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White Paper: Glass Industry

Technology Cluster Manager

Technology Centre System Program (TCSP)

Office of DC MSME, Ministry of MSME

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KPMG

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Introduction

Glass is an inorganic transparent product made from silica sand, limestone, soda ash and sodium carbonate. It differs in color, density and quality based on further chemical composition. Its properties of transparency, scattering, absorption and thermal response allows multiple applications.

Glass is a global product with utility in small, medium and hi-tech applications ranging from household mirrors, solar panels, optical fibre to radiation shielding glasses in nuclear facilities. It is perhaps most widely known for its extensive use in glass windows and bottles. It is increasingly being used in construction applications. Tempered glass, in particular, is being employed in roofing applications as well as in manufacturing of glass windows. In developing countries, tempered glass is replacing standard glass in roofing applications on account of its high strength properties. Nowadays, even waste glass in the powder form is gaining usage as part replacement of cement in concrete, a trend set to gain momentum over the coming years.

The world glass industry generates a revenue of USD 75 billion and is still evolving in terms of performance (structure stability in terms of chemical, physical and thermal effects), energy usage, emissions, furnace design and environmental friendly technology. One of the main reasons for the growth of glass industry is that it provides a very attractive packaging alternative. In Europe, the world's largest producer of container glass (bottles, jars, etc.), glass stands for 34% of total packaging market for beverages and has an annual growth rate of 4.2%[1]. More than 90 per cent of glass industry products are sold to other industries. Glass manufacturing is significantly dependent on the building construction sector, car manufacturing and the food and beverage industry. However, there are also smaller volume sectors that produce high-value technical or consumer products.

Different glass products require different furnace designs ranging from recuperative, regenerative to oxy-fuel vis-à-vis the combustion system used. Furnaces in turn uses different types of refractories that range from acidic, alkaline to inert type based on oxide species contained. Refractories are further connected to diverse parameters as raw material selection, batch moisture and/or other furnace parameters that need research, development and improvements.

Global Glass Industry

Consumption of glass is highest in countries such as Europe, China and North America, that together account for almost 74 per cent of global demand for glass[2]. Europe is the most mature glass market and has the highest proportion of value added products. The major glass producing countries in the world are Germany, USA, UK, China and Japan while the major importing countries are USA, Germany, Japan, France, Italy and Australia.

Rising demand from wide applications in residential and commercial infrastructure projects, increasing demand for glass substrate from automotive & transportation sector, growth in electronics and semiconductor industry, infrastructure development in emerging economies, have propelled the demand for glass over last few decades.

The most common products manufactured in the global glass industry are flat glass, glass containers, and fiberglass and specialty products such as lenses, optic fibres, mirrors, and glassware and TV

[1] Sectoral Manual-Glass Sector, TERI
[2] Sectoral Manual-Glass Sector, TERI

tubes. Lower quality float and sheet glass production is gradually being replaced by high quality float glass across the globe. The top 5 global companies account for production of almost 60-70% of the total high quality float glass in the world. These companies are NSG/Pilkington, Saint-Gobain, Asahi and Guardian. Asahi Glass is the world's largest glass company[3]. Asia Pacific is expected to remain the largest float glass market due to increase in urbanization, strong housing demand and increasing investment by glass manufacturers in this region

Indian Glass Market Overview

The glass industry in India has made a steady progress since independence and has matured a lot over last few decades. The glass making methodologies prevalent in the country ranges from traditional mouth blown, basic hand-made practices to modern electric techniques of glass melting/making. This reflects the diversity and expanse in the sector with a varied range of entrepreneurial establishments including Micro, Small, Medium and Large enterprises in the sector. The growth in glass sector has been primarily driven by India's booming automotive and construction sector. As per ASSOCHAM report, glass industry was estimated at around USD 4.9 bn in 2015 with the share of organized market standing at 55%.

Exports of glass & glassware in India decreased to 100.54 USD million in 2016 from 385.36 USD Million in 2015. Exports of glass & glassware in India averaged 294.37 USD Million from 1996 until 2016, reaching an all-time high of 701.82 USD million in 2014 and a record low of 53.22 USD million in 1998.[4]Majority of the items that are exported from Indian market are bottles and jars, glass fibres, glass beads, float glass and sheets, electrical fittings, etc. Lately the growth has been sluggish in the glass sheet and glass fibre whereas the growth in the glassware sector has been on an upscale.[5]

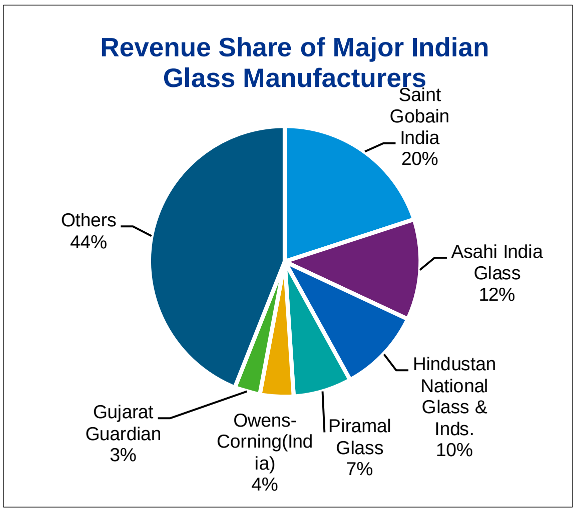


Figure 1: Revenue share of leading glass manufacturer in India

The glass industry is mostly confined to Uttar Pradesh, Maharashtra, West Bengal, Bihar, Jharkhand and Punjab. Ceramic industries in Uttar Pradesh mainly produce sheet glass, hollow and pressed wares (bulbs, chimneys, reflectors and motor headlights), while Bengal and Maharashtra are famous for glass tubes, test- tubes, beakers and flat glass. Punjab predominates in the production of hollowware's and scientific and precision goods.

