The future we see through

# CONDITIONING WORKING END FOREHEARTH

**COMBUSTION AND COOLING**
**STIRRER**
**EQUIPMENT**
**FOREHEARTHS**
**THERMAL MAPS**

BDF® industries

OUR HERITAGE

The development and integration of complex technologies to help industrial progress has been BDF Industries core business since 1906.

The **global market** requires the multi-tasking, multicultural and multi-expertise approach of BDF, that over the years has been able to evolve and shape itself according to the necessities.

With its collaboration instinct and the professionalism demonstrated in more than **115 years of tradition**, BDF offers the chance to take part in a first-rate technologic group ready to challenge current and future business opportunitites in terms of **competitivity**, **performances** and **reliability** of products and processes.

## The future we see through.

OUR MISSION

**BDF Industries is a manufacturer of technologically advanced machinery, a Group where performance and innovation melt together in an everlasting pursuit of excellence.**

## MELTING

BDF Industries Melting product line includes the complete glass melting and conditioning technologies for design and supply of furnaces, working end & forehearths. The range of products includes also the **relavant equipment** like oil and gas burners, firing system air, exhaust reverse valve, batch chargers and forehearth glass mixers.

BDF Industries furnaces are engineered with an **high level of customization**, focusing in particular on energy efficiency and environmental impacts. Thanks to a long time experience, combined with a team of skilled people that work together in a synergistic way, BDF Industries is able to offer a wide range in **design, manufacture and supply** of different furnaces types for production of containers, tableware, lighting ware and technical glassware.

## FORMING

BDF Industries glass container Forming product line is the historical core business. BDF Industries is able to provide a wide range of machineries with a high level of production flexibility to meet the customers' requirements.

With more than 65 years of experience in glass forming field, BDF Industries can offer a complete range of IS machine including gob forming and delivery, ware handling, container and variable equipment. The glass forming machineries are fully designed and assembled in house at BDF Industries in Italy, which has relevant knowledge of production process with the most important glass manufacturers in the world (e.g. strong credentials for forming business in O-I, Saverglass, Sisecam, Vetropack, Vitro...).

## SERVICE

BDF Industries has a Service organization dedicated to provide a complete spectrum of the highest quality service solutions to satisfy the needs of our clients from a single source. Our services support the entire product value chain from melting glass making to forming, filtering, energy facilities and automation.

The service product line includes installation & startup, upgrades of mechanical equipment and automation, technical assistance for repairing and overhauling, training, performance evaluation & long term service agreement, integrated maintenance management & diagnostic solutions and systems, spare parts.

The contents of service are the following:
- Supply local qualified supervisors
- Supply of certified end/or upgraded OEM (Original Equipment Manufacturer) spare parts for all maintenance operations
- Performance of all equipment maintenance
- Repairs using state-of-the-art technology
- Optimization of Spare Parts inventory
- On the job Training of local maintenance and operation personel.

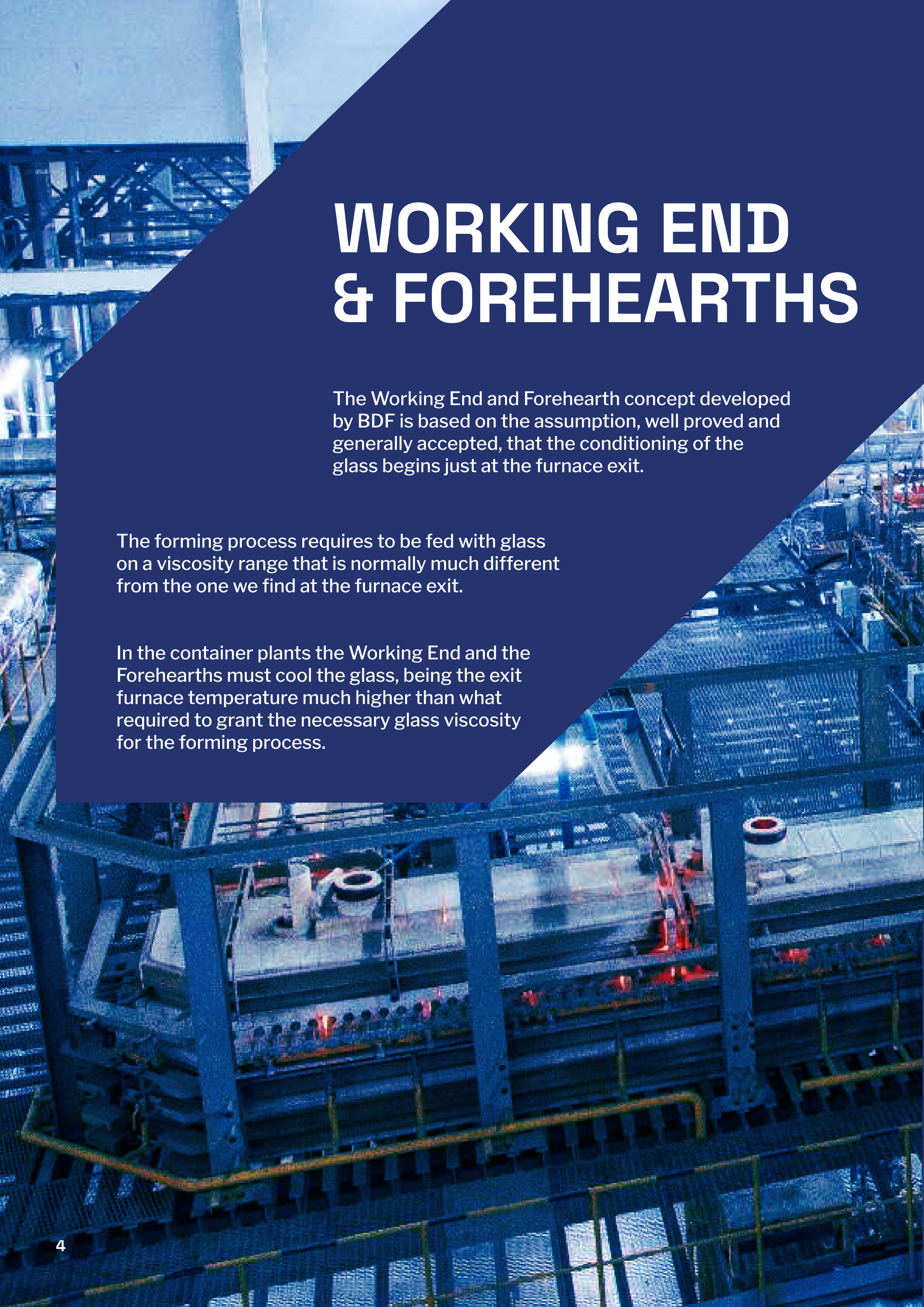
The BDF Industries Learning Center in Italy and strategically located Service Centers offer a wide range of programs in technical courses. Our technical courses are presented by field-tested experts combining understanding of theory and practical experience.

