International Journal for Multidisciplinary Research (IJFMR)

E-ISSN: 2582-2160 ● Website: www.ijfmr.com ● Email: editor@ijfmr.com

A Glimpse on the Evolutionary Studies on Glass Tank Furnace in Terms of Raw Materials, Melting Process, Refractories and Energy Efficiency

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Abstract

This paper discusses the raw materials used in ancient glasses. Following a consideration of some archaeological reasons for studying glass, the discussion concentrates on the evidence provided by the chemical analysis of the glass and focuses on glass from later prehistoric Western Europe. Consideration of the major, minor, and trace components of the glass leads to the conclusion that prehistoric glass artisans were able to closely control the addition of small quantities of colorants, opacifiers and clarifiers to the glass melt. Some possible ways of introducing such small quantities of these substances are suggested. Reduction of fuel consumption in glass melting furnaces can cut the cost of production, and tackle the global warming. The paper presents three independent solutions to reduce the fuel consumption in industrial glass melting furnaces. The solutions include air preheating, raw material preheating, and improving the insulation of combustion space refractory. Energy balance equations are derived and used to identify the effects of each solution. The results indicate that the three solutions reduce the fuel consumption by 9.5%, 17%, and 34% respectively. An insight into the refractory usage is shown for different sections of the glass tank furnace.

Keywords: Glass tank furnace, Raw Materials, Refractories, Fuel Consumption

1. Introduction

The scientific study of ancient glass can have a variety of special archaeological ramifications, perhaps leading to well-informed speculation about the kinds of raw materials employed and where they came from. However, these studies typically neglect crucial archaeological examinations of the glass, which have consequences for the socio-economic value of the material to the area as a whole and to wider systems. Indeed, it is accurate to state that both scientific and archaeological research on glass has advanced to the point where careful consideration must be given to the socio-economic niche that theglass sector and its products filled in ancient societies. Before discussing how glass raw materials are included in this specialization, it is important to first look at an illustration of how the glass sector fits intothis larger context. The glass industry may be seen as a type of specializations in later European prehistory.Long-distance material commerce is typically seen as essential for the establishment of states (Sherratt 1972)

[1]. It was observed that glass and glass components were sufficiently alien to ancient European civilization to be components of that trade-system. Glass is likely to have formed part of a distinct system of circulation that also probably included Mediterranean coral (Webster 1970 [2] and Champion 1976 [3]) and decorated bronzes. This raw material was often associated with a particular geographical or manufacturing location, thus giving the artefact a provenance. The 'provenance postulate' assumes that low variability in chemical groups indicates that the material came from the same source, while high variability suggests that the material came from different sources (Weigan et al., 1977, 24) [4]. The potential sources and uses of raw materials for glass make it possible to deduce some cultural phenomena, such as the specific technical expertise required, the emergence of "fashions" or requirements for particular glass forms, and to claim models for artisan interaction and cooperation that would have been necessary for a workshop or guild to operate effectively. In these ways, Brill's (1970) [5] reconstruction of ancient Far Eastern glassware has been a noteworthy success. manuscripts from the Library of it at Nineveh (dated 668–626 B.C.) and translations of recipes from Middle Babylonian manuscripts, which date to around 1400–1200 B.C., provided information on the raw ingredients and the heating conditions used. However, there are still issues with the environment. The third study, whose title makes reference to the year 1443, suggests purifying soda ash to produce a refined melting agent. To produce a purer kind of glass known as cristallino, this procedure is required. It is referred to as cristallo in tutta perfezione in later recipe books. But there is also a formula for making chalcedony glass in this book. This manuscript is supposed to be the earliest recipe for making chalcedony glass, assuming the year in the title is true. Segreti per colori, an unidentified Bolognese manuscript from the sixteenth century, is broken up into eight chapters and contains 393 distinct recipes on various topics. Glass is the subject of Chapter VII, which contains detailed information about using glass for mosaics, enamels, and imitation precious stones [6]. Recette for fare vetri colorati et smalti d'ogni sorte havute in Murano 1536 [7, 8] is an important manuscript from the sixteenth century that comprises According to Indian techniques, glass was earlier manufactured from rock crystal or from translucent quartz stones that had to be heated, thrown into water, then crushed and sieved..Sand obtained from a river's mouth might likewise be used to make glass. Agricola recommends the refined ash of musk ivy (Cinere anthillidis) or other plants, together with the ashes from the salsola soda plants or rock salt (Sali fossili candido), as fluxing agents. It was necessary to combine one part quartz powder or silica sand with two parts soda, rock salt, or salts made from ash purification, along with a tiny amount of sea salt (modicum salem ex aqua salsa vel marina) that acted as a decolorizer. Ashes from oak(querci), holm oak (ilignei), hard oak (roborei), turkey oak (cerrei), beech (fagini), and fir (abiegni) could be used in the absence of these salts, but the glass produced was of low quality. Agricola then provides advice on how to burn these plants to produce high-quality ash and when to remove them. The use of refractory materials that provide a suitably long duration of the glass melting oven and high glass quality is a crucial safety measure for the manufacture of glass. Therefore, strong corrosion resistance and a minimal possibility for stones, knots, cords, and blisters in the glass are the most crucial requirements for refractory materials. Modern glassmaking process requirements demand higher process temperatures, higher energy efficiency, greater melting rate capacity, increased glass quality, and a longer service life of the glass melting furnaces due to the danger of increasing competition for the glass from other materials, such as metals and plastic (PET). Greater convective flow results from higher temperatures and faster melting rates, which has a significant impact on how tank refractories wear out. Glass contact locations experience uneven wear of glass tank refractories. The service life and whether an interim repair is required for the furnace are determined by highly

