

## ***Glass Melting Technology***

**SORG**

*Perfect Solutions for the Glass Industry*



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# Foreword

*“At Home in the World of Glass”  
– the validity of this statement  
is demonstrated by over 250  
SORG® designed furnaces in  
operation in more than 60  
countries throughout the  
world.*

SORG® customers benefit from this success, which is founded on technical competence, flexibility, reliability and, above all, an enormous wealth of experience. SORG® are able to supply many different types and sizes of furnace for the widest range of production and site conditions.

Float glass furnaces with a melting capacity of 700 t/24 h or more are an integral part of the programme, as is the smallest opal glass furnace for lighting ware, with a capacity of 1 t/24 h.

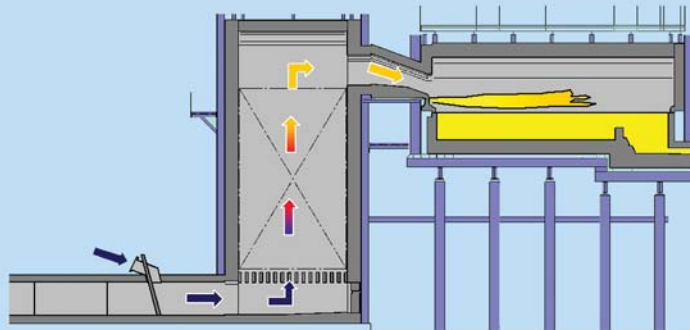
Not only soda-lime glass, but also lead-free crystal, full lead crystal, opal and borosilicate glasses of differing compositions and water glass are melted in SORG® furnaces. The articles produced on our installations cover almost the complete range of glassware commonly produced – tableware, lighting ware, tubing, insulators, fibres, pellets, flat glass, rolled plate, water glass and, of course, all types of containers.

SORG® has long been renowned for furnace development. This programme has led to significant improvements in conventional furnace technology and to the development of completely new furnace concepts.

This brochure contains information about conventional furnaces, such as regenerative end-fired furnaces, and also innovative concepts and various supplementary systems – all supplied by SORG®.

# Regenerative Air Preheating

In modern fossil-fired furnaces the heat contained in the waste gases leaving the furnace is used to preheat the combustion air, in order to produce higher flame temperatures and improve efficiency. The air preheating system most commonly used is the regenerative system.



Typical regenerator chimney block packing during construction

The regenerators, which form an intermediate storage medium, consist of two chambers, each of which is filled with a network of refractories, referred to as the packing. The waste gases from the furnace are passed through one of the chambers, and the refractories in the chamber are heated up. The combustion air enters the furnace through the other chamber.

After a certain period of time the flows of air and waste gases are reversed. The combustion air now flows through the hot chamber and is heated by heat transfer from the refractories, whilst the waste gases pass through the other chamber and heat the refractories in this chamber again.

Regenerator chambers are normally vertical constructions in which the waste gases pass

downwards, whilst the combustion air travels upwards. On most furnaces single pass regenerators are used where the gases flow in one direction through one chamber. However, where there is insufficient cellar depth available for the installation of the necessary packing volume multiple-pass regenerators can be used.

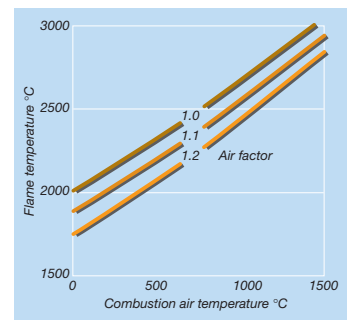
There are various forms of regenerator packing, but only two are now widely used. Both designs utilise specially shaped blocks, cross-shapes for the cruciform system, and square section tube shapes for the chimney block system.

Regenerative furnaces can be divided into two basic types on the basis of the location of the burner and the flame path:

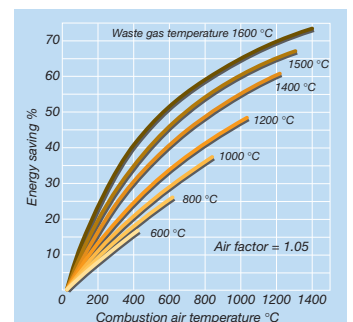
- end-fired furnaces
- cross-fired furnaces

## Advantages

- High preheat temperatures of up to approx. 1350°C possible
- Excellent energy consumption possible

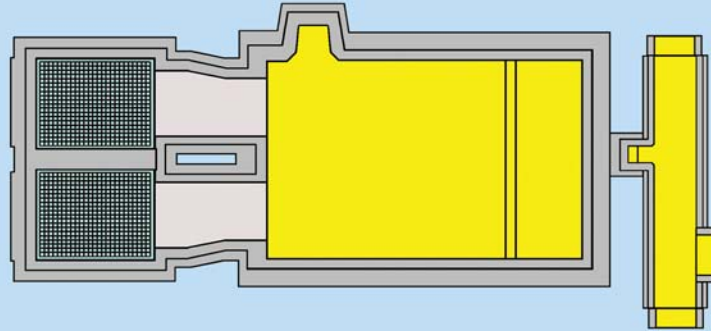


Correlation between flame and preheated air temperature



Energy savings dependency on preheated air temperature

# End-fired Regenerative Furnaces



This type of furnace has two burner ports, located side by side in the furnace rear wall, and the regenerators are situated behind the furnace. Each port is equipped with 2 – 4 burners, depending on the size of the furnace.

The flame travels forwards from the burner port, turns through 180° and exits through the second burner port. This creates a flame and waste gas path in the shape of a horizontal “U”. As a result the combustion gases in the furnace have a relatively long residence time, which produces good energy utilisation.

The raw materials enter the furnace through one or two dog-houses installed on the furnace sides, immediately next to the rear wall.

Very large furnaces of this type have a melting area of approximately 150 m<sup>2</sup>, whilst small units of approximately 20 m<sup>2</sup> are also in operation.

## Typical applications

Glass type:

- Soda-lime glass

Typical products:

- containers
- rolled plate

Melting capacities:

- 20 – 450 t/24 h

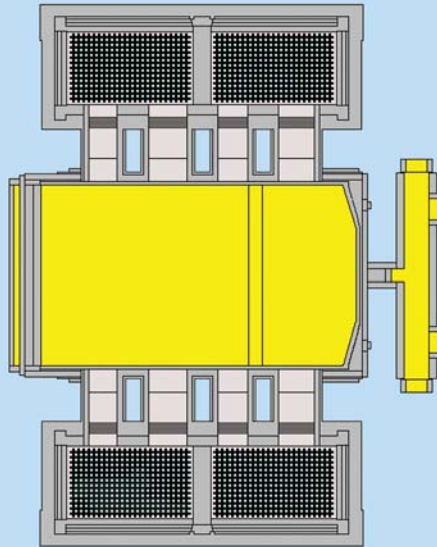
## Advantages

- Very flexible furnace type
- Lower construction costs than with cross-fired furnaces
- Lower energy consumption than a cross-fired furnace

*100 m<sup>2</sup> regenerative end-fired furnace for containers*



# Cross-fired Regenerative Furnaces



The burner ports are situated along the furnace side walls, normally covering almost the complete length.