The most common types of glass are made primarily with soda ash and silica, as well as other additives. Indian is one of the world's fastest growing soda ash markets, driven by India's high economic growth rate. The per capita consumption of container glass in India is 1.8 kg[6] as compared to 17 kg consumption in the developed countries. This reflects a huge potential to be capitalized upon in the Indian glass market.

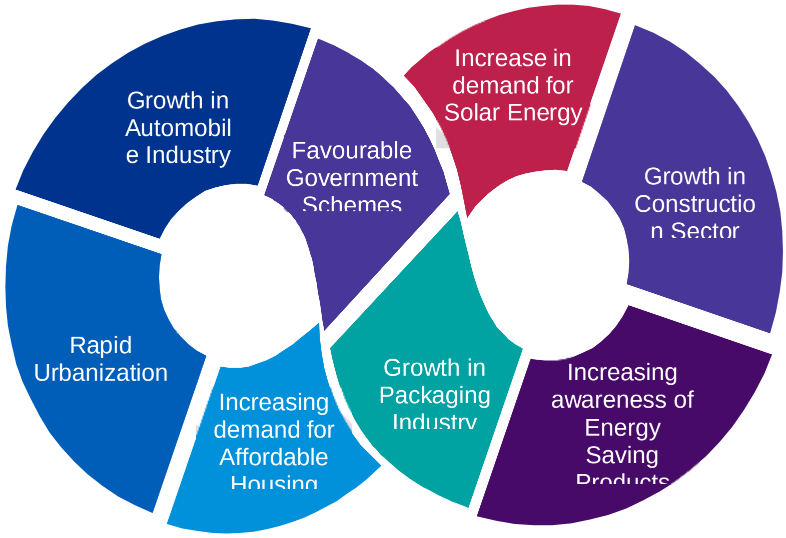
[3] CARE Ratings – Glass Industry, June 2018
[4] Exports of Glassware – Trading Economics
[5] CARE Ratings
[6] CARE Ratings – Glass Industry, June 2018

The industry is characterized by the increasing use of processed and high-performance glass in the automotive and architectural sectors because the Indian customer has become more aware about the importance of glass in effectively addressing the concerns of safety and energy efficiency.

Glass Industry – Key Growth Drivers

With increasing urbanization and rise in disposable income, Indian glass sector is poised to grow over coming years. The growth is steered by automobile Industry, construction sector government schemes, increase in demand for solar energy, packaging industry and increasing awareness about energy saving products.

Government schemes and initiatives are driving the level of development, construction, infrastructure, etc. which will in turn lead to demand for glass. Also, greater use of solar energy is being supported by growing environmental awareness. This will provide an impetus to demand for glass used in solar energy glass applications, and therefore demand for glass processing machines serving the solar energy segment, is expected to offer significant growth potential for glass industry. This is expected to trigger the demand of the glass industry.



Product Categorization in Glass Industry

The Glass industry can be categorized into following glass producing industries:

- Bangles – Multi pot furnaces, Day Tanks
- Artefacts – Pot furnaces, Day Tanks
- Non-Standard bottles – Day Tanks
- Fibre glasses – Oxy fired furnaces with electric Boost
- Container Glass High speed pressed / blown ware – End Fired Furnaces
- Rolled Glass – End Fired Furnaces
- Sheet Glass - End Fired Furnaces
- Float Glass - Cross Fired Furnaces
- Solar Photovoltaic Glass – End / Cross Fired Furnaces
- Photochromic Glasses - Oxy fired furnaces with electric Boost
- Marbles – Recuperative furnaces

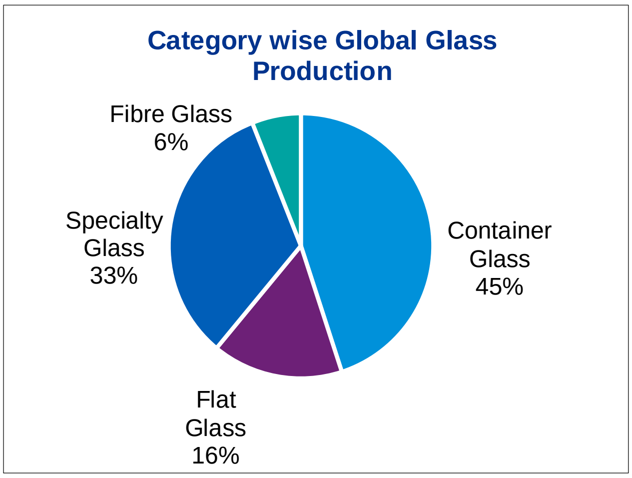


Figure 2: Category wise glass production

Container Glass

This is one of the largest segments in the glass sector. The container glass industry find its applications in industries such as food & beverages, pharmaceuticals and cosmetics industries. It is majorly used in packaging of products for these sectors. Also, growing consumer awareness towards health and hygiene is spurring the growth of container glass industry.

Flat Glass

The first float glass plant started in India in the year 1992. Since then the Industry has grown at a fast pace – both in the upstream and the downstream segments. The global flat glass market size is expected to reach USD 124 billion by 2022[7], posting a CAGR of 7.1% during the forecast period. Robust growth of the building and construction sector in developing countries is expected to be a key factor propelling the market.