stressed sections in glass melting tanks.

Premature wear frequently results in an increase in glass flaws, a loss in furnace efficiency, and a requirement for more cooling and patching. The throat, the weir wall, the doghouse corner blocks, the bubbling blocks, and the flux line area are crucial sections in glass melting furnaces. The most popular refractories in the glass melt contact region are fused-cast AZS materials for the fabrication of alkaline oxide-earth alkaline oxide-silica glasses. The increased demand described above for the crucial regions cannot be satisfied by fused-cast AZS materials.

About 70–80% of the total amount of thermal energy used in glass production is absorbed by a conventional glass furnace. A furnace that runs efficiently uses around 4000 kJ of specific energy per kilogramme of fuel-derived glass. Utilising regenerators, around 1500 kJ/kg of glass is recovered in combustion air [9]. The specific energy required by the furnace decreases as the preheat temperatures of the combustion air rise, and it also aids in raising the flame temperature within the furnace. About 60– 65% of the heat input to the regenerator is recovered by a well-designed regenerator. The economics of running a glass mill heavily depend on the regenerator's effective functioning. The regenerative system is made up of a storage-type matrix for holding flue gas waste heat and releasing it to pre-heat combustion air. Hot air is continuously pumped through a couple of regenerator matrices. For the furnace's total performance estimation, a precise assessment of regenerator efficiency is crucial. Schack [10] and Trinks [11] considered estimating regenerator performance, a collection of preliminary measurements for estimating the heat transfer coefficient for various regenerator packing configurations. In 1999, the Netherlands' energy-intensive businesses were encouraged to take part in a programme called Benchmark Energy Efficiency [12]. Most Dutch glass manufacturers took part in this programme. To reduce national consumption of energy and CO_2 emissions over the next 12 years, the Dutch government plans to implement energy efficiency benchmarks for processes or industries utilising more than 0.5 PJ annually. Companies that take part in the Benchmarking the Efficiency of Energy programme must demonstrate their energy-saving strategies in order to demonstrate that they will rank among the world's most energy-efficient manufacturing facilities. These businesses will receive advantages, including tax and CO exemptions as well as more flexible licenses. Glass boiler energy consumption ratios are benchmarked in the first phase. A furnace's particular energy consumption value is compared to the average energy consumption of all furnaces in the same industry. Research is being done to find out how much energy the furnaces need to generate the same quantity of glass melt as they do for container and float glass.

2. RAW MATERIALS OF THE PAST:-

a) **Vitrifiers** : Silica, which was present in the forms of ore sands that were found on the ground, is the vitrifying factor responsible for the construction of glass. On the other hand, quartz powder, which is produced by crushing quartz stones or quartz pebbles, may also function as a vitrifying agent. However, by the fourteenth century, Ticino River quartz pebbles became the most widely utilised material for producing more translucent, higher-quality glass.

b) **Fluxes:** Silica's melting point is lowered by soda or sodium carbonate (Na_2CO_3), which makes glass combinations easier to fuse. Glass is made 'longer' by soda, which indicates that it takes longer for the glass to harden extending the period that it may be worked. Egyptian natron, sodium plant ash, and potash plant ash were the three different types of fluxing agents formerly employed. Since the end of the thirteenth century, soda ash made from burning marine plants has been known as allume catina. Other varieties of soda ash (Barilla) were also mentioned, dating back to the seventeenth century. The usage of potash ashes derived by burning inland vegetation such blackberry bushes, cabbage, fern, borage, and oak is occasionally mentioned in documents from the fifteenth century forward. In the seventeenth century, soda forms were imported from Maltasuch as Sicily (Catania). Evidently, the Leblanc and Solvay procedures were the first artificial sodas to be made industrially.

c) **Stabilizers:** The fundamental stabilisers that make glass water-resistant are alumina and alkaline earth oxides. The only time marble or calcium carbonate is found is in twentieth-century creations. Calcium carbonate increases the difficulty of handling glass manually while lowering the melting temperature of a batch and stabilising the glass to prevent damage from water and surface degradation. Stabilisers include zinc oxide, which came from Alessandria in the form of tuzia, and zinc silicate (also known as zelamina or calamina), which has been employed since the sixteenth century.