The number of ports depends on the size of the furnace and usually lies within the range 3 – 5. Each port is provided with 2 – 4 burners, according to the furnace size.

The flame travels from one side of the furnace to the other and the waste gases are exhausted exactly opposite the entry burner port. The maximum flame length available is therefore determined by the furnace width.

The two regenerator chambers are located on the sides of the furnace and, in most cases, they are almost as long as the tank. With this type of furnace the regenerator chamber supplies several burner ports. The air/gas ratio of the individual burner ports can only be controlled accurately if the regenerator chambers are split into sub-chambers to accommodate the number of burner ports.

The single doghouse is situated on the furnace rear wall and the batch is usually charged over almost the complete tank width.

As a result of the greater number of ports and larger regenerator chambers, the heat loss area is greater than with comparable end-fired furnaces. Furnaces of this type smaller than approximately 70 m<sup>2</sup> are used only rarely.

## Typical applications

Glass type:

- Soda-lime glass

Typical products:

- containers
- float glass
- rolled plate

Melting capacities:

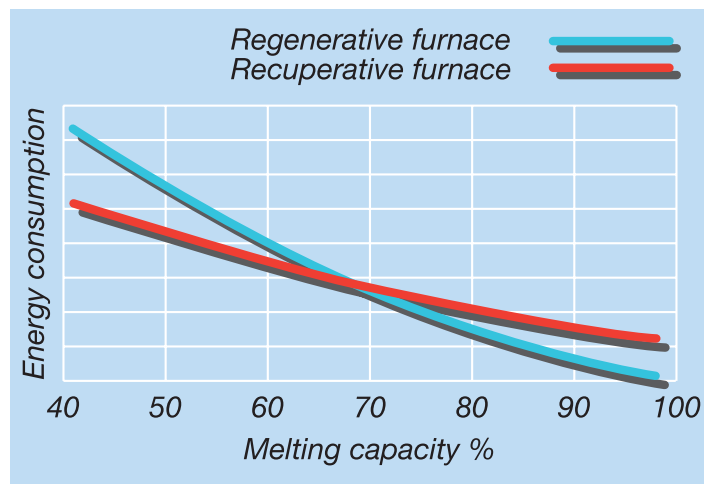
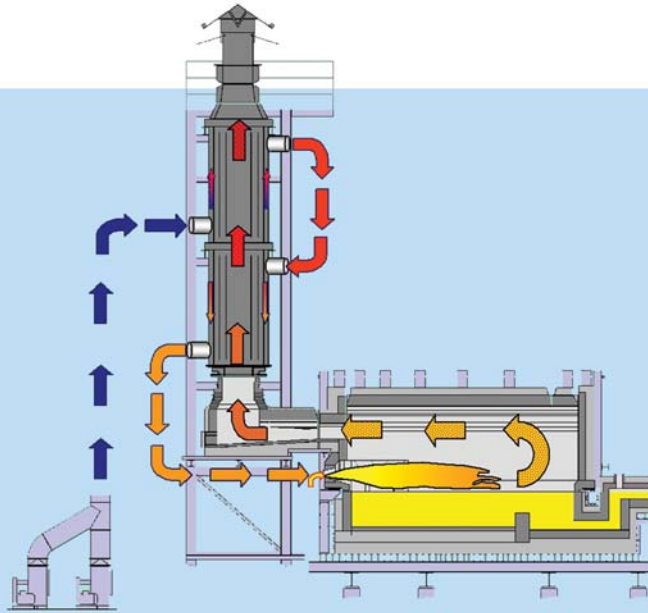
- 200 – 800+ t/24 h

## Advantages

- can also be built for melting capacities > 500 t/24h

# Recuperative Air Preheating

In the glass industry recuperators are used to preheat combustion air. The hot waste gases and the cold combustion air pass through parallel but separate channels and heat transfer takes place through the intermediate wall.



Comparison of energy consumption of a regenerative and a recuperative furnace at part load

Recuperatively preheated combustion air provides stable heating without the flame/waste gas path reversal that is necessary with regenerative systems. However, there is the disadvantage that the air preheat temperatures are lower than with regenerators.

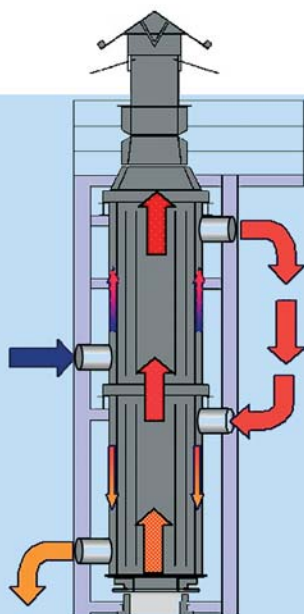
Most recuperative furnaces for glass melting utilise steel recuperators. These are always installed vertically, whereby the waste gas flows either upwards or downwards.

Two basic types of steel recuperator are used:

- double shell recuperator
- tube cage recuperator

## Advantages

- stable flame path without reversal
- lower investment than regenerators
- with part load energy consumption increases more slowly than with regenerative furnaces



### Double shell recuperator

This type of recuperator consists of two concentric high temperature resistant steel tubes of similar diameter, so that a narrow annular slit is formed between the two tubes. The hot waste gases pass through the inner tube, whilst the combustion air passes through the annular slit. The air may be passed in the same basic direction as the waste gases (parallel flow) or in the opposite direction (counterflow). Single modules of this type can be used alone, or they can be placed one after another to form a complete unit.

Double shell recuperators are capable of giving a typical air preheat temperature within the range 450 – 650 °C. The majority of these units are used for small furnaces up to a melting capacity of approximately 50 t/24 h.

### The tube cage recuperator

In a tube cage recuperator the combustion air is led through a large number of individual small diameter steel tubes arranged in a ring around the inner circumference of a large diameter outer tube, through which the waste gases flow. The outer tube is made of steel, lined with refractory material.

The small diameter air tubes are suspended from the top and sealed with refractory material at the bottom in such a way that the tubes are free to expand.

This type of recuperator can give air preheat temperatures of up to 750 °C. They are usually installed on larger furnaces.

A double shell recuperator may be added downstream of the tube cage unit to form a complete aggregate.