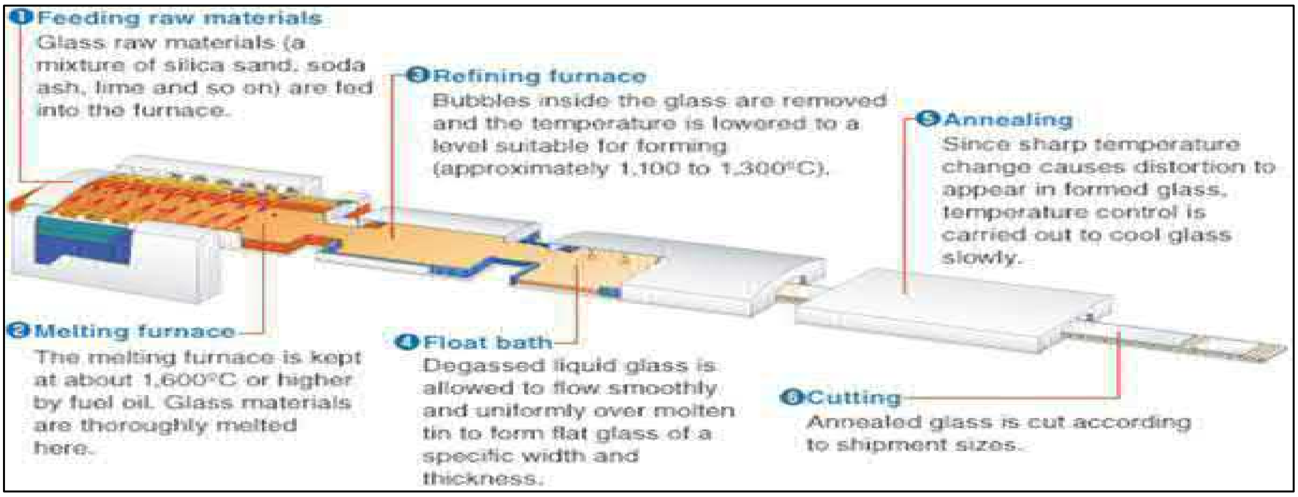


Figure 3: Flat Glass Manufacturing Process

Flat glass segment comprises of sheet plate float glass, rolled glass, cast glass, which are mostly used in architectural and automotive applications. Flat glass, also known as float glass, plays an important role in today‘s construction and vehicles manufacturing industries. Architectural glass accounts for about 80% of total flat glass demand[8], with the rest used in the automobile industry and for other assorted uses.

With the development of the float glass process and thin film coating technology, flat glass has remained the transparent material of choice for automotive and construction applications. It is also used in solar and specialty segments.

There are two types of specialized glass under the umbrella of Flat glass:

- Patterned Glass – Typically translucent and has a pattern on at least one side of the glass. Often used in private office doors, bathroom doors and windows to create privacy in spaces where transmitted light is also desirable.
- Tinted Glass – Commonly found in red, amber, blue, green and black colour.

[7] Glass Market Size – Grand View Research
[8] Summary of worldwide glass trends – GDP 2017

Specialty Glass

Specialty glass is mainly used for technical applications such as optics, electronics, lighting, engineering, ophthalmic lenses, etc. It is used in enhancing privacy, cooling purposes, etc. Borosilicate glasses are also included in this category.

Fibre Glass

Fibre glass consists of thin filaments of glass fibre that are used primarily as reinforcement material in polymer products. The resultant composite is called Fibre Reinforced Polymer (FRP) or Glass Reinforced Plastic (GRP), commonly referred to as fibre glass.

The products in this category also include fiberglass (glass wool) insulation for buildings, roofing and panels. Fibre glass are used in aircraft, boats, automobiles, bath tubs, swimming pools, septic tanks, water tanks, roofing, pipes, etc.

Glass Manufacturing Process

Glass manufacturing is a high-temperature, energy-intensive process that produces greenhouse gases (GHGs) as by-products (Sulphur dioxide, carbon dioxide and nitrogen oxides). The production of 1 kg of glass in a gas-fired furnace generates around 0.6 kg CO2, out of which 0.45 kg comes from fuel combustion and 0.15 kg from dissociation of carbonate raw material ($CaCO_3$ and dolomite) used in the batch. This raises environmental concerns in the sector.

The manufacturing process of glass consists of five major operations: (1) Batch Preparation (2) Melting, (3) Fabrication, (4) Annealing, (5) Finishing. Each operation is being discussed briefly as follows:

Batch Preparation

The cullet (broken glass - either scrap from the manufacturing process or from recycling centres), raw materials (soda ash, silica sand, calcium carbonate, etc.) and decolorizer are finely powdered in grinding machines. These materials are accurately weighed in correct proportions before they are mixed together. The mixing of these materials is carried out in mixing machines until a uniform mixture is obtained. Such a uniform mixture is known as the batch or frit and it is taken for further process of melting in a furnace.

Melting

The ingredients called batch materials (silica sand, soda ash, calcium carbonate, cullet, etc.) are mixed in the appropriate proportion and heated to fusion in a furnace. There are many designs of glass furnace available in the market for melting purpose. The two most commonly used furnaces are pot furnace and tank furnace. Other types of furnaces are regenerative furnaces (cross-fired, end fired), recuperative melters, oxygen-fired unit melters, etc.

Melting in Pot Furnace

These are structures built of refractory materials in which there is no contact between the furnace and the glass. Glass is melted in several pots made of refractory materials which are resistant to glass attack at high temperatures. The pots are charged with a batch, which is melted over a number of hours. The total time required for melting is about 16-18 hours. During routine melting operation, each pot is charged consecutively three times after completion of melting of the previous charge material so as ensure that it holds glass to its maximum holding capacity.