d) **Fining Agents:** Fining agents are substances that glassmakers have employed in the past— perhaps unknowingly—to help remove gas bubbles in molten glass that are created during the reaction and breakdown of raw materials as well as to homogenise the glass as it melts. Along with nitrates, the sulphates and chlorides that were present as impurities in raw materials likewise had a fining effect. Recipes from the fourteenth century contained nitrite.

e) **Opacifiers and Colouring Opacifiers:** The most ancient opacifier is calcium antimonate ($Ca2Sb2O7$)**.**Some Venetian glass was previously made using calcium antimonate in the nineteenth century. Tin is added to the batch as tin calx or lead/tin calx, which are produced by heating tin or a metallic compound of tin and lead. Recent studies suggest that this type of opacifier has been used since either the 1st or 2nd century B.C.

f) **Colourants:** From the 14th to the twentieth centuries, basic colourants were made with silver salts, copper oxides, iron, manganese, cobalt, and iron oxides. The first mention of gold was in the fifteenth century. It takes until the eighteenth century for chromium oxide, uranium oxide, metallic selenium, and cadmium sulphide to appear. Pink glass was created by mixing silver and gold. In the nineteenth century, selenium and cadmium sulphide were employed to make red glass. Chromium was first introduced in the nineteenth century in the form of potassium dichromate or oxide, which was used to manufacture green glass.

g) **Reducing Agents:** Red, clear, or opaque glass and aventurina are the two materials most commonly treated with reducing chemicals. These types of glass used metallic copper or copper protoxide as their colouring agent.

3. Present-Day Raw Materials (from the Nineteenth Century Onwards)

The chemical industry saw rapid and unpredictable expansion in the 20th century, which led to a swift change in the sorts of raw materials formerly utilised in the production of glass.

a) **Vitrifiers**: With the advancement of mining science and the industrialization of the processes for mineral extraction and enrichment, a variety of new and improved high-quality raw materials with dependable compositions quickly gained popularity. Beginning in the early 20th century, quartz and nepheline became increasingly prevalent as natural, less expensive materials in the production of technical glass (glass packing and flat glass), which requires high amounts of alumina and silica.

b) **Fluxes:** Calcium carbonate, ammonia, and sodium chloride are used to generate sodium carbonate (synthetic soda). Known as saltpetre, potassium nitrate was once collected from deposits of nature or made in a "nitrere" by combining plant ash with straw, dung, and urine.

c) **Stabilizers:** The function of modifier/stabilizer oxide in glass manufacture was eventually recognised during the first half of the nineteenth century. As a result, the usage of naturally occurring raw materials comprising calcium, magnesium, and barium oxides increased. It was originally made synthetically in the first half of the 19th century using natural barium sulphate (baryte), and it was primarily employed in the manufacture of glassware.

D) **Fining Agents:** Salt or sodium chloride and fluidifying agents such as fluorides also have a good fining action

E) **Opacifiers**: Natural and synthetic fluorite, natural and synthetic cryolite, and sodium fluosilicate are some of the basic ingredients still used in industrial opal glass manufacture today. Fluorine opal glass varieties are readily fuseable, and the great homogeneity of their opacity created by alkaline and alkaline-earth fluorides is particularly valued in lighting systems.

F) **Colourants:** In the nineteenth century, new hues like uranium yellow began to be used in the manufacture of glass. Glassmakers first used metallic selenium in combination with cadmium sulphide in the second half of the 19th century to create so-called "Imperial red." To produce a different shade of yellow, they also employed cadmium sulphide alone. At the start of the 20th century, rare earth elements were employed to create hues with unique shades that changed based on the light's wavelength. In particular, erbium oxide gives glass a pinkish hue, neodymium oxide gives it a blue-violet hue, and praseodymium oxide gives it a pale green hue.

4. Glass Tank Furnaces of Past in Melting Process:

The first record of ancient glass furnaces is found on tablets from Nineveh. These tablets, which date to the seventh century B.C. provide details of two furnaces, one for producing frit and the other for melting it. Different hues in these cuneiform writings depict changing furnace temperatures; yellow denotes the greatest temperature (about 1100 C) in the melted chamber. Due of how challenging it was to carry out the initial melting process beginning with raw materials (Figure 1), we have already stressed that relatively few furnaces were employed. We have to already mentioned that Bet Eliezer in Israel is the most significant archaeological find that offers a clear picture of how raw glass is produced. There have been found seventeen major glass-making furnaces dating to the sixth and seventh century A.D. These 2×4 metre furnaces are seen in the reconstruction drawings in Figure 1; they were largely subterranean and two pre-chambers linked to the start of the melt chamber were used to burn wood in them. Over a period of 10 to 15 days, a batch of sand and natron was melted at a temperature of roughly 1100 C. When the glass was melted, which typically weighed eight or nine tonnes it was swiftly cooled by water jets. Then it was divided into substantial pieces. The Mediterranean Sea was used to transport this raw glass to other glass production facilities, where it was remelted and turned into finished goods.