Conventional recuperative furnaces can be divided into two types on the basis of the location of the burner and the flame path:

- end-fired furnaces
- side-fired furnaces



Tube cage recuperator

# End-fired Recuperative Furnaces

There are several installation arrangements for burners and the recuperator in end-fired recuperative furnaces, but one particular method has proved to be the most beneficial.

In this version the burners are located on the furnace rear wall, with the waste gas port immediately above, in the same wall. The flame leaves the burner and travels along the furnace, turns upwards and back to exhaust immediately above the burners. The flame path created is in the shape of a vertical "U".

The single doghouse is located on a side wall, immediately next to the rear wall.

This furnace concept is primarily used for small installations, with melting capacities of up to approximately 35 t/24 h.

## Typical applications

Glass types:

- soda-lime glass
- lead-free crystal glass
- soft borosilicate C glass
- water glass

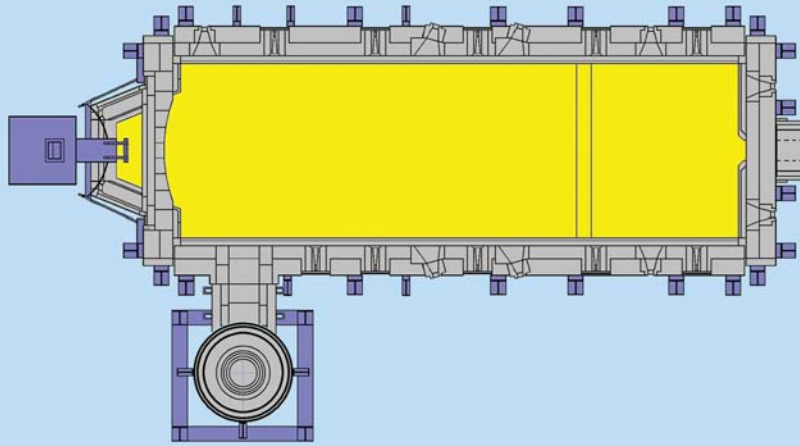
Typical products:

- containers
- glass bricks
- fibres
- lighting ware

Melting capacities:

- up to approx. 35 t/24 h

# Side-fired Recuperative Furnaces



The burners of side-fired recuperative furnaces are installed along both side walls and the waste gases are exhausted towards the rear. Either one or two exhaust ports are installed in the furnace rear wall or a side wall.

The furnace can be designed with either a single or a twin doghouse, located either on the rear wall of the tank or on the side, immediately adjacent to the rear wall.

Temperature control of larger furnaces can be divided into a number of control zones along the length of the furnace.

The specific energy consumption of side-fired recuperative furnaces at full load is higher than that of comparable regenerative furnaces, but is lower with partial load.

## Typical applications

Glass types:

- soda-lime glass
- soft borosilicate C glass
- E glass

Typical products:

- containers
- glass bricks
- rolled plate
- fibres

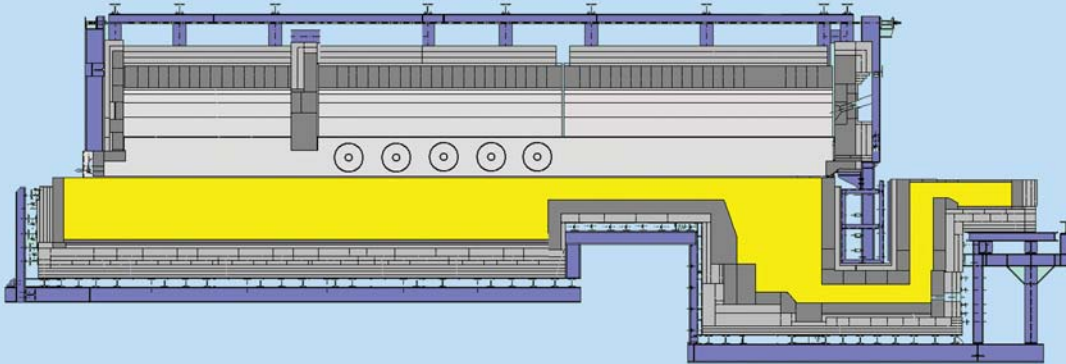
Melting capacities:

- 20 – 350 t/24 h



*Recuperative side-fired furnace for containers*

# LoNOx<sup>®</sup> Melter



The LoNOx<sup>®</sup> Melter is a special kind of recuperative furnace concept developed to operate with unusually low NO<sub>x</sub> emission levels.

The LoNOx<sup>®</sup> Melter has a long, narrow tank divided into melting and refining zones. The batch is charged over the complete width of the furnace through a dog-house on the rear wall.

Gas or oil burners are installed in the front part of the melting area and the waste gases are drawn off to the back over the top of the batch and cullet. An intermediate arch divides the superstructure to ensure that the raw materials entering the furnace are not directly heated by radiation from the hotter part of the furnace. This produces a high level of heat transfer between the waste gases and the raw materials.

A refining bank is installed to improve the refining process and this is followed by a Deep Refiner<sup>®</sup> (see page 16).

After leaving the furnace through waste gas flues installed at the rear in the furnace side walls, the waste gases are first passed through recuperators to preheat the combustion air and they then enter an external cullet preheater where they transfer even more heat.

Although the combustion air preheat temperature is relatively low compared with regenerative

furnaces, the extent to which energy is retained in the system is indicated by the low exit temperature of approximately 200 °C at which the waste gases leave the cullet preheater. The energy consumption of LoNOx<sup>®</sup> Melters is comparable with the best regenerative furnaces.

Extensive emission measurements have shown that with this furnace concept it is possible to maintain values less than 500 mg/Nm<sup>3</sup>, corrected to 8 % O<sub>2</sub> in the waste gases, during stable continuous operation.