# WORKING END & FOREHEARTHS

The Working End and Forehearth concept developed by BDF is based on the assumption, well proved and generally accepted, that the conditioning of the glass begins just at the furnace exit.

The forming process requires to be fed with glass on a viscosity range that is normally much different from the one we find at the furnace exit.

In the container plants the Working End and the Forehearths must cool the glass, being the exit furnace temperature much higher than what required to grant the necessary glass viscosity for the forming process.



The glass is a material that can not be strongly cooled, therefore the cooling process to be applied must be designed taking into account a number of variables such as the thermal balance, the glass colour, the path, the “head loss”.

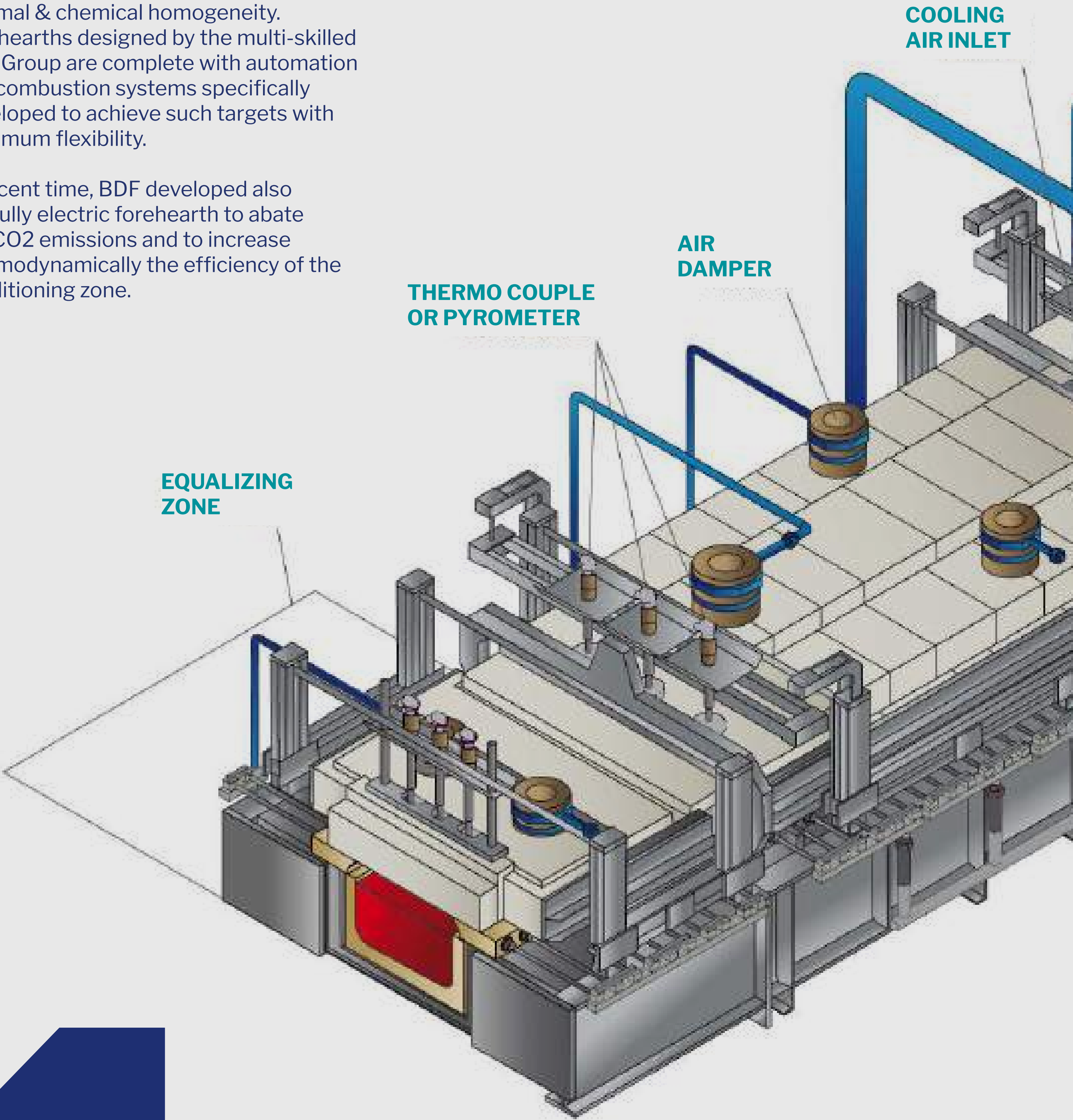
We also cannot forget the chemica aspect, as sometimes the glass quality may be affected by the characteristic of the atmosphere which it is in contact with.

The process of glass cooling down taking place after the furnace throat through distributor and forehearths is commonly known as “conditioning”. The conditioning process involves not only the forehearth, but the whole path from the throat to the spout entry.