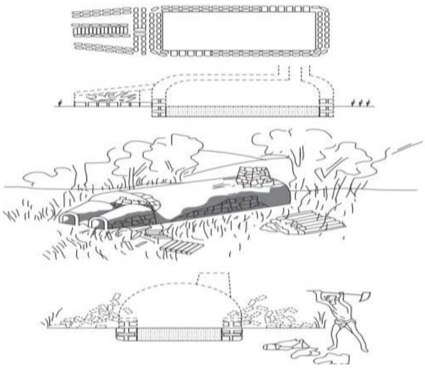


Figure 1. Reconstruction of drawing of furnaces of section view

Two baked clay oil lamps were discovered in Dalmatia (Asseria) and in Voghezia in Ferrara (Italy), both of which have noteworthy engravings of a Roman-era glass furnace. Two chambers are stacked one atop the other in each furnace. The higher one serves as the glass melting chamber, while the bottom one serves as the wood combustion chamber. work De Universo by Rabano Mauro depicts a glass furnace from the Middle Ages. This miniature is most likely a recreation of a painting from the fourth or fifth century. The furnace is made up of three levels: the lower one was the wood combustion chamber, the mid-level acted as the glass melting chamber, while the upper section was used as a glass annealing chamber. Only Theophilus' work from the 12th century A.D., De diversibus artibus [13], gives a more thorough account of a glass furnace. The 'clibanus operis', or melting furnace, was rectangular in design and dimension was 15 feet long and 10 feet broad. The wood combustion chamber was split into two halves on the lowest level. The upper level included two portions as well; the combustion chamber and glass melting chamber were joined by two central openings through which the flames soared. Several apertures in the boiler wall made it easier to access the pots that were located close to these holes. It's possible that the glass melting chamber's second part was used to prepare frit. Theophilus also speaks of another boiler, known as a "clibanus refrigerii." The rectangular structure, which measured ten feet long by eight feet broad by four feet high, was most likely an annealing furnace. The longer side of the furnace had a wide entrance used to remove or introduce the glass products, while the smaller side had an opening for adding wood. Both Georgius Agricola's Re Metallica and Vannoccio Biringuccio's De la Pirotecnica from the sixteenth century include whole chapters devoted to the description of glass furnace construction. With this thought, Agricola begins a thorough explanation of the furnaces: "Some glass-makers use three furnaces, others use two, others use one. Those who employ three melt the material in the first, remelt it in the second, and then cool the burning glass vessels and other items in the third (figure 3). A vitreous mass (the frit) was prepared in the first furnace (Figure 2), which resembled an oven, before being thoroughly melted in the pots of the second furnace.

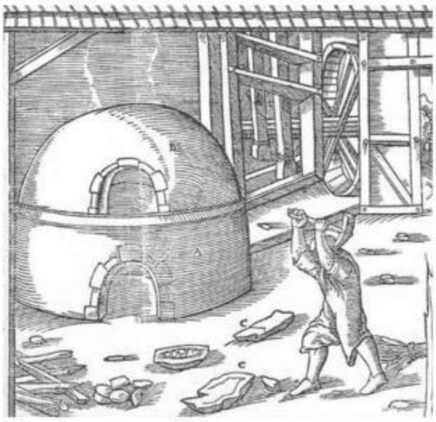


Fig2. First Furnace to make frit

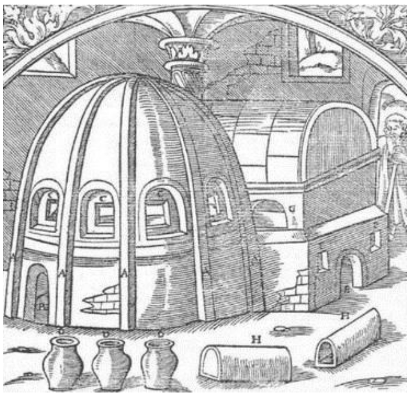


Fig3. Second and Third Furnace for melting

Eight windows that led to the same number of pots were present in the top chamber's wall. The annealing furnace was located behind the main furnace and was attached by a heat-transfer aperture that was eight feet long and six feet broad (Figure 4). The annealing furnace was divided into three chambers: a lower chamber for wood combustion, a middle chamber with pots for melting glass, and a third superior a chamber where the finished glass objects were annealed. The lower chamber was used for wood combustion, while the upper chamber was designed to accommodate the glass product to annealed.