## Advantage

- NO<sub>x</sub> values lower than 500 mg/Nm<sup>3</sup> possible

## Typical applications

Glass types:

- soda-lime flint, amber and green container glass

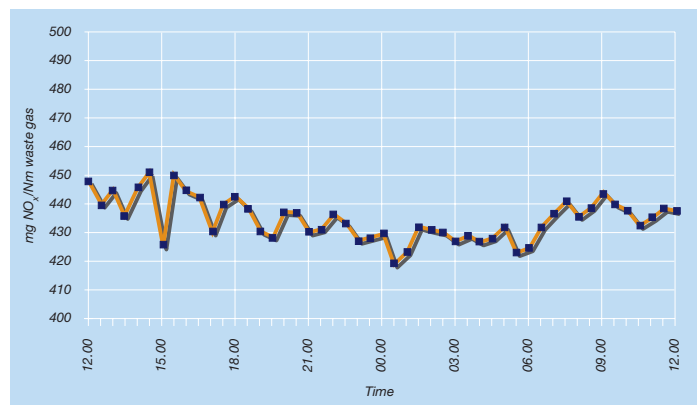
Typical products:

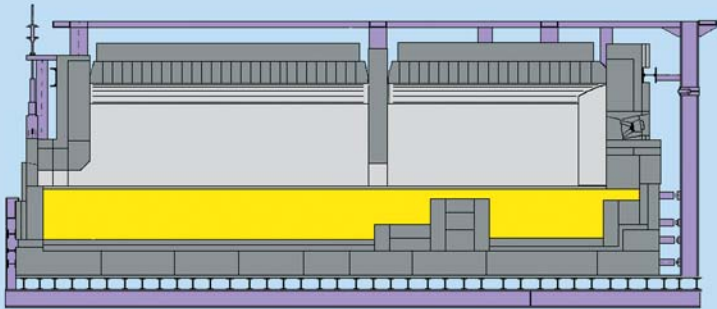
- containers

Melting capacities:

- 150 – 450 t/24 h

**NO<sub>x</sub> measurements on a LoNOx<sup>®</sup> Melter at a load of 220 t/24 h**





The FlexMelter® concept is designed for continuous or discontinuous production of high quality glass. It is not necessary to drain glass during periods when the furnace is not being pulled.

The batch is charged over the complete width of the furnace through a doghouse on the back wall.

A row of electrodes installed at the end of the melting section acts as a barrier between the melting and refining areas and increases the temperature of the glass flowing into the refining area.

A refining bank is installed to improve the refining process and prevents any return flow of glass.

The burners are installed at the front end of the melting area and in the refining chamber. The waste gases from all burners are passed backwards along the furnace and exhausted through ports situated in the superstructure side walls next to the rear wall. Intermediate arches in the superstructure prevent direct heat transfer by radiation from the hottest part of the furnace to the colder raw materials. This produces a high level of heat transfer between the waste gases and the raw materials.

FlexMelter® furnaces are designed to operate with a high percentage of fossil energy. However, the proportions of fossil fuel and electricity can be determined at the design stage, depending on the type of glass being melted.

The flexibility of this type of furnace is based on the consequent splitting of the three main functions involved in the glass melting process – melting, refining and homogenisation. The furnace design prevents any return flow between the various areas.

## Typical applications

Glass types:

- soda-lime flint and coloured glass
- potassium and soda crystal glass
- semi and full lead crystal glass

Typical products:

- household and tableware
- stemware
- high quality flacons
- tubing
- insulators
- automotive headlamp glass

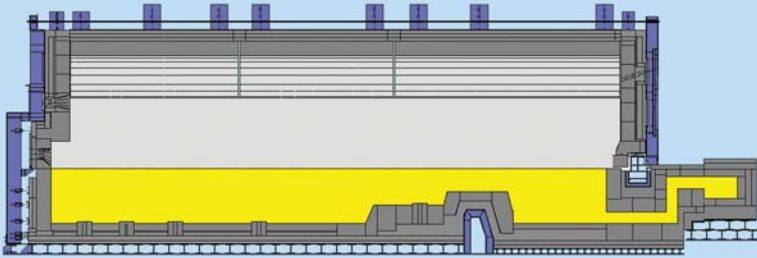
Melting capacities:

- 6 – 130 t/24 h



SORG FlexMelter®

# Boro-Oxy-Melter®



The melting and refining of borosilicate glasses (expansion coefficient  $33 - 36 \times 10^{-7}$ ) and TFT glass are difficult and require special furnaces. Relatively high temperatures are required and the refining is also made more difficult by the fact that only a limited number of refining agents can be used. In addition the volatilisation of boron-alkali compounds, that takes place from the glass bath surface, leads to boron-alkali depletion of the surface glass and, as a result, silica enrichment occurs with a tendency to crystallise in the form of cristobalite.

The Boro-Oxy-Melter® is a SORG® development designed to deal with the problems of melting such difficult glasses.

The main source of energy is an oxy-fuel heating system with the appropriate burners installed along both sides of the superstructure. The energy input is increased by a high-capacity electric boosting system in the melting area. A SORG® refining bank, with a much shallower glass bath depth, is installed in the refining area. The refining process is improved as the glass is forced upwards towards the glass bath surface, i.e. into a high temperature area.

With such glasses the use of cullet is limited and therefore it is possible to use screw chargers that do not require a doghouse. These chargers are introduced into the furnace through circular openings in the rear wall of the superstructure.

Only a low waste gas volume is produced and therefore waste heat utilisation is not viable. However, the waste gases must be cooled, before they are led to an electro-static filter. The waste gases are cooled in a quench chamber operated with air or water, or a combination of both.

## Advantages

- Excellent glass quality
- Low energy consumption

## Typical applications

Glass types:

- Pyrex® type borosilicate glass ( $\alpha = 32 - 40 \times 10^{-7}$ )
- neutral borosilicate glass ( $\alpha = 50 - 60 \times 10^{-7}$ )
- TFT glass

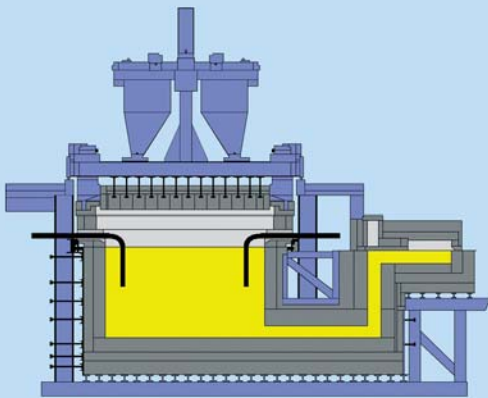
Products:

- tubing
- blown ware
- pressed ware
- flat glass

*Batch charging system for a Boro-Oxy-Melter®*



# VSM® All-electric Furnace



The SORG VSM® all-electric furnace is a cold-top, vertical melter, in which the processes of batch charging, melting, refining and homogenisation all take place in a vertical direction.

The furnace is normally 6 or 12 sided, or round, which permits a relatively even loading of the 3 phase electrical supply. The electrodes are divided into two or more electrode levels to give better control of the vertical temperature gradient through the furnace.

Most VSM® furnaces use the SORG® patented rotating crown batch charging system. The complete furnace crown is supported on roller units fitted with electric drive motors, and the crown can be rotated about the vertical axis of the furnace. A number of vibratory chutes are mounted on the crown above small openings at varying distances from the furnace vertical axis. As the crown rotates the vibratory chutes lay concentric rings of batch onto the furnace surface.