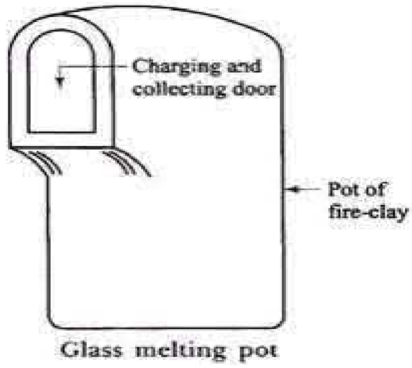


Figure 4: Pot Furnace Schematic Diagram

Figure 5: Pot Furnace - Sample Photograph

Pot furnaces are used where the glass is formed by hand and mouth blowing. It is majorly used by bangle making units. The quality and colour of melt glass is dependent on raw material composition and colouring additives in a charge batch.

Melting in Tank Furnace

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

During the melting lot of frothing is caused owing to the evolution of the gases like CO_2, SO_2, O_2, etc. When the frothing subsides, the temperature is raised and the molten glass is allowed to settle, called refining. Its objective is to form a homogeneous mass free from gas bubbles and bits of undissolved material or batch stones.

Tank furnace is a continuous process and usually employed for the production of large quantities of only one variety of glass at a time. These furnaces are employed for production of:

- Container glass
- Flat glass
- Tableware glass
- Fibre and glass wool
- Most speciality glass

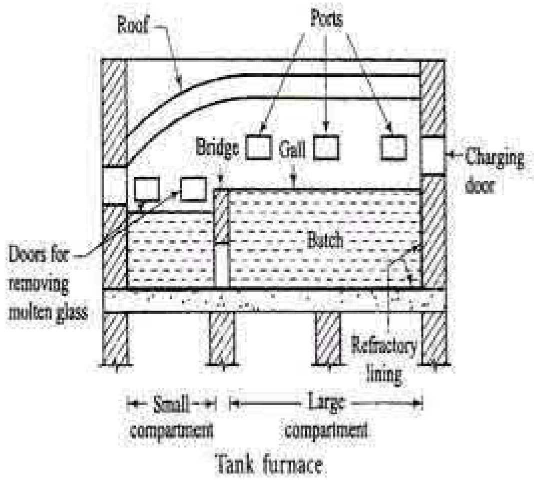


Figure 6: Tank Furnace - Schematic Diagram

Figure 7: Typical Tank Furnace – Sample Photo

Fabrication

The plastic glass formed in the furnace is next shaped or formed into the desired articles. It can either be done by hand or by machine. The hand fabrication is adopted for small scale production and machine fabrication is adopted for large scale production. Following are the different ways of fabrication:

- Blowing – A blow-pipe is used wherein one end of the blow-pipe is dipped in the molten mass of glass and the operator blows vigorously from other end of blow pipe. This blowing causes the molten mass to assume the shape of a cylinder.
- Casting - The molten glass is poured in moulds and it is allowed to cool down slowly. The large pieces of glass of simple design can be prepared by this method. It is also adopted to prepare mirrors, lenses, etc.
- Pressing - In this process, the molten glass is pressed into moulds. The pressure may either be applied by hand or by mechanical means. This process is adopted for ornamental articles, hollow glass articles etc.
- Rolling - There are two methods of rolling. In one method, the molten mass of glass is passed between heavy iron rollers and flat glass plate of uniform thickness is obtained. In another method, the molten mass of glass is poured on a flat iron casting table and it is then turned flat with the aid of a heavy iron roller.
- Spinning - In this process, the molten glass is spun at high speed by a machine to form very fine glass fibres. It is used for providing insulation against heat, electricity and sound.

Annealing

The glass articles, after being manufactured, are to be cooled down slowly and gradually. This process of slow and homogeneous cooling of glass articles is known as the annealing of glass.

This is a very important process and if not carried out properly, can lead to breakage of glass articles under very slight shocks or disturbances. If glass articles are allowed to cool down rapidly, the superficial layer of glass cools down first as glass is a bad conductor of heat. The interior portion remains comparatively hot and it is therefore in a state of strain.

Annealing can be done in two ways:

- Annealing Lehr – The annealing kiln called “Lehr” is constructed in such a way that there is gradual decrease in temperature from one end of flue to the other. The red-hot articles of glass are allowed to enter at the hot end of Lehr and they are slowly moved on travelling bands. They become cool when they reach the cool end of flue. This method is useful for large scale production.
- Oven Treatment – The red-hot glass articles are placed in ovens where temperature can be controlled. After placing the glass in ovens, the temperature is slowly brought down. This method is useful for small scale production.

Finishing

The cooled glass obtained after annealing are subjected to a number of operations such as cleaning, polishing, grinding, rounding edges, etc., for bringing them to a useable form.

Environmental Impact of Glass Production

The major environmental impact of glass production is caused by atmospheric emissions from melting activities. Glass manufacturing being a high temperature process, results in the emission of harmful gases such as Sulphur dioxide, carbon dioxide and nitrogen oxides. The combustion of natural gas/fuel oil and the decomposition of raw materials during the melting lead to the emission of CO_2. This is the only greenhouse gas emitted during the production of glass.

Further, Sulphur dioxide (SO_2) formed due to decomposition of sulphate in the batch materials can also contribute to acidification. Nitrogen oxides (NO_x) due to the high melting temperatures and in some cases due to decomposition of nitrogen compounds in the batch materials also contribute to acidification and formation of smog.