Fig4. Ancient furnace with windows for entry of raw materials and melting

5)Glass Furnace for Melting (Present One)

Day tanks typically have a capacity of two tonnes of glass, are heated by natural gas, and have recovery and filtering systems. The melting chamber in day tanks is heated by one or two burners andoperates at a temperature of 1100°C during the working (gathering) phase, lasting roughly 10 hours. With the development of mechanical methods for serial manufacturing in the second half of the nineteenth century, continuous furnaces entered the glass industry. These furnaces operate continuously for a whole year, 24 hours a day. The vitrified batch, which consists of raw materials and cullet is automatically fed into tank furnaces that have waste gas filters and heat-recovery equipment for environmental reasons. One end of the tank is used to charge the furnaces, while the other end is used to discharge melted, refined glass into a conditioning channel, where it is supplied to one or more feeders after passing through a throat-like tunnel. Feeders provide gobs to the shaping machines in relation to the manufacturing of hollow articles. Melting chambers in factories that make containers have a surface area of 100 m^2, while those that make flat glass have one of 600 m^2. The tank, which is heated by oil or natural gas burners in container manufacturing facilities, operates at a maximum temperature of 1600 °C while the feeders maintain a temperature of around 1250 °C. Once the containers have been automatically created by the machine, they are moved into the annealing lehr along a ribbon conveyor while temperature is gradually lowered to prevent thermal strain. The bottles are put through automatic quality control processes at the end of this tunnel. A container furnace can generate 300 metric tonnes of material per day, whereas flat glass furnaces, which can create glass with thicknesses ranging from 2 to 20 mm, may produce up to 600 metric tonnes. Tank furnaces are used in modern glass manufacturing, especially when huge volumes of glass need to be treated. They are made up of lower and higher portions as well as preheating chambers for the combustion air. The actual melting container is located in the lower part, which is lined with top- notch refractory material. The type of glass being produced determines the size and design of the tank furnace. Day tanks and ongoing tanks are both available.

6) Tank Construction

Tank is in close proximity to the superstructure and the glass. The depth of the glass in the former typically varies from 900 to 1400mm. The cooler glass can rise from the bottom to be heated and refined by being divided from the melting and refining ends by a single- or double-row dam or weir wall (Figure 5). One can boost productivity, assure the requisite quality, or improve production flexibility and energy consumption by promoting convection and preventing shortcuts in the flow. Such a dam may need to be securely 'anchored' in the furnace bottom by a specifically shaped block and can be composed of thick Cr-based refractory or 41% ZrO_2 AZS (Alumina-Zirconia-Silica). The operating circumstances affect the number, kind, and thickness of the refractory layers that make up the tank bottom. It normally has five layers, each serving a particular purpose. The pavement is comprised of the top two levels. These plates are made of fuse-cast ASZ or, for extremely corrosive melts without a special demand for glass colour, Al_2O_3-Cr_2O_3 plates with a thickness of about 120 mm, stacked offset (i.e., so that the joints of the bottom layer are hidden by the higher plates). It's crucial that there be no bubbles formed at the brick-melt contact. A thin layer of zircon ramming mass, approximately 80mm thick, is positioned beneath the pavement to absorb pressures brought on by the paving's thermal expansion during heating-up. Additionally, it successfully blocks any metal dribbles and tiny glass melt puddles that locally penetrate the pavement. The fourth layer, which is 200 mm thick and formed of the sillimanite (Al_2SiO_5) family of materials, provides the mechanical support. Depending on the depth of the glass bath, this layer must support the weight of the higher refractory layers and the glass melt, which can reach 8 t/m2 for a deep fining zone. It is directly attached to the steel structure that holds the entire building aloft. Bricks constructed of light chamotte form the fifth layer. Its purpose is to insulate the bottom from heat, and the thickness is determined by the intended function. A basin that is 200-300mm in depth surrounds the whole melting and refining area. Since the refining end can be as deep as 2800mm for thick soldier blocks that are put without mortar, it is necessary to leave intervals of about 2mm between the blocks so that they can compact firmly at 1550°C due to thermal expansion. A unique configuration of steel bracing allows the bottom layers, the wall, and the palisades to relax upon heating up while guaranteeing that no seams remain open. This is done to account for thermal expansion mismatch between layers.

Continuous tanks vary mostly in size and heating configurations. The most popular types include regenerative side-burner tanks, which preheat the fuel and combustion air, regeneratively heated V-tanks for small output, which take up relatively little space, and unit melters or long tanks, which have a unique design for making bottles and use horizontally opposed burner systems to save space but use more energy. The pull of the melting tank (thermal load) determines the ideal half-cycle period, in theory. There are no flames within the furnace during the 30- to 60-second burner reversal. To prevent the boiler from cooling down too much, the reversal time (also known as the no-firing interval) should be as brief as feasible. Because they make up around 70% of a furnace's total mass, the regenerators' refractories are a major contributor to overall investment costs. As shown by an end-fired regenerative furnace (Figure 6), there are so many components to take into account when describing a regenerator in detail that only a select few crucial components will be covered in this article. The port neck that links the regenerator to the melter is crucial in this regard. On the one hand, the regenerator and melting end's differential expansion, particularly vertically, needs to be controlled to prevent any unintended movement and maintain the expansion joints throughout the complete sections. A regenerator is made up of a regenerator chamber in which refractory bricks have been arranged like checkers or just plain checkers. Due to the differing temperature conditions of the firing and flue gas phases, as well as chemical assault from fuel and batch vaporisation, the entry on the regenerator side is under the most strain. A maximum amount of heat may be stored in the checks for 20 to 30 minutes before being transferred to the combustion air because to the regenerator head's specific capacity.