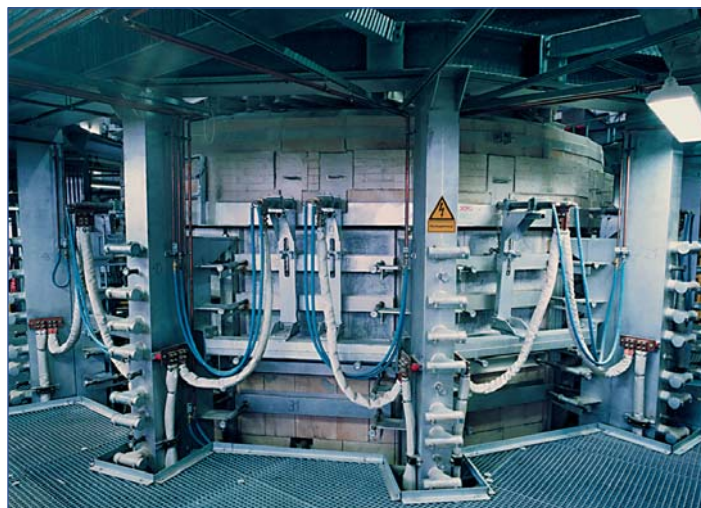
This type of batch charging system requires no moving parts within the furnace superstructure. In addition, the complete superstructure is easy to seal, which means that a relatively small bag filter for the removal of dust can be easily attached to the furnace.

Smaller furnaces are provided with a vibratory or screw feeder to transport the raw materials into the furnace, and a rotating distribution arm within the furnace superstructure to spread the batch.

Specially developed SORG® Top Electrodes are installed in almost all VSM® furnaces. These electrodes

are inserted through the furnace superstructure and enter the glass bath through the surface. They can be swung out of the furnace for inspection and exchange.

As this type of electrode requires neither holes nor water-cooling in the furnace side wall blocks the refractory material is subject to much less damage caused by temperature changes. Top Electrodes are situated further away from the side walls than conventional horizontal electrodes and so the convection currents produced by the electrodes cause less wear on the refractory material.



## Advantages

- Rotating crown batch charger - simple dust retention
- Enclosed superstructure – almost no in-factory dusting
- Top Electrodes – longer campaign

## Typical applications

Glass types:

- fluoride opal glass
- lead crystal and lead-free crystal glasses
- soft borosilicate C glass (insulating fibres)
- hard borosilicate Pyrex® glass
- soda-lime glass

Products:

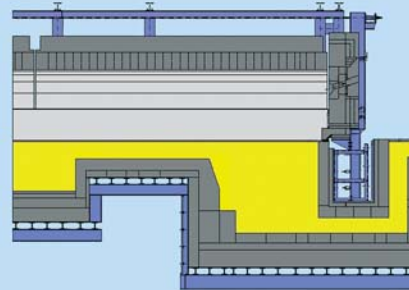
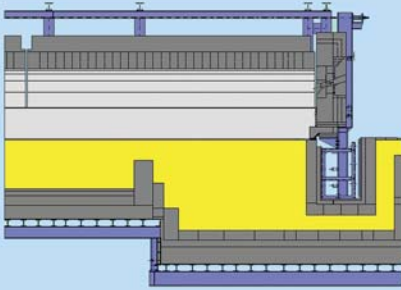
- lighting ware
- tableware
- stemware
- high quality flacons
- fibres
- tubing

Melting capacities:

- 3 - 180 t/24 h

*All-electric VSM® for 60 t/24 h C glass with Top Electrodes*

# Barrier Wall • SDR – SORG Deep Refiner® • Refining Bank



## Barrier wall

In conventional glass melters the convection currents in the furnace have a significant influence on the melting capacity and glass quality.

An upward current is produced at the hot spot as a result of the temperature distribution in the furnace. This current interrupts the forward flow of the colder bottom current and diverts it upwards to areas of higher temperatures. This prevents lower quality bottom glass from flowing directly into the throat.

Nowadays this effect is intensified by a barrier that is anchored in the bottom and projects upwards. This barrier wall is installed from one side of the furnace to the other at the location of the hot spot. The height of the barrier depends on the glass bath depth.

The combination of a well-engineered design (e.g. a double row of blocks with offset joints) and modern refractory materials (e.g. chrome blocks) results in an installation that will function correctly during the whole of the campaign.

### Advantage

- improved glass quality, especially at higher specific melting rates

## SDR – SORG Deep Refiner®

The Deep Refiner® is a part of the furnace between the barrier wall and the throat where the glass bath is much deeper than in the melting area. The temperature of the glass in this area is highest at or near the surface as a result of the normal furnace superstructure heating. This creates an area in the glass bath with slow moving glass currents that flow down towards the throat.

The use of the Deep Refiner® increases the residence time of the glass in the furnace, especially in the refining area. This gives more time for the re-adsorption of the gas from the remaining bubbles and for the establishment of the micro-homogeneity so important in the forming process. The increase in residence time of the glass in the furnace also leads to lower glass temperatures in the throat and the working end.

The Deep Refiner® concept can be applied to all types of conventional fossil-fired furnaces.

### Advantages

- increases the residence time and improves refining
- improves the micro-homogeneity of the glass

## Refining bank

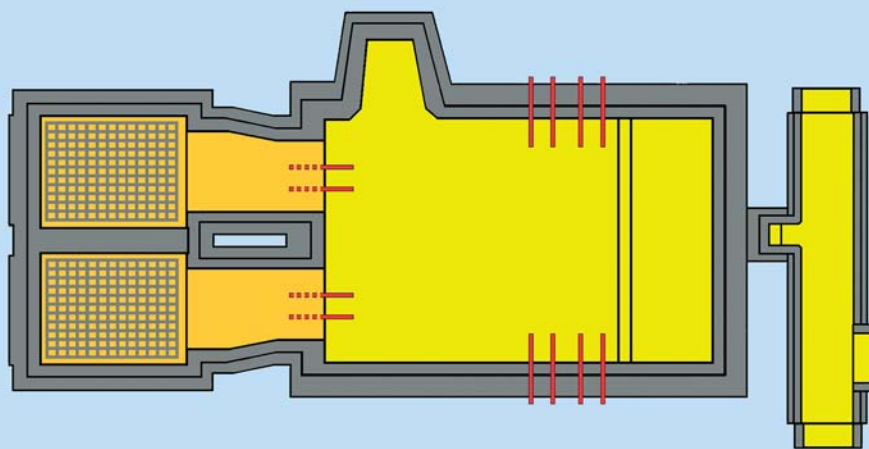
Successful refining of a glass is largely dependent on two factors: time and temperature, whereby temperature has the most influence. The refining bank is an additional device in the tank, designed to raise the glass temperature in the refining zone, without increasing the superstructure temperature.