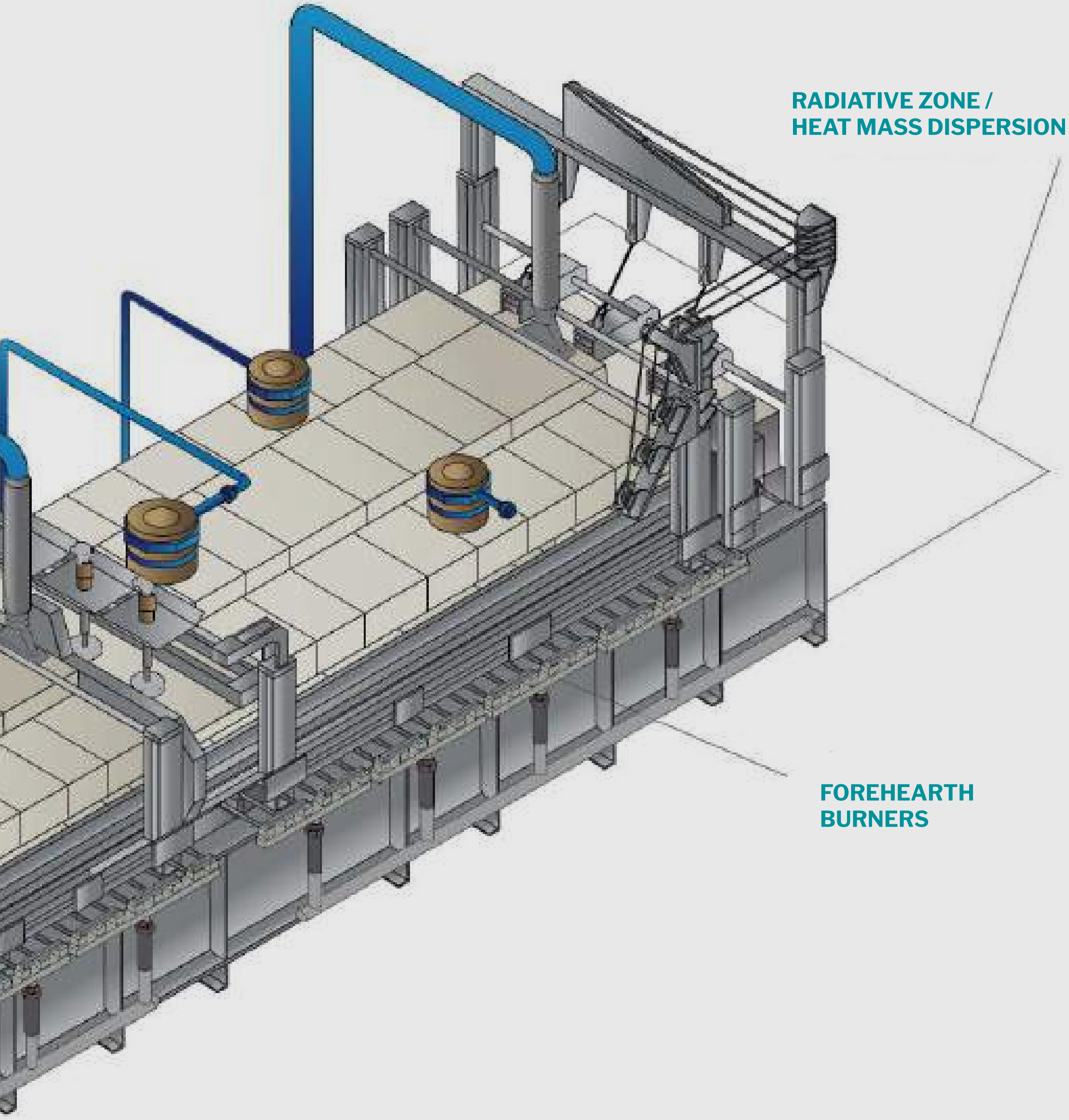
# FOREHEARTH

The molten glass exiting the throat must reach the spout with precise characteristics in terms of temperature, thermal & chemical homogeneity. Forehearths designed by the multi-skilled BDF Group are complete with automation and combustion systems specifically developed to achieve such targets with maximum flexibility.

In recent time, BDF developed also the fully electric forehearth to abate the CO2 emissions and to increase thermodynamically the efficiency of the conditioning zone.




**NNPB Ready**




| WIDTH (inches) | | 16” | 26” | 36” | 43” | 48” | 54” | 60” |
|---|---|---|---|---|---|---|---|---|
| GTFS |  | ● | ● | ● | ● | | | |
| GTHP |  | | | | ● | ● | ● | ● |
| GTHP 4C |  | | | | | ● | ● | ● |
| PULL<br>(data are only approximate) | | 5-20 | 20-45 | 40-75 | 70-100 | 90-145 | 115-180 | 150-230 |