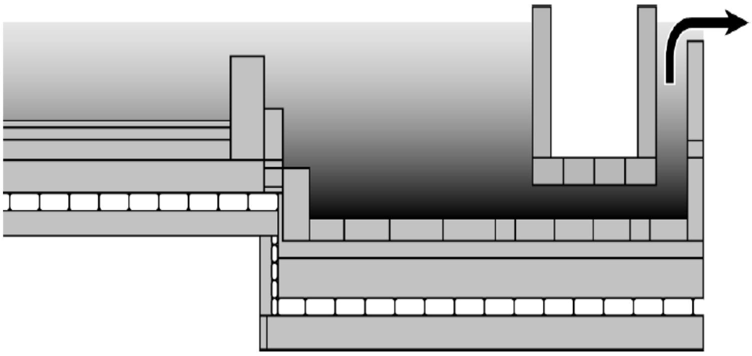


Fig5. Sketch of the dam wall for melter in a glass tank furnace

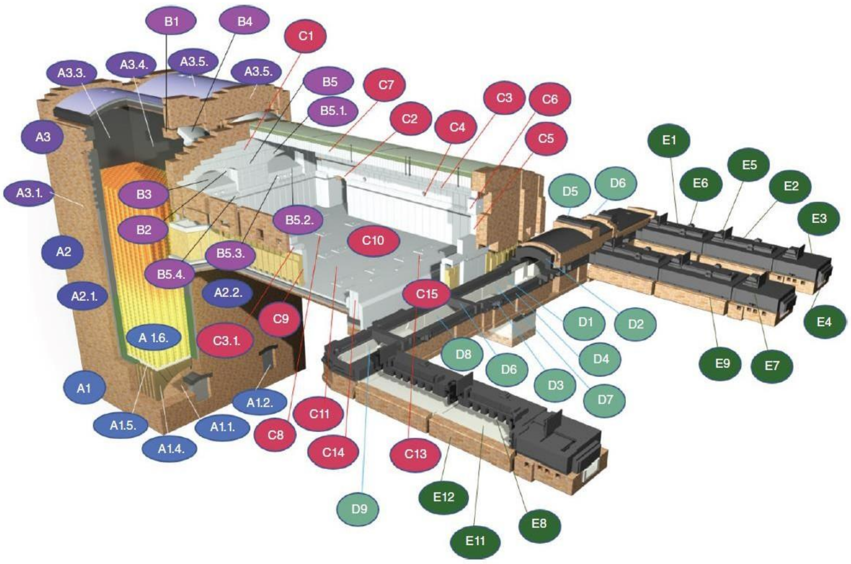


Fig 6. Individual components of a end-fired regenerator furnace

A. Regenerator: 1. Downpart: 1.1. bottom, 1.2. wall with cleaning openings, 1.3. flue gas channel (notvisible here), 1.4 rider arch, 1.5. spanner tiles and transition layer, 1.6. checker work; 2. Central section: 2.1. side walls, 2.2. front wall (oppositeside: rear wall; orange interior: checker work); 3. Head: 3.1. side walls, 3.2. entrance wall, 3.3. target wall, 3.4. middle wall, 3.5. crown.

B. Port neck: 1. regenerator entrance arch, 2. side wall, 3. bottom, 4. cap or crown, 5. port mouth: 5.1.entrance arch blocks, 5.2. apron block, 5.3. burner blocks with distance blocks in-between, 5.4. tuckstone block;