Container press and blow machines generate most emissions due to contact between molten glass and equipment lubricants. Manufacturing of flat glass, container glass, tableware, and artistic glass also generates emissions related to combustion in the annealing process where the glass product is maintained at 500–550° Celsius.

Other environmental issues are water pollution, the use of non-renewable natural raw materials such as sand and minerals, production of solid waste and emission of volatile organic compounds.

Organizations can adopt following methods to mitigate the environmental impact caused by glass production:

- Energy efficient melting technique – regenerative furnaces are more energy efficient than recuperative furnaces
- Use of fuels with low sulphur content
- Increase cullet utilization
- Reduction in the amounts of sodium or calcium sulphate in the batch materials
- Waste heat recovery from furnace flue gases – heat may be used for batch or cullet preheat
- Use of air or oxy supplied respirators

Technology Recommendations

Indian MSMEs continue to deploy primitive means of technologies and suffer from low energy efficiency due to two primary reasons that are Poor furnace design because of the unbalance between capital cost and operational cost and Short term views and compromises to keep the costs low.

Introduction of latest technologies would help unlock the true potential of the sector from both local and global perspective. Adoption of relevant technology based on a research driven approach would improve competitiveness and provide accelerated growth in the sector. Glass furnace design should essentially encompass following requirements:

- Low specific energy consumption to make the process viable
- Low emission of hazardous waste gases
- Safety of personnel and equipment
- Desired Glass quality
- Total cost viability

Electric Boosting (e-boosting)

There are two types of furnaces that are used for melting and heating purposes; fuel based top firing systems and electric melters. These days new type of furnaces are being developed, Electric Boosters, which use a combination of both. Using the favourable cost economics of the fossil fuels, the furnace get 70% to 80% of the required energy from the top fired burner-based combustion systems and the last 20% to 30% energy from electric boosting to deliver the last mile connectivity with its associated advantages. Fluctuations in temperature and melting characteristics are compensated at the micro level by precisely controlled voltage, current and power inputs into the furnace and the end result is a glass melting and controlling process with minimum variation.

Glass melting is an energy intensive process and can vary for each type of glass. Inadequate melting capability of the furnace makes it difficult to handle surges in glass melting demands. Hence, introduction of electric boost system in a running furnace helps increase the ability of furnace to enhance glass quality and/or increase melting capacity without an interim furnace shut down. This intervention can provide relief till a bigger furnace is built. Electric boosting helps in enhancing the glass melting process, increase efficiency and improve glass quality. It also provides a useful control parameter for advanced glass temperature control strategies and pull rate fluctuation compensation.

There are several methods of applying electrical energy to a furnace, like multi tap switched or slide wire-controlled transformers, both having their specific advantages and disadvantages. Another method is to use SCRs (Silicon Controlled Rectifiers) to control the power. Globally majority of glass industries are already going electric for many reasons related to quality, environment and precise control facilities.

Although transition to electric mode of combustion has many advantages, its adoption in already existing traditional furnaces is still a tedious task. Such interventions are more cost effective and beneficial when introduced in the design stage of a glass melting furnace.

Oxy Gas Burners

Furnaces for glass production have traditionally burned natural gas or oil with preheated air to produce glass. The high temperature and raw materials required for glass manufacturing result in significant emissions of Nitrogen Oxides (NO_x) and particulates. Usage of air-fuel combustion systems introduce 4 times the volume of Nitrogen as compared with the actual Oxygen required for combustion. This Nitrogen combines with Oxygen after combustion and exits the furnace through the chimney in the form of Oxides of Nitrogen which manifest themselves as NO_x.

The· oxy-fuel furnace substitutes oxygen with air in the combustion process. This is done by adding exact volume of pure Oxygen directly into the furnace by the usage of Oxy-gas burners. This process change significantly reduces NO_x emissions and fuel consumption required per ton of glass produced and reduces levels of other exhaust gases.

The oxy-fuel combustion technology can be used for special glasses as well as for standard soda lime glass with several advantages:

- Reduced of energy consumption
- Increased glass pull
- Reduction of spares required for the furnace
- Reduced emissions

- Easy to achieve the high temperatures required for special glasses, such as borosilicate glasses, etc.
- Lower capital investment compared to regenerative or recuperative furnaces as no regenerators or metal recuperators are required
- Continuous firing (compared with regenerative furnace)

By using oxy-gas burners, NO_x problems will be completely solved, and all environment related issues will cease to exist. And the glass manufacturing unit will have additional benefits like significant improvement in glass quality, in line with global standards.

Optical Glass Melting / Glass Melter Furnace Camera System

Glass melting at optimized conditions which is a situation where quality, energy consumption, operating cost and environmental safeguards are all at desirable levels requires a measurement and control facility on a real time basis so that all parameters are constantly, continuously and consistently maintained.