The bottom of the tank is raised over a certain distance, to give a shallower glass depth. The glass flowing to the throat is forced upwards into the hotter area near the glass bath surface. This fulfils one of the prerequisites for improved refining – higher temperatures.

Higher glass temperatures in the refining zone result in lower glass viscosity, so the refining gases reach the glass bath surface more easily. The shallower glass bath means that the actual distance to the surface is shorter – another advantage.

The refining bank is not designed to improve the melting capacity of a furnace. It improves refining and therefore the achievable glass quality.

The application of electrical energy as an additional energy source in conventional fossil-fuel fired furnaces is referred to as electric boosting.



Molybdenum electrodes can be installed horizontally through the tank side walls, or vertically through the furnace bottom. A combination of these methods is also possible.

Most SORG® boosting systems use induction regulators that provide stepless voltage variation. For smaller installations a thyristor unit is used.

Under some circumstances an electric booster can be installed in an operating furnace: in some furnaces provision for a later installation is made during construction.

Boosting systems can be divided into three groups according to their usage:

## Melting booster

A boosting system in the melting area supplies additional energy directly to the glass bath and this leads to a higher melting capacity.

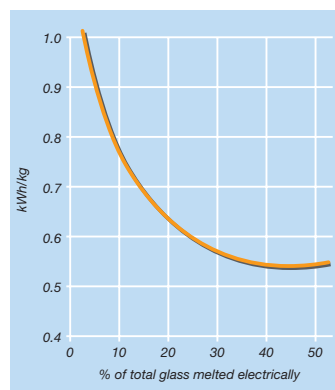
Systems with bottom electrodes increase efficiency, especially in larger furnaces, and reduce electrode wear. However, such systems are not suitable for furnaces with high cullet ratios. Here there is the risk that too much metal is introduced into the furnace with the cullet.

Whereas small and medium-sized furnaces are normally equipped with a single electrical booster, for larger installations it is advantageous if the installed electrical energy is split between two separate systems. This exerts the maximum influence on the convection currents and can produce high specific melting capacities.

## Barrier booster

The installation of an electric booster around the hot spot increases the convection currents and this raises the bottom temperature of the glass bath. This has a positive effect on the glass quality.

Furthermore, additional energy is supplied to the glass bath and the temperature of the glass flowing from the hot spot to the melting area is increased. This can lead to a small increase in the melting capacity.



## Local booster

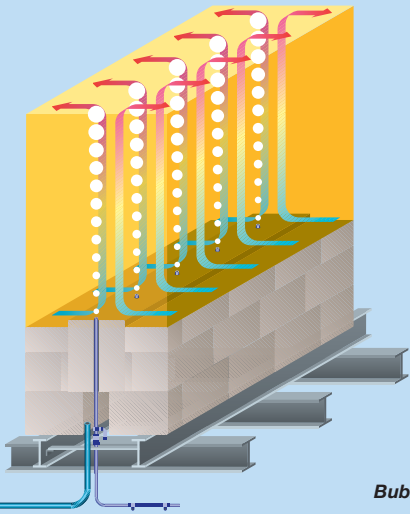
Here the electrodes are installed in order to heat a specific area of the glass bath.

The majority of these boosters are installed in the throat and riser, where the glass can cool down too much when the melting rate is low. These areas are also at risk during furnace commissioning before normal temperatures and flow velocities have been reached.

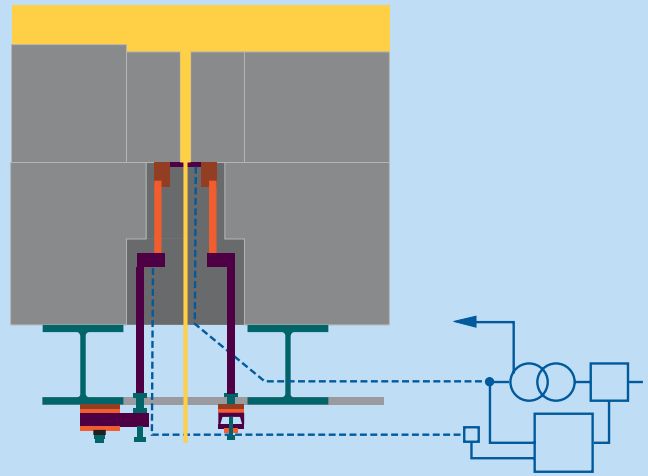
Most installations consist of just 2 or 3 electrodes and a small transformer with an installed power between 40 and 100 kVA.

Correlation between electric power of booster and the additional tonnage in medium-sized and large furnaces

# Bubblers • CONTI-DRAIN®



Bubbling principle



CONTI-DRAIN® – cross section

## Bubblers

Air or other gases are blown through special bubbler nozzles installed in the furnace bottom. This produces large bubbles in the glass and these rise to the surface and the gas is exhausted into the furnace atmosphere.

The upward movement of the bubbles produces strong localised convection currents around their path, and these currents move bottom glass upwards causing an increase in the glass temperature at the bottom of the tank. The bursting bubbles on the glass surface also create an effective barrier that prevents unmelted batch from moving forwards on the glass bath surface.

In most cases the bubbler tubes are installed in a row across the complete furnace at the location of the hot spot to strengthen the convection currents at this location.

Sorg® bubblers normally have bubbler tubes made of molybdenum disilicide. This material is extremely resistant to high temperatures and does not require cooling.

Ceramic capillary tubes that become blocked more slowly, if the air supply fails, may be used as an alternative. For special glasses the ceramic may be overlaid with a platinum alloy sheath.

### Advantages

- simple method for increasing bottom temperature
- assists retention of unmelted batch in melting area

## CONTI-DRAIN®

Zircon cords in finished articles are the result of corrosion of the refractory material that is used in large quantities in modern glass furnaces.

Zircon has a significantly higher density than normal soda-lime glass. As a result, zircon-rich material formed as a result of refractory corrosion tends to collect on the furnace bottom.

The Conti-Drain® is designed to permit the continuous draining of very small quantities of material from the melter, working end or forehearth bottom. The low draining velocity prevents glass from higher regions being pulled down as a result of the funnel effect and ensures that contaminated material is removed effectively from the furnace bottom.

The system consists of a high-temperature resistant steel nozzle plate and a small electrical heating

system. The drain nozzle is installed on the underside of a special refractory drain block in the bottom. The electric heating heats the glass in the drain hole and maintains the temperature necessary for the required draining rate.

The drain can be started or stopped at any time by switching the electrical heating on or off.