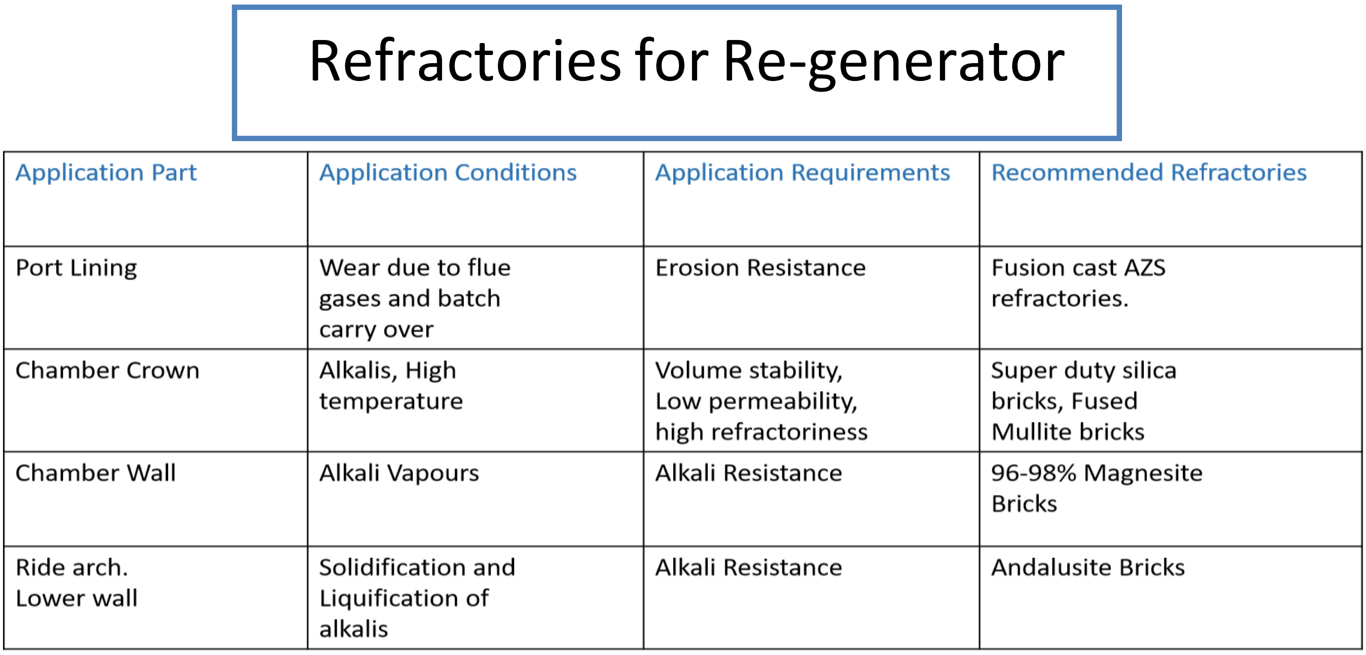
C. Melter: 1. back wall above port mouth (port gable wall), 2. doghouse entrance arch, 3. breast wall withbackup layers and insulation, 3.1. tuck stone, 4. peep hole, 5. front wall or throat gable wall, 6. TV camera block, 7. crown, 8. doghousewith cover, 9. basin with soldier blocks and insulation, 10. melting end, 11. tank bottom, 13. bottom electrodes, melting end, and barrier boosting, 14. weir or dam wall, 15. refining end, 16. throat, 17. riser with distributor entrance;

D. Distributor: 1. entrance zone, 2. center forced cooling devices, 3. peep hole, 4. pencil burner lining, 5.radiation opening, 6. zone dividing wall, 7. basin and bottom, 8. heating/cooling zone, 9. alcove as heating zone.

E. Feeder: different components not explained in detail.

Refractories for Different Parts of Glass Tank Furnace

Application	Application Conditions	Application Requirements	Recommended Crown Refractories
Crown	Alkali Vapours, High temperature	Volume stability, Low permeability, high refractoriness	Super duty silica bricks
Super structure	Wear by carried over batch constituents, High temperature.	High thermal shock resistance, Corrosion and erosion resistance	Zirconia-Mullite Bricks , Mullite Bricks
Lower Side walls	High Temperature, Glass Corrosion	Corrosion resistance	Zirconia-Mullite Bricks
Bottom Paving	High Temperature, Glass Corrosion, High load	High Refractoriness under Load, Corrosion resistance	Fusion Cast AZS- Refractories
Safety Layer	High Load	High Refractoriness under Load	High Alumina Bricks
Insulation	Higher Thermal Load	Low Thermal Conductivity, good mechanical strength.	Silica Insulating bricks
Repair	Alkali Vapor Corrosion.	Good Thermal Shock & Corrosion resistance	Fused Silica bricks, Zircon based Ramming &Patching masses



Refractories for Re-generator

Application Part	Application Conditions	Application Requirements	Recommended Refractories
Port Lining	Wear due to flue gases and batch carry over	Erosion Resistance	Fusion cast AZS refractories.
Chamber Crown	Alkalis, High temperature	Volume stability, Low permeability, high refractoriness	Super duty silica bricks, Fused Mullite bricks
Chamber Wall	Alkali Vapours	Alkali Resistance	96-98% Magnesite Bricks
Ride arch. Lower wall	Solidification and Liquification of alkalis	Alkali Resistance	Andalusite Bricks