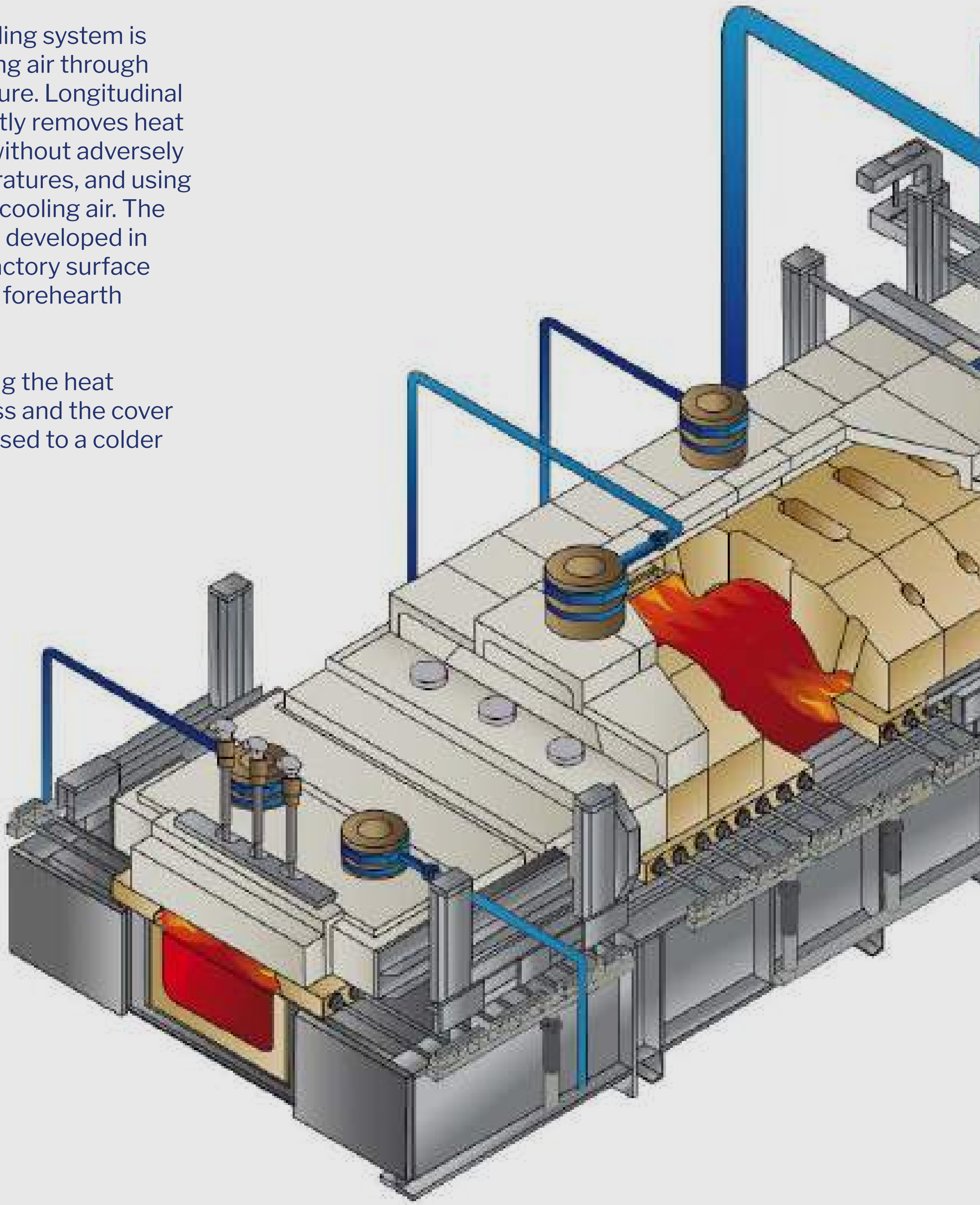
# Cooling Concept

Very often the energy to be removed from the glass to deliver the required gob temperature is much higher than what is possible to achieve by the dispersion from the refractory and it is necessary, in this case, to implement some additional cooling.

The forced convection cooling system is based on introducing cooling air through the forehearth superstructure. Longitudinal centre line cooling, efficiently removes heat from the hot centre glass without adversely affecting side glass temperatures, and using relatively small volumes of cooling air. The cover roof design has been developed in order to maximize the refractory surface exposed to the glass in the forehearth centre.

This shape allows increasing the heat exchange between the glass and the cover roof since the glass is exposed to a colder large refractory surface.

The application of this system basically involves the application of openings in the superstructure roof blocks, also used for the combustion waste gases exhaust.



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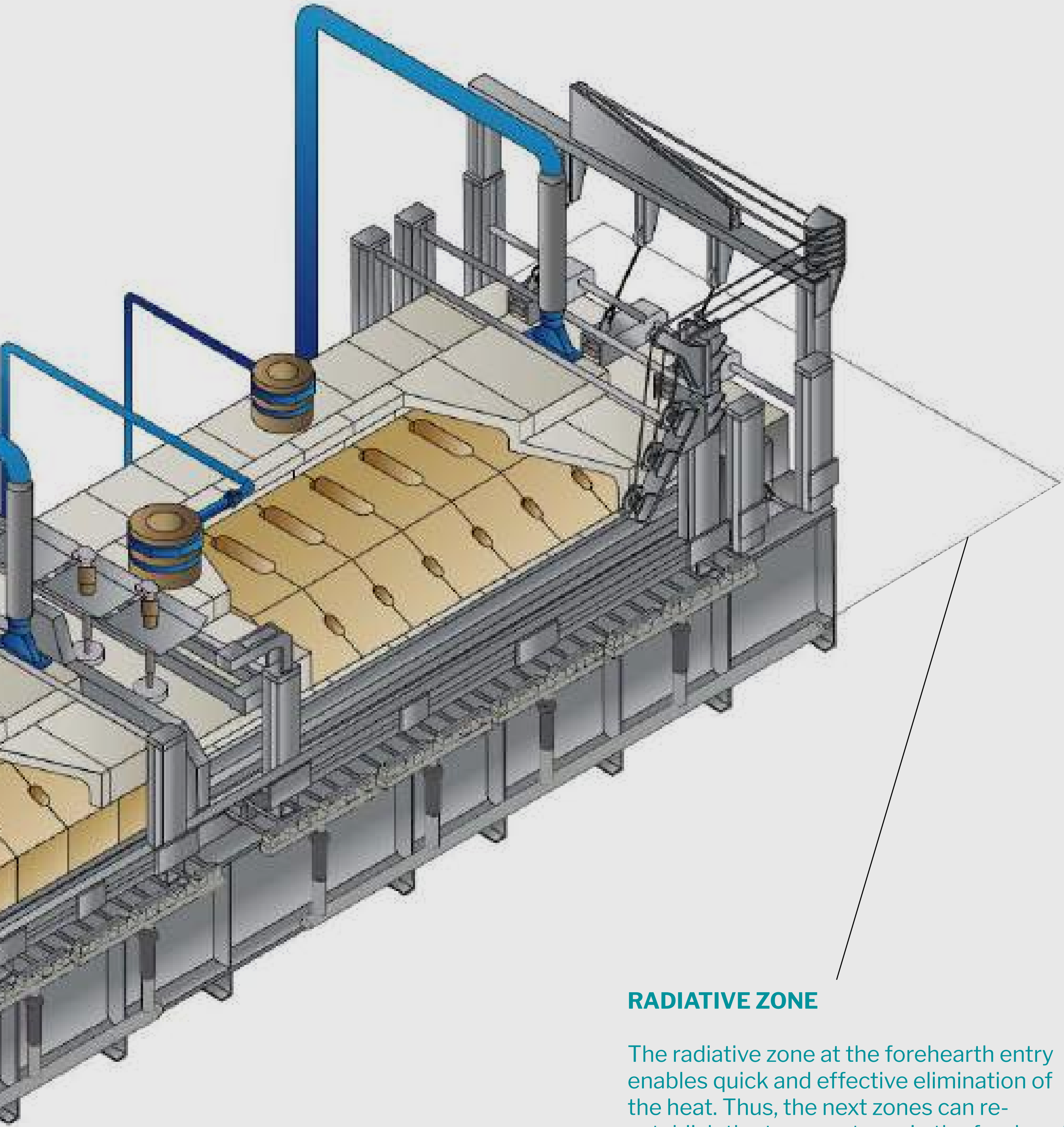
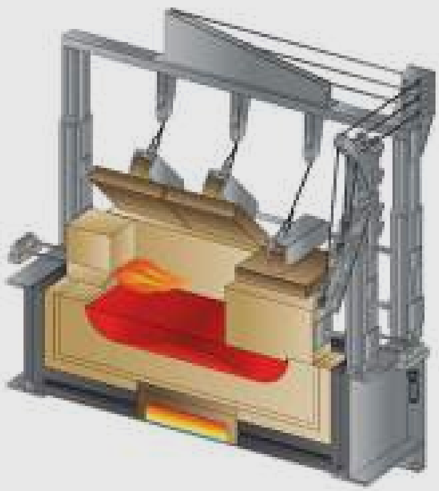


