forms images by bouncing light waves off its surface. Modern mirrors commonly use a thin coating of silver or aluminum applied to smooth float glass, chosen for its hardness and clarity. This makes mirrors essential in everyday life, from personal grooming to scientific equipment.

Types of Mirrors:

Back-Silvered Mirror: Silver coating applied on the back side of the glass.

Front-Silvered Mirror: Reflective coating on the front for precise reflection (used in telescopes).

Flexible Mirror: Made from flexible materials for adjustable reflections.

Nonlinear Optical Mirrors: Used for advanced optical applications like lasers.

Glass Specifications:

In mirror plants, glass thickness is selected based on requirements, commonly: 3 mm, 3.5 mm, 4 mm, 4.5 mm, 5 mm

Standard size: 72 x 84 ft^2

Distilled water is used instead of regular water to prevent contamination during processing.

The process of Mirror Manufacturing includes Aluminum Coating. In this process, silver coating is replaced by aluminum coating, commonly used for cost efficiency and durability. The overall steps remain similar but with key changes in the sensitizing and coating stages.

Fig: Mirror plant Coating

Process

Washing Section: High-quality float glass is selected and thoroughly washed with liquid polishing powder (Calcium Carbonate, $CaCO_3$) and distilled water. This removes dust, oil, and other contaminants, ensuring a clean surface.

Sensitizer Section: The glass is treated with Hydrochloric Acid (HCl) or other sensitizing chemicals to enhance surface adhesion. Unlike the silvering process, this step prepares the glass specifically for aluminum deposition.

Aluminum Coating Section: Instead of silver nitrate, vacuum deposition or sputtering techniques are used to coat the glass with a thin, uniform layer of aluminum.

Vacuum Deposition: Aluminum is vaporized in a vacuum chamber and deposits on the glass surface.

Sputtering: Aluminum atoms are ejected from a solid target using gas plasma and deposited on the glass. This creates a highly reflective layer with excellent durability.

Plasma state: Plasma state is needed in aluminum coating over glass because it enhances the deposition process by improving adhesion, uniformity, and surface quality. In plasma-assisted physical vapour deposition (PVD) or plasma sputtering, aluminium atoms are ionized into plasma under high energy, which offers several advantages:

Better Adhesion: Plasma creates a highly energetic environment where aluminium ions bond more strongly with the glass surface.

Uniform Coating: Ionized aluminum atoms are evenly distributed, ensuring a smooth, defect-free reflective layer.

Surface Activation: Plasma cleans and activates the glass surface by removing impurities and promoting better metal bonding.

Lower Processing Temperature: Plasma enables efficient coating at relatively lower temperatures compared to traditional vacuum evaporation.

Improved Durability: The resulting aluminium layer is more resistant to oxidation, corrosion, and mechanical stress. Plasma-assisted coating ensures high-quality mirrors with superior reflectivity and longevity.

Copper Sulphate & Iron Spray Section (Optional): This step is less common with aluminium mirrors. If used, a copper sulphate ($CuSO_4$) solution may be sprayed to enhance adhesion and corrosion resistance.

Paint Section: The aluminium-coated glass is sprayed with protective paint (often liquid aluminium or other durable paints) to shield the reflective layer from oxidation and scratches. This also improves longevity.

Heating Section: The glass is heated gradually in three stages to cure the paint and stabilize the coating:

Heater 1: 50°–60°C

Heater 2: 70°–80°C

Heater 3: 100°–120°C

Gradual heating prevents cracking or distortion. Heating and drying are crucial processes in a mirror plant to ensure the quality, durability, and performance of the final product. Removing moisture from the glass surface before aluminium coating prevents oxidation, poor adhesion, and coating defects. Warm surfaces also improve the bonding of sensitizing agents and metallic coatings, ensuring uniform and consistent aluminium deposition. After coating, protective paints or lacquers require heat curing to achieve hardness, durability, and resistance to corrosion. Additionally, drying helps avoid defects like bubbles, peeling, or blistering in the metal or protective layers, reducing the risk of mirror deformation or haze formation. Overall, proper heating and drying are essential for achieving high reflectivity, strong adhesion, and long-lasting mirror performance.

Roller System:

Glass is transported through each section using rollers:

Rubber Rollers: Prevent scratches.

Foam Rollers: Absorb vibrations.

Iron Rollers: Control final movement.

8. Recovery Section (Not Applicable): Unlike silver coating, aluminium coating doesn't require recovery since no expensive materials are lost during the process.

Final Quality Checks:

The finished mirrors undergo quality tests, including:

Surface Inspection for scratches or bubbles. Edge Light Detection for cracks or chips. Reflectivity Tests to ensure consistent performance. Using aluminium instead of silver makes the process more cost-effective and environmentally friendly. It is ideal for everyday mirrors, automotive applications, and large-scale industrial use.

Final quality checking in a mirror plant ensures the mirrors meet industry standards before packaging. Key checks include:

1. Visual Inspection:

Examine the surface for scratches, bubbles, stains, or cracks. Checks for uniformity in the aluminium coating and absence of defects.

2. Reflectivity Test:

Measures the reflectance percentage using reflectometers.Ensures the mirror reflects light as per the required specifications.

3. Adhesion Test:

Uses tape tests or scratch tests to check if the aluminium and protective coatings adhere properly to the glass surface.

4. Durability Test:

Tests resistance to corrosion (salt spray test) and humidity (humidity chamber test). Simulates environmental conditions to ensure long-term performance.

5. Dimensional Accuracy:

Checks thickness, flatness, and size to meet design specifications. Verifies proper edge polishing and grinding.

6. Impact and Load Test:

Ensures mirrors can withstand mechanical shocks and loads without breaking.

Only mirrors that pass all these checks are approved for packaging and distribution.