While we have temperature and pressure sensors for the furnace, glass level sensor to perfectly balance the input of batch raw materials and output of the glass, and oxygen sensors to report on the condition of the combustion, the latest addition to the basket of controls is the Optical input. For years it has been the job of the furnace operator to look inside the furnace with a protective “blue” glass and take appropriate action. The furnace camera exactly serves this purpose and eliminates

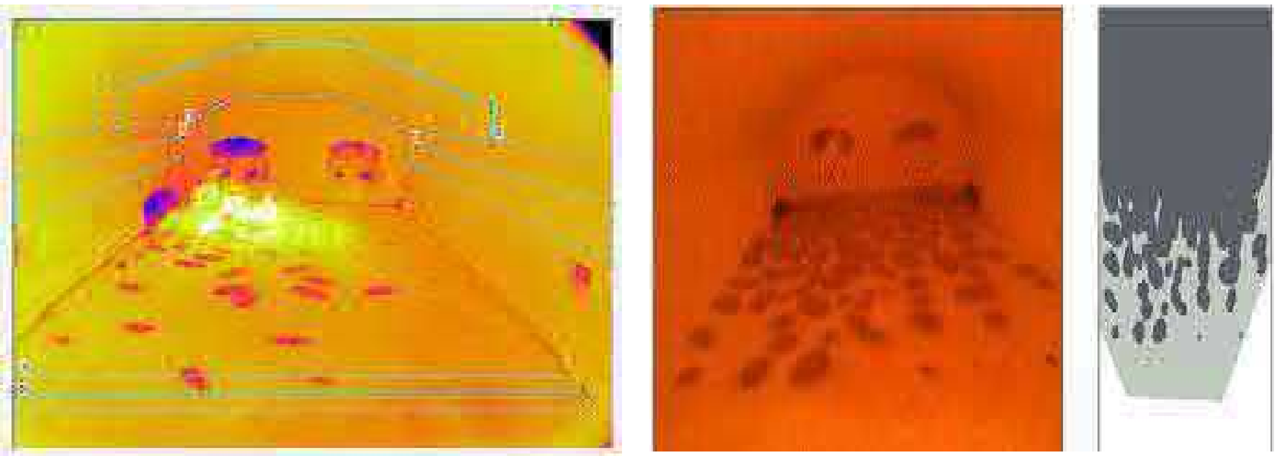


Figure 8: View from Furnace Camera System – Representation Purpose

the use of manual intervention in monitoring the furnace.

However, for years the CCTV input was just a video input. Now the technology has been developed to analyze the video input and use the data to create a matrix which shows the precise spots where the batch piles are concentrated and where they are sparse and use that data to focus heat energy where it is needed so that an overall balance is maintained. To derive best results from this technology it is necessary to have at least 20% of electric boost since it is very easy and convenient to control electric energy.

This technology deploys furnace probe cameras which are used to safely view and optimize burner flame geometry, material mix, formation patterns, melting point and molten glass surface condition. The furnace probe cameras consist of a CCD (charged couple device) black-and white or CCD color camera, a furnace probe lens and probe camera housing.

Use of cameras will help in reducing inadequate batch flow due to insufficient melting caused by disturbance in convection currents inside the melt. Also, it will help in curbing inconsistent melting characteristics leading to excess fuel consumption and increased glass defects.

To install the cameras, provision needs to be made in the furnace refractory for introduction of cameras along with cooling and safety equipment. High temperature cameras with water/air cooling facilities along with computerized programs may cost to the tune of INR 25 to 30 lacs.

Globally, glass industries are already implementing instrumentation and computer-based methods for efficiency improvement. With the help of this technology, Indian MSME industries will also be able to compete on a global platform by improving efficiencies and productivity.

All Electric Melter

Glass furnaces are generally considered as extremely energy intensive because in effect the technology of glass melting with fossil fuels is a very inefficient method of heat transfer. We use a refractory bath, top firing combustion systems and regenerators as heat saving devices but in effect even the best furnaces have an overall efficiency of less than 30% which is the energy that actually goes into melting the glass and maintaining the desired temperatures suitable for forming and actual production. The balance 70% goes into heating up the refractories of the bath, the ports, the regenerators and a sizable chunk of energy is carried away in the waste gases.

In comparison, electric heating and melting is an epitome of efficiency. The energy is fed directly into the glass and even the top surface of the glass remains cold. Efficiencies above 75% are the norm. But availability and cost of electric energy have been the major constraints worldwide causing this technology to take a back seat. Now however with photovoltaic solar panels bringing in cheap and affordable power, the time is not far when the world at large will shift to electric melting.

These type of melters receive all of the energy for glass melting through electrical heating, and not by combustion systems. Electric current is passed through the glass by means of electrodes and the glass is heated. Due to the design of these furnaces, there is typically no fit for oxygen-enriched combustion. It is suitable for special glass production with expensive, easy evaporating and poison contents in the batch.

In these furnaces, the energy input is not done by means of fossil energy, but exclusively by means of electrical energy through electrodes. Rod electrodes with specially developed water-cooled electrode holders, top electrodes or block electrodes can be used.

The electrodes can also be arranged in the bottom of the tank or in the basin side walls. The suitable location and wiring of the electrodes lead to diminished corrosion of the refractories and a longer furnace lifespan. The batch is charged by a cold top batch charger through an open sidewall of the furnace superstructure directly onto the glass bath, forming a homogenous and even batch layer. The melting, refining and homogenization processes take place vertically in the cold top melter.

Currently, there are only a few all electric melters running in the country – mainly for production of fluoride-based Opal glasses. The furnaces have very short life span due to the highly corrosive nature of fluorine and there is tremendous scope for improvement in the area of electric melting technology.

It would be a great idea for the TC at Firozabad, CDGI to lead the onset of electric melting in the country. A rooftop solar farm for power generation linked with a pilot plant with electric melting, electric fore hearths and one or two glass forming lines for some high technology product would give CDGI the cutting edge to not only get involved in the highest technology but also become equipped to train personnel from industry and also play an advisory role in the development of industry in the future.