## RADIATIVE ZONE

The radiative zone at the forehearth entry enables quick and effective elimination of the heat. Thus, the next zones can re-establish the temperatures in the forehearth section.

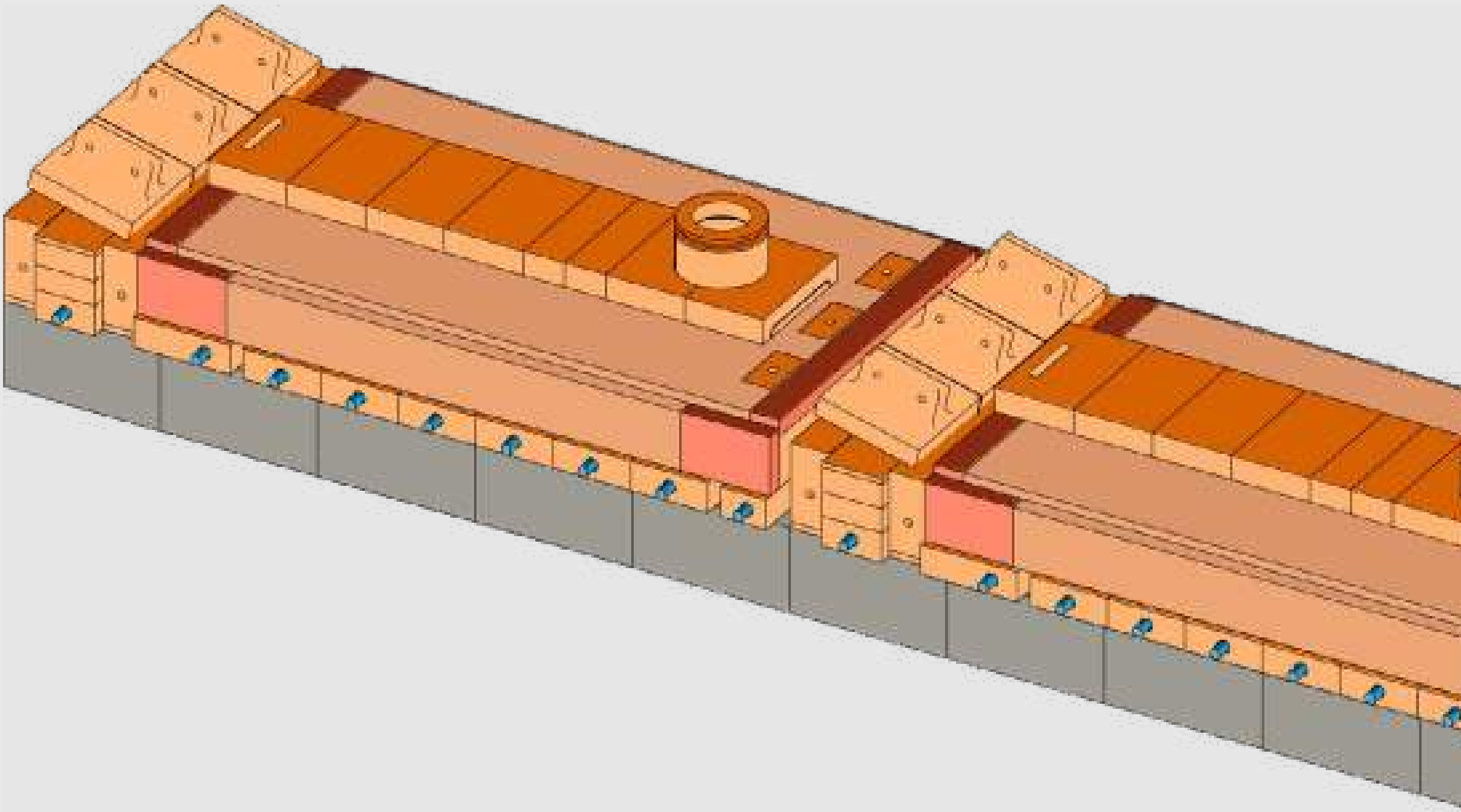


## THE HEAT MASS DISPERSION ZONE

Sometimes the air cooling and the refractory dispersion is not enough to cool the glass properly. In this case it s possible to increase the heat loss by exposing part of the glass surface to the environment.