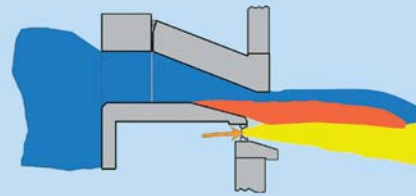
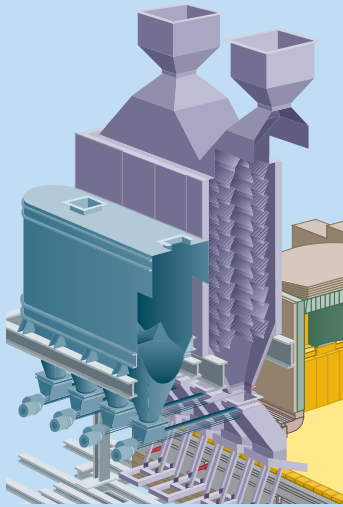
### Advantages

- allows controlled drainage of very small amounts (<500 kg/24 h)
- possible to extract contaminated bottom glass



CONTI-DRAIN® – in operation

# Cullet Preheating • NO<sub>x</sub> Reduction



## Cullet Preheating

When the cullet content in the batch amounts to more than 60%, as is often the case in container furnaces, the use of cullet preheating to recover additional heat from the furnace waste gases is an economically viable proposition.

The SORG® cullet preheating system, first introduced in 1987, is based on the direct heating principle, where the hot waste gases and the cullet to be heated are in direct contact with one another.

Cullet enters the tower construction at the top and slowly makes its way downwards to the exit. The waste gases enter at the bottom on one side and are exhausted at the top on the other side, and so the cullet and the gases are in cross counterflow.

The internal arrangement of the preheater features louvre type vanes, which distribute the waste gases throughout the column of cullet.

The velocity of the cullet in the preheater is very low, which gives a residence time of several hours. This leads to very low mechanical wear of the steel parts of the preheater.

The waste gases enter the preheater at a temperature of approximately 500 °C and leave with a temperature of approximately 200 °C. The cullet preheat temperature is typically approximately 400 °C.

## NO<sub>x</sub> Reduction

SORG® has been confronting the problem of NO<sub>x</sub> reduction since 1985.

Although prevention of the formation of thermal NO<sub>x</sub> is closely related to better control of the combustion process, it has become apparent that there is no single system or procedure that will reduce NO<sub>x</sub> emissions to the level required today.

The design of the port necks and the complete furnace superstructure are very important, as these features exert a major influence on the mixing of the fuel and the air contained in the combustion air.

The distribution of the burners and certain installation details, such as their position and angle in the port necks, and the sealing in the burner block are also significant factors as they influence the flame formation.

The heating control system is also important. On the one hand, a stepped control system prevents

unnecessary fluctuations in the fuel supply, especially after the reversing process in regenerative furnaces. On the other hand, with individual burner control the fuel supply to the individual burners can be controlled, so each burner is supplied according to its requirements.

Finally, the SORG® Cascade Heating System can be installed on regenerative furnaces to reduce NO<sub>x</sub> emission levels. The system uses a low velocity gas flame in order to create under-stoichiometric conditions around the main flame root. As a result of this effect the main flame root is insulated from the oxygen contained in the combustion air. NO<sub>x</sub> production in this area is significantly reduced.

In most cases it is possible to reduce the emission of thermal NO<sub>x</sub> to the current limits by implementing all the measures mentioned here.

# Individual Burner Control



**Oxygen station for individual burner control**

## Advantages

- reduces NO<sub>x</sub> values
- compensates for uneven burner conditions

## Typical applications

- can be used for any type of furnace

With nearly all types of furnace two or more burners are grouped together and supplied with fuel. The fuel distribution for the individual burners is controlled locally by means of control valves. However, as a result of current efforts to reduce NO<sub>x</sub> emissions a much more comprehensive flame control is now required.

To a great extent NO<sub>x</sub> generation is dependent on the energy distribution and its stability in the port. In order to achieve constant ratios it is absolutely necessary to meter and control the fuel supply to the individual burners.

With oxy-fuel heating it is also possible to measure and control the oxygen quantity on each individual burner.

The control equipment, consisting of a control valve and metering equipment for each individual burner, is installed in a station. An overall control valve can be installed in the gas supply station, so that normal "all burner" control can take place if required.

# Oxy-Fuel Heating

Normal combustion air consists of approximately 80 % N<sub>2</sub> as ballast. The N<sub>2</sub> must still be brought to the normal flame temperature and this requires energy.

The use of oxygen instead of air solves this problem and leads to significant energy savings.

The lack of N<sub>2</sub> ballast leads to a great reduction in the waste gas volume, which makes waste gas heat recovery difficult. In certain cases attempts have been made to use batch preheating to recover part of the residual heat.

However it is still usually necessary to cool the waste gases before they can be led to an electric filter. Waste gas cooling takes place in a quench chamber, that is operated either with air or water, or a combination of both.

The waste gases from oxy-fuel heating contain much more water (approx. 60 %) than those from conventional heating systems and this must be taken into account when the waste gas system is designed.

With oxy-fuel heating special attention must be paid to refractory selection. The type of material, the manufacturing tolerances and the quality of the installation work are important.

As there is very little N<sub>2</sub> available in and around the flame the production of thermal NO<sub>x</sub> is greatly reduced. However, as the waste gas volume is also reduced, relatively high volume-related NO<sub>x</sub> values (e.g. mg NO<sub>x</sub> per Nm<sup>3</sup> waste gas) emerge.

Therefore manufactured quantity based values, such as kg NO<sub>x</sub> per ton glass must be used to evaluate the emission values.

The main components of a SORG® oxy-fuel heating system are the supply and control stations for oxygen and gas and the gas/oxygen burners.

The supply stations for gas and oxygen contain the pressure control equipment and all necessary safety devices and an overall control valve for regulating the total gas or oxygen quantity. The control valves for the individual burners are installed in the control stations. This gives individual control of the amount of gas or oxygen on each burner.

In some countries (e.g. USA) oxy-fuel heating systems are now standard and are used in all sectors of the glass industry. In other parts of the world oxy-fuel heating is mostly used in the special glass sector.

## Advantages

- extremely low NO<sub>x</sub> values
- low energy consumption

## Typical applications

- can be used for any type of furnace



**Burner installation on a SORG® oxy-fuel furnace**

# Batch Charging Technology

*The way in which raw materials – normally a mixture of batch and cullet – are charged into the furnace can have a significant influence on the melting process.*

## Pusher

The ideal charging pattern in the melter consists of numerous, relatively small batch piles that almost cover the glass bath in the melting zone.

As far as possible the batch piles should not be in direct contact with the refractory material of the side walls and corners of the doghouse, or the rear and side wall tank blocks, as this causes premature corrosion of the refractory material.

Heat losses, dusting and uncontrolled infiltration of cold air are three important problems that can occur at the doghouse.

Different types of batch charger with different characteristics for various applications are available.