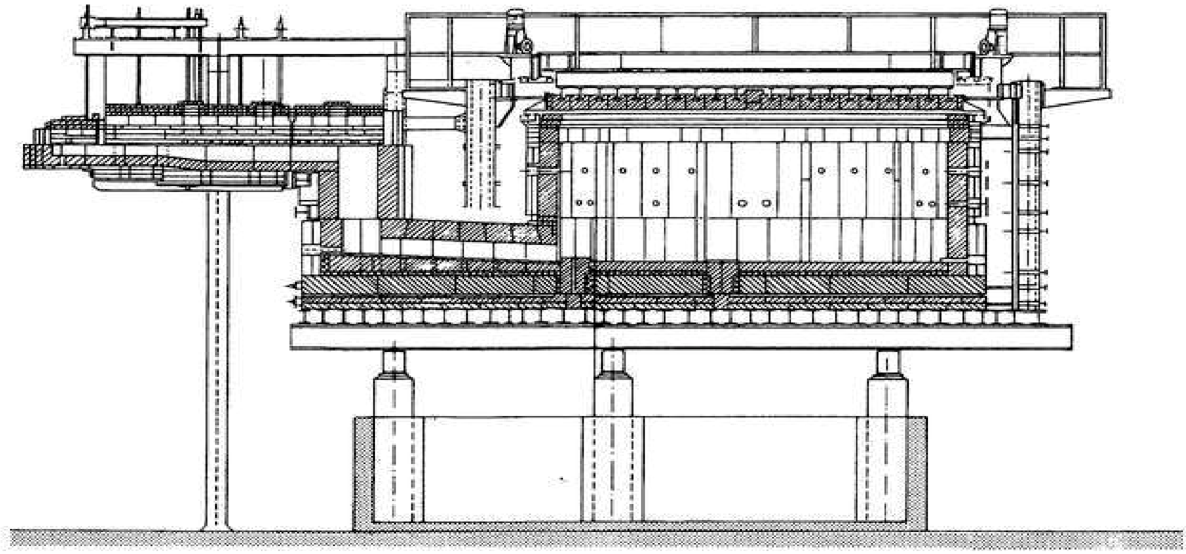


Figure 9: Typical All Electric Melter - Representation Purpose

Direct Water Cooling

Furnace design and operation is a trade-off between increasing the temperature for effective glass melting and cooling the refractory walls to minimize corrosion and enhance life of the furnace. A significant amount of energy is therefore consumed in cooling the refractory walls where corrosion is found to be most severe. Such areas which need forced air cooling are identified as below:

- Side wall blocks at the glass level – Corrosion of the refractories is seen to be most intense at the glass level because it is this point where temperature is the highest and all 3 phases viz. solid, liquid and gas exist that add to the rate of corrosion. Here typically air is blown at a positive pressure so that a stable steady state situation is achieved. During the initial years of the furnace operation, the rates of corrosion are higher but as the wall thickness reduces due to corrosion the cooling become more effective and the rate of corrosion drops.
- Furnace crown and ports – The crown is usually insulated heavily to keep energy consumption under control but as the furnace ages, corrosion at a specific point gives rise to “Rat Holes” which necessitate the removal of insulation and introduction of forced air cooling. Another area of the crown which requires continuous cooling is the skew back refractory which is housed in steel supports. The cooling becomes necessary to protect the binding steel.
- Throat – The throat is the small passage connecting the main melter with the distributor from where the molten glass is distributed to several forming or production lines. All the molten glass flows through the throat so the corrosion due to molten glass attack is highest in the throat and very often the furnace life is determined by corrosion in the throat.
- Forced air cooling at higher positive pressures are the globally accepted methods of cooling the throat cover and side blocks. It helps in reduction in throat cover block corrosion and enhancement of furnace life. Glass flow from the melter to the working end is highly corrosive and the brunt is taken by the throat cover blocks. However, in recent times, direct water cooling is being investigated as an effective solution across the glass industry.

- No doubt there are risks and hazards using water to cool the hot refractory. It can lead to immediate thermal shock resulting in cracking and complete collapse of the furnace due to glass leakage. But when done in a planned manner using best technological measures the throat corrosion can be permanently stopped and this will no longer become a weak point in the whole design, and it will no longer lead to pre-mature furnace shut down.
- The best method of introducing water cooling to a hot furnace throat with glass flowing through is to start very slowly say at 1 drop per minute and ramp up to 1 liter per hour and finally over a period of 45 days, reach a water flow rate of 1000 liters per hour or more and keep the exit water temperature not more than 40 – 50 Deg C. Very efficient flow meters and very efficient flow control valves are absolutely mandatory. Another very important requirement is to ensure total continuity of water flow. Gravity flow with overhead storage tanks must immediately get activated in case of power outage and stoppage of pumps.
- The advantage of water cooling is that even if there are cracks in the refractory cover blocks molten glass which enters the cracks will immediately be chilled and solidified and the glass will itself act as a protection thereafter.

Summary of throat cooling techniques:

- Throat cover blocks are generally cooled by blower air.
- This is used to reduce corrosion due to highly corrosive nature at high temperatures.
- Main reason for throat corrosion is the high flow rate of glass which has to pass through the small opening of the throat.
- Other options have been blower air in addition to water jackets and water coils in contact with the throat cover blocks.
- Latest method is direct water falling on the throat at very high flow rate (1000 liters per hour).
- This not only arrests the corrosion but also saves energy of the cooling blower (15 kW x 24 x 8) = Rs. 2,880 per day.