The heat mass dispersion zone is normally installed at the forehearth entry, where the glass temperature is higher and the heat loss is more efficient.

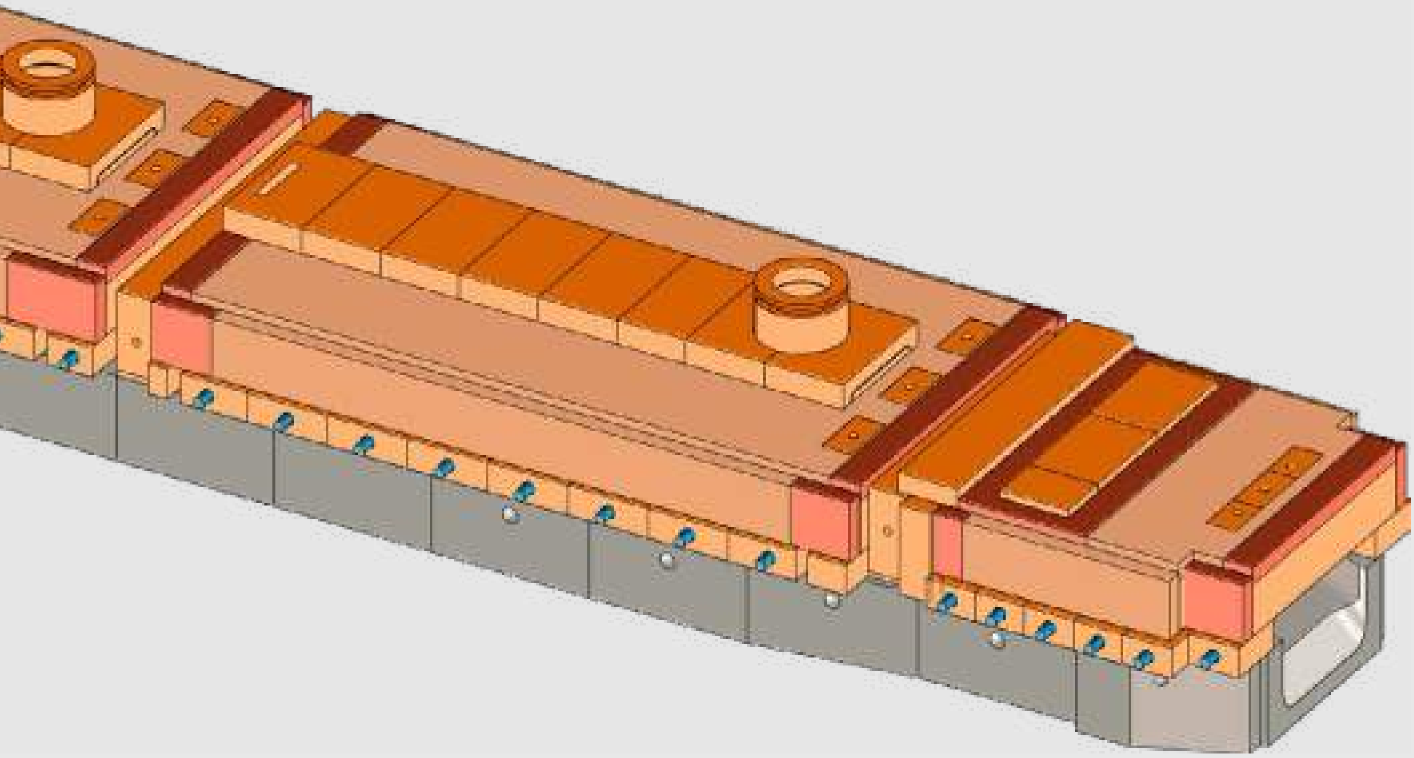
# ELECTRIC FOREHEARTH

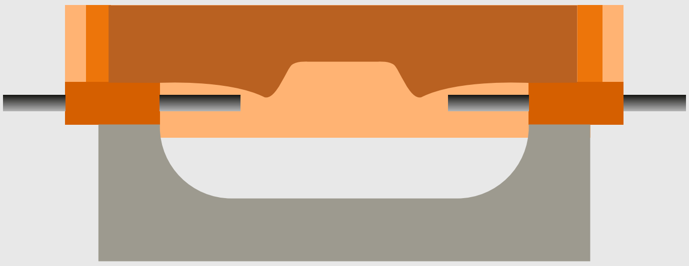


In recent time, BDF developed also the fully electric forehearth to abate the co2 emissions and to increase thermodynamically the efficiency of the conditioning zone.

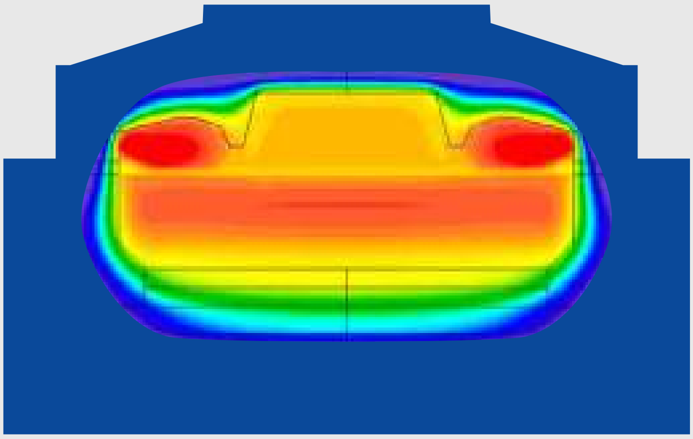
Peculiar to BDF electrical heating glass conditioning philosophy is the replacement of the pencil burner flame with a radiative element that give the same amount of energy to the glass but with more than 3 time efficiency. The heat transfer from the flame to the glass comes by radiation but a lot of energy will be lost by the heat in the exhaust that is not collected or recuperate.