The raw materials taken from the feed hopper are placed on the glass bath by a stationary vibratory chute. The batch floats on the glass bath and is then pushed into the furnace by an independent water-cooled pusher.

As a result, charging and material movement in the doghouse are carried out independently, which produces a good batch coverage.

The batch cover is optimised by the operation of a freely programmable swivel mechanism on the charger, allowing the batch to be charged in several directions at slightly different angles.

A curtain or cover greatly reduces radiation and provides protection against dust and cold air infiltration.

Pusher chargers are used frequently, especially for end-fired regenerative furnaces as they achieve excellent batch coverage.

## Blanket charger

The water-cooled chute, that tilts down towards the doghouse is moved backwards and forwards by an eccentric. During the forward movement the batch is deposited on the back of the chute, whilst the batch floating on the bath surface in the doghouse is pushed into the furnace.

The basic charging rate can be varied by setting the stroke length and height of a slide baffle on the discharge outlet of the feed hopper. The charging rate is varied by stepless adjustment of the chute movement speed or by switching the movement on and off.

This charger is normally installed as a single machine on furnaces with low melting capacities, e.g. from 40 – 70 t/24 h.

A non-water-cooled version is used for operation on large cross-fired furnaces, where several chargers are installed next to one another.

## Enfolding charger

The raw materials stored in the furnace bunker are transported by a vibratory or screw conveyor to a feed hopper installed on the batch charger. From here the batch falls by gravity onto a water-cooled tray that pushes it in individual portions into the furnace. The whole machine is swivelled by a freely programmable mechanism, so that charging takes place in several directions and optimum bath coverage is achieved.

The charger is mounted directly on the doghouse and seals off the whole area. This has the advantage that heat losses are reduced, dusting is low and no cold air can enter the furnace.

### Screw charger

The raw materials from a small bunker are charged into the furnace by a rotating screw installed in a water-cooled tube. The charging rate is varied by the changing rotation speed of the screw.

A conventional doghouse is not required for this type of charger, which is installed in a simple opening in the superstructure side wall.

This simple installation reduces dusting and the infiltration of cold air as it is almost completely sealed.

Screw chargers are normally used for small furnaces for special glasses that use low amounts of cullet.

### Charging technology for electric furnaces

The specific characteristics of an electric furnace, which normally has a batch blanket over the complete melting area, require a completely different charging technology than a conventional furnace.

Frequently so-called X-Y chargers are used for electric furnaces. Here a conveyor is introduced through an opening in the superstructure side wall and makes programmed movements to distribute the batch evenly over the glass bath. As only the conveyor itself is inserted into the furnace a great deal of space is required outside, immediately next to the furnace. Much more serious, however, is the fact that the opening for the charger causes very high dusting near the furnace. It is also extremely difficult to extract and clean the batch gases as a great deal of cold air enters through the charging opening.

### Distributor arm

For smaller electric furnaces SORG® uses a distributor arm. The L-shaped, water-cooled arm enters the furnace through a slit in the crown and is positioned so that the horizontal part is just above the glass bath. The batch is charged into the furnace by a vibratory chute and spread over the entire glass surface by the rotating distributor arm that rotates around the vertical axis of the furnace.

### Rotating crown

The SORG® patented rotating crown is used on larger furnaces.

Several small vibratory chutes are installed above the crown, which has small openings for the introduction of the raw materials. The complete crown, with the vibratory chutes, rotates around the vertical axis of the furnace and the chutes deposit concentric rings of batch on the glass bath surface.

It is easy to completely seal the system so there is virtually no dusting in the factory itself. Dust extraction is also simple as no cold air is drawn into the enclosed superstructure.

# SORG® Furnaces for Special Glasses

*Although the majority of SORG® furnaces are used to melt soda-lime glasses, in recent years a number of interesting installations for other glasses have been made. Below is a review of the various furnace types for these glasses.*

## Lead crystal

Lead-containing glasses are most successfully melted in all-electric furnaces. The use of molybdenum electrodes with low frequency electricity produces excellent results.

Alternatively it is also possible to use a FlexMelter® with fossil-fuel heating, although here the emission levels must be considered.

## Fluoride opal glass

Fluoride opal is used for the production of bottles (e.g. in the cosmetic sector) and tableware.

Fluoride volatilisation causes two sorts of problem: fluoride loss can lead to significant problems with the quality (fluorine is responsible for the opalisation) and fluoride emissions are subject to very low emission limits.

The SORG VSM® all-electric furnace (see page 15) provides the ideal solution. The cold batch blanket on the glass bath suppresses the fluoride volatilisation.

SORG VSM® all-electric furnaces with melting capacities up to 70 t/24 h have been used to melt fluoride opal glass since 1970.

## Borosilicate glass

$$\alpha = 32 - 40 \times 10^{-7}$$

Very high temperatures are required to melt and refine hard borosilicate glass. SORG® offer two different solutions.

The Boro-Oxy-Melter® (see page 14) was developed especially for such glasses. The combination of an oxy-fuel heating system in the superstructure, a high capacity electric booster and a refining bank produces the necessary conditions. So far this furnace type has been built for melting capacities up to 70 t/24 h.

An alternative for melting this glass is provided by the SORG VSM® all-electric furnace (see page 15). So far VSM® installations with melting capacities up to 45 t/24 h have been built for this glass type.

### E glass

E glass is used for the production of textile fibres used, for example, to strengthen plastic items such as printed circuit boards. The production process requires absolutely clean glass free of any gaseous or solid inclusions.

In the main, recuperative side-fired furnaces are used for this type of operation. SORG® have constructed such installations with daily melting rates up to 200 t/24 h.

However, the largest SORG® furnace for this glass type and probably the largest E glass furnace in the world, is an oxy-fuel melter with a maximum melting capacity of 305 t/24 h.

### C glass

C glass is used to produce fibres for insulating wool. The glass has a high alkali content combined with boron and therefore the problem of volatilisation from the glass bath surface occurs.

C glass has been melted in SORG VSM® all-electric furnaces (see page 15) since 1975 and excellent results have been achieved. So far VSM® furnaces for C glass have melting capacities of up to 160 t/24 h.

However, a recuperative furnace is most suitable if fossil fuels are to be used. SORG® installations have melting capacities up to 120 t/24h.

More recently SORG® oxy-fuel furnaces have been built for this glass.

### Basalt or mineral wool

Mineral wool is an alternative insulating material to glass fibre.

The basis material can be melted in furnaces that are similar to glass melting furnaces. Such furnaces have recuperative heating.

The material has a very high iron content and so has a low radiation transmission. Therefore the installation of an electric booster to assist the fossil-fuel heating is very advantageous.

SORG® have built furnaces of this type with melting capacities up to 120 t/24 h.

*For your notes*



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