7. Energy efficiency of glass tank furnace:

Over the past 30 years, glass melting furnaces' specific energy consumption has fallen significantly, mostly as a result of better furnace designs, furnace controls, combustion, and insulation of the melting tank and furnace walls[14]. The recycling of cullet as a raw material has risen in the container glass sector over the past fifteen years, and this branch will continue to expand its cullet recycling activities. When melting container glass, a furnace typically used 0.24 m^3 of natural gas per kilogramme of molten glass in 1960; by 1985, this had dropped to 0.16 m^3 of natural gas per kilogramme. Modern container glass furnaces use even less natural gas to create glass today—less than 0.13 m^3 per kilogramme of glass. Electricity or fossil fuels are used to power furnaces for melting glass. Numerous strategies to lower the fuel consumption of these furnaces have been developed as a result of high energy prices, stringent environmental restrictions, and intense rivalry among glass makers. Increasing thermal efficiency, reducing environmental impact, and preserving glass quality are the three basic objectives of glass manufacturing. Despite recent improvements in energy reduction, there is still a long way to go. For existing furnaces using inefficient thermal conditions worldwide, the issue is more serious. The melting end's waste gas channel is used as a heating source for the leftover heat that would otherwise be wasted. The kind of furnace (air/fuel or oxy/fuel, for example), as well as the temperature and purity ofthe flue gases exiting the furnace or the regenerator, all have an impact on waste heat recovery choices. Depending on the heat recovery system, the amount of heat recovered from flue gas ranges from 60 to 8 percent, helping to keep the primary energy input for melting at 4.5 to 4.8 GJ per tonne of glass. High efficiency heat recovery systems produce leftover gases with little heat content, preventing further use of the outgoing gases. For process control purposes, alternatives that do not use the leftover heat to restartthe melting process may be desirable; nevertheless, these alternatives may need cleaning the flue gases and maintaining temperatures above 200 °C to prevent the formation of sulfuric acid (for example, preheating natural gas for annealing).

Oxygen Enrichment:

The fuel uses some of its energy to heat the nitrogen that is present with the oxygen that is provided by the air for burning. The fuel used to heat the nitrogen produces very little glass heating. The amount of nitrogen heated is reduced by adding more oxygen to the air or enhancing it. Higher flame temperature and more heat are released from the furnace per unit of fuel as a result. Due to the greater flame temperature, oxygen enrichment has historically been viewed as a technique of boosting production [15]. The fact that more glass can be extracted from a furnace is real, but so is the fact that more glass is made per unit of fuel. As a result, fuel is saved. The specific tank design and, in particular, the insulation of the superstructure, determine how much gasoline is saved. The theoretical flame temperature rises from 1970 °C to 2151 °C when the oxygen percentage is increased from 21% to 23%. The radiant heat transmission would potentially increase by a factor of 1.25 with such a rise in flame temperature. In one instance, exploratory tests on a production melter led to productivity increases of up to 12% [16] The shorter, more intense flame required a 2 to 4 degrees modification in the flame orientation angle. Theoretically, increasing the oxygen percentage to 30% causes the furnace's usable heat to rise by 43 percent, from 350 Btu/CF of fuel to 500 Btu/CF of fuel. Because oxygen enrichment is costly, it hasn't been employed. This cost penalty could be lessened if the glass plant is close to an oxygen plant. Installation lead times for storage tanks, handling systems, etc., would likely be more than a year.

Conclusions:

Today, the majority of glass melting tanks exhibit extremely broad glass melt residence time variations. For the majority of commercial melting operations, the average residence duration might be 6 or 8 times the minimal residence time. A decrease in the volume of the glass melting tank of more than 50% would be possible with a minimum versus average residence time ratio of 0.40. This results in lower heat losses through the walls of a more compact furnace and lower capital expenditures for the building of the furnace using fewer quantities of refractory materials. A 50% volume modification in the melting tank might result in a 15% reduction in overall energy use. However, the batch melting-in process needs to be modified in order to realise this transition from a standard melting tank design to an "advanced" melter with a reduced volume and greater energy performance. The direct heat input from the combustion region into the batch blanket must be boosted by specific technologies in the absence of substantial recirculation glass melt flows (this recirculation dominates the wide residence time distribution). One such technology is the submerged combustion melter. Each crucial process step also needs its own set of circumstances, which are determined by the temperature, the degree of mixing, the chemistry (redox state, fining agent, melting fluxes, viscosity based on composition), and the amount of time needed to finish the step under the specified conditions. The ideal circumstances for melting-in, sand particle dissolution, or homogenization are considerably different from the ideal conditions for fining (gas removal from melt). Convection flows can be enhanced in the boiler using a variety of techniques (fuel distribution adjustments, weirs, bubblers, boosting, etc.). The quality of the refractories used has a big impact on how long a boiler lasts. The lifespan of the furnace might be significantly shortened by refractory corrosion. The analysis of the impact of various parameters on fuel consumption may be done effectively using simulations of glass melting furnaces. In order to examine the sensitivity of fuel consumption, this study varies the temperature of warmed air, the temperature of raw materials, and the total heat transfer coefficient of the combustion environment over a wide range. According to the findings, combustion airis further preheated from 1373 to 1700 K, which results in a 9.5% fuel reduction. Preheating raw materials from 300 to 1000 K, however, results in a 17% reduction in fuel use. Lastly, a 34% fuel savings is achieved by lowering the total heat transfer coefficient from 10 to 2 W/m^{2}K. Each of the aforementioned components' effects is examined independently. The use of several distinct approaches is possible.

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