The electrical heating element technology permits to transmit energy by radiation to the glass without any exhaust and, consequently, without the related losses (see blow also a cfd simulation of similar project):





Section of Heating System



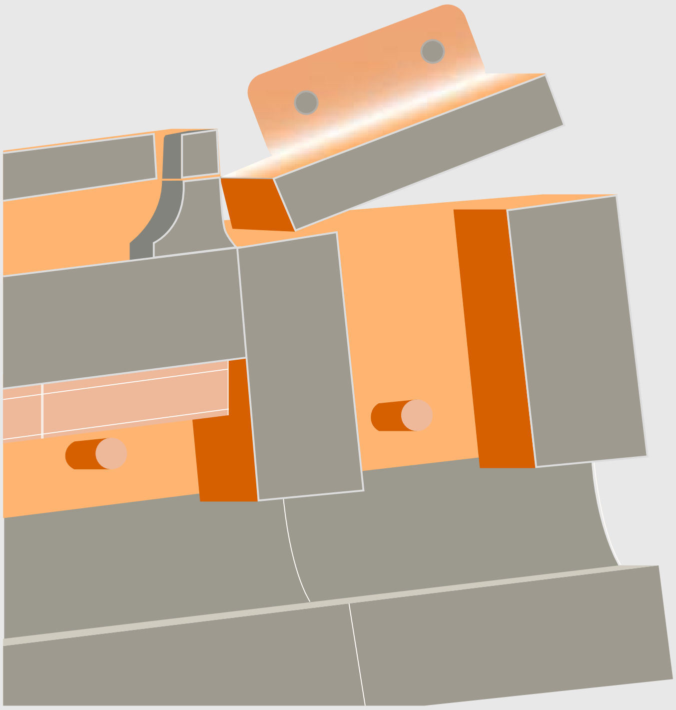
CFD of BDF Electric Forehearth

In case of need it is always possible to adopt the submerged electrodes in contact with the glass, especially for dark glasses to improve the thermal homogeneity in equalizing zone. The electrical power regulation to the heating elements is automatically operated by scr power module driven by pid regulator, according to the temperature setup.

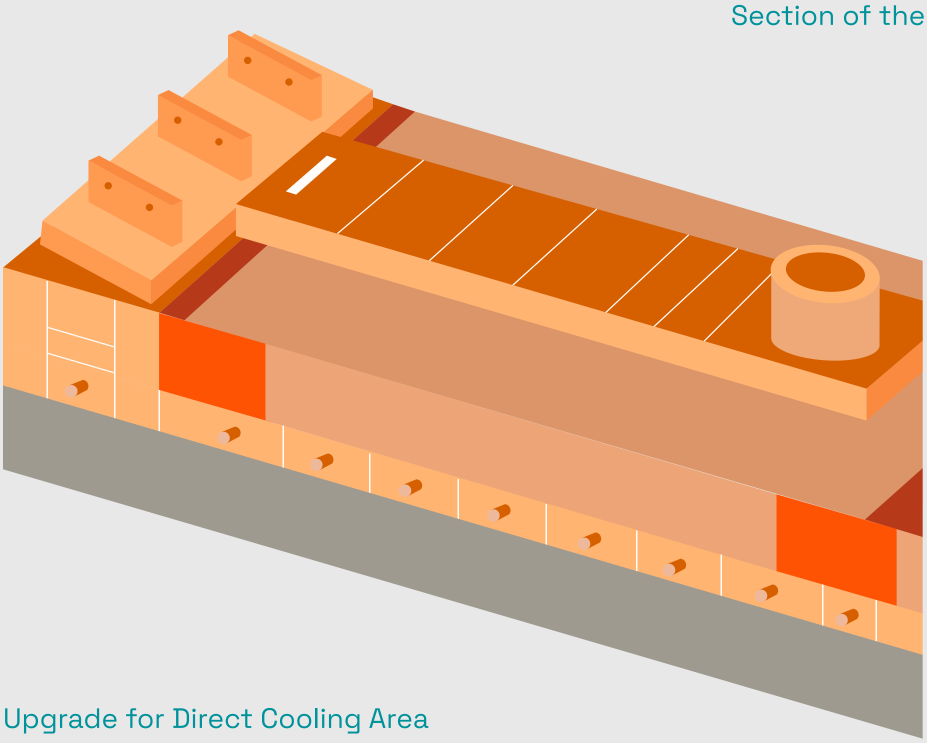
In combination with the electrical heating system, also a cooling system is needed to be installed for a proper glass conditioning.

Indirect cooling type in combination with the radiative zone (or massive heat dispersive zone) are the cooling solution for achieve the result: it means that no direct air goes in contact with the glass surface.

The radiative zones work in an efficient way and with even thermal dispersion when the glass temperature, especially at the entrance of forehearth, is still high. It is also possible a solution with 3 tiles (items) will be provided in order to have the possibility in balance the cooling effect between sides and center. The tiles open/close regulating system is manually operated with the possibility to make it automatic in a second stage using a pneumatic actuator to move each tile individually:

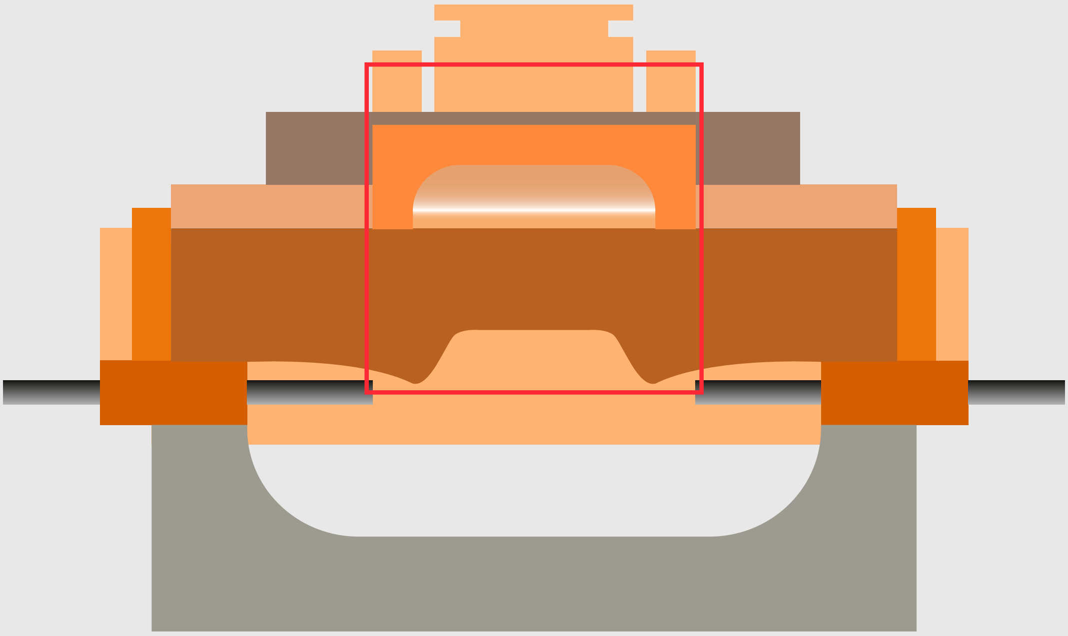


Section of the Radiating Zone



Upgrade for Direct Cooling Area

Then, the indirect cooling (with the possibility to move it also in combination with partially direct) permits the fine temperature conditioning:



Indirect Cooling Shape Section

Stability of the cooling air pressure to centralized cooling station is automatically effected by frequency controlled fan motor. The air flow control for each cooling zone is automatically operated by a servomotor driven by the pid regulator implemented into the control system.

Temperature measuring is effected in the cooling zones with single-level thermocouples, whilst in the equalizing zones three tri-level thermocouples are installed. This arrangement of thermocouples gives a 9-point grid measurement which provides a matrix to determine the thermal homogeneity of the glass in this location. Control of temperature is achieved by variation of energy input.

The control functions will be performed by the redundant software control system for furnace and glass conditioning system. Please refer at the image here below as an example

# COMBUSTION & COOLING

**COMBUSTION AND COOLING AIR**

To supply the correct volume of cooling and combustion air to the forehearth, only one blower is used, with significant saving in terms of investment costs and operating costs.

The system is preassembled in one unit, it contains the necessary number of operating fans and fans in stand-by and it is equipped with adequate absorbent support and filters.

## COMBUSTION & COOLING CONTROL UNIT

The rack is designed to control the gas-air mix, the cooling air and the damper air pressure, for each forehearths zones, by fully automated gas and air regulating valves.

- It is designed to keep the air/gas ratio steady
- Cooling and heating are grouped in one rack only
- Linear regulation valves are used to vary the flow according to valve opening
- Critical components for good forehearth management are pre-assembled and installed in a dedicated unit, usually positioned in an area less exposed to the heat coming from forehearths and w/e.

# COMBUSTION & COOLING UNITS

To control the heating and the cooling BDF provides a unit which is normally supplied preassembled and ready to be installed.

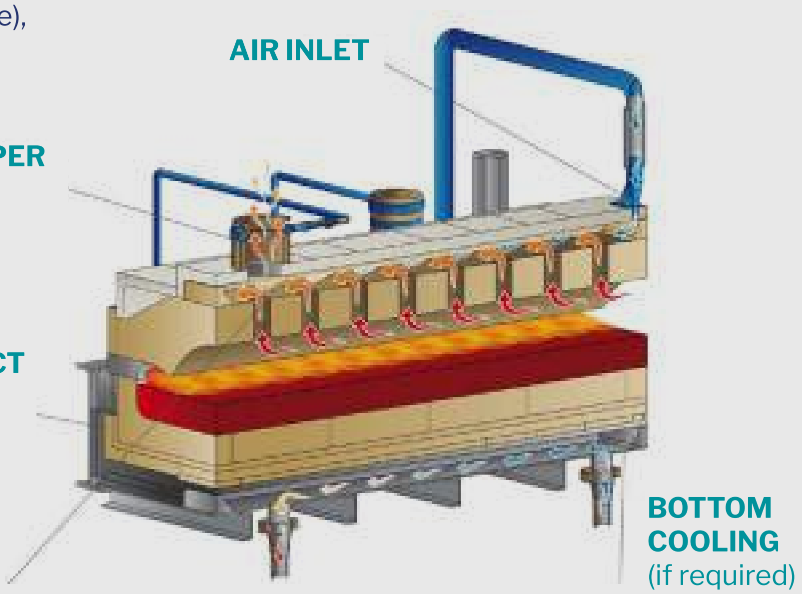
The same ventilators are used for the combustion and for the cooling. The air is fed into a main box to which the heating–cooling section are connected. The burners are installed on the forehearth sides, and they are fed with an air-gas mix, that is introduced in the room over the glass and that burns thanks to the ambient high temperature. The air-gas mix ratio must be kept constant, since any change compared to the optimal value could cause defects (most of all seeds and blisters).

This can be achieved by regulating the gas flow rate depending on the air flow rate, whose valve is operated by the control system. Each cooling and equalizing zone is equipped with an independent group feeding the burners. The temperature control system regulates the opening of the air valve depending on the value detected by the temperature sensor (optical pyrometer or thermocouple), independently on each zone.

The air -gas mix to be sent to the burners is generated independently per each section. A linear characteristic regulating valve with electric actuator is driven by the temperature control system to control the air flow which is passing trough a mixer. The air pressure is detected after the air regulating valve and it is used to control the gas flow by a gas regulator. The gas is fed into the mixer to achieve a proper air–gas mix to be sent to the burners.

The system is designed to assure a constant air–gas ratio in a range of 1 to 10 in terms of supplied energy. The cooling air flow is controlled independently per each section by a butterfly valve with electric actuator driven by the temperature control system.

The same actuator drives the air to be sent to the air damper to control the pressure into the forehearth superstructure in order to avoid fresh air infiltration through the chimney when the cooling is working at low capacity.