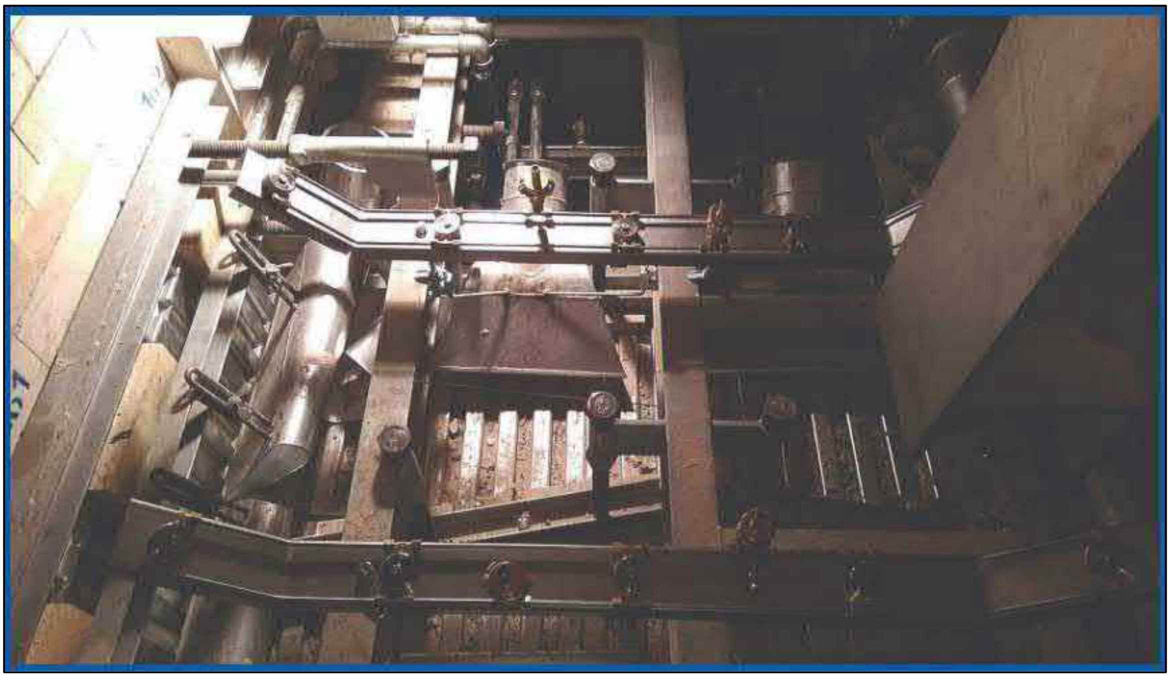


Figure 10: Direct Water Cooling - Representation Purpose

Sand Beneficiation Procedures for removal of iron

Silica is a major component in glass manufacturing process. Despite its importance, the use of silica is limited since it contains harmful minerals and impurities, mainly iron oxide, which restricts the use of sandstone for the production of high quality glass. Iron contaminations in sand are generally not suitable for clear flint glasses.

- Iron content in glass manufacturing sand is a big concern
- Washing can act as a scalper and can remove surface layers rich in iron oxides
- With a properly designed system it is possible to reduce total iron from 500 ppm to around 100 ppm
- Low iron sand beneficiation can help reduce costs and improve quality especially in flint glasses.
- Another method is to separate iron rich particles by high power rare earth magnets (11000 Gauss or more)
- Both techniques can be helpful in reducing cost of naturally occurring low iron sand and obtaining high quality flint glasses.

There are two main methods of making glass grade sand suitable for high quality products by removal of both free iron and also chemically combined iron in the oxide form:

- Free iron can easily be removed by usage of magnets
- Chemically combined iron can be removed in part in full by beneficiation process which essentially uses water or acids at high pressure to scalp the surface of the sand grains thereby removing iron contaminants which generally occur on the surfaces.
- A third method of removal of iron involves the use of much powered rare earth magnets (10,000 – 20,000 Gauss) which remove even the chemically combined iron contaminants.

The best and most effective process would comprise a combination of the 3 methods above with the washed sand being dried and subjected to strong magnetic separation Typically sand beneficiation using the three methods would require a capital outlay as below:

- Normal drum magnetic separators – INR 5 to 10 Lakhs
- Sand washing plant with water conservation and drying facilities – INR 4 Crores for a 300 TPD plant
- High Powered magnetic separators to remove chemically combined iron – INR 1 Crore for 100 TPD capacity.
- In some cases the sand is not dried since anyway dust prevention measures may require the need for moist sand

Technology Adoption – TC Perspective

The manufacture of glass for various applications, whether a capital-intensive high capacity plant, or MSME category industry with limited capital and minimum operating costs, will necessarily have to address the following issues:

- Customer acceptable glass quality
- Affordable operating costs
- Environmentally acceptable emissions
- Safety for personnel and equipment
- Effective resource management including wastes

While the large capital-intensive industries with adequate resources opt for high capacities which make their products commercially viable, the MSME units are constrained both by limited capacities and capital expenditure which result in higher operating costs.

This is the area where technical support with cutting edge technologies need to be provided in an affordable manner to the MSME category industries; so that even at low capacities they too can compete on cost and quality levels with the major high-volume industries. Technology Centers like CDGI Firozabad, under the Ministry of MSME, Govt. of India, can provide the following services which would greatly help the MSME industries

Role of Technology Centres in Development of MSMEs

- World class analysis and testing facilities along with relevant advice from experts
- Consultancy services for energy conservation, optimization and trouble shooting.
- Plant and layout designs along with validated state-of-the-art furnace designs
- Training and knowledge upgradation seminars for operating personnel in MSME industries.
- Optimization of chemistry of the glasses depending on the application
- Regular and periodic seminars with expert faculties from India and abroad on latest cutting end technologies with technical support for actual implementation.

For further information, please connect with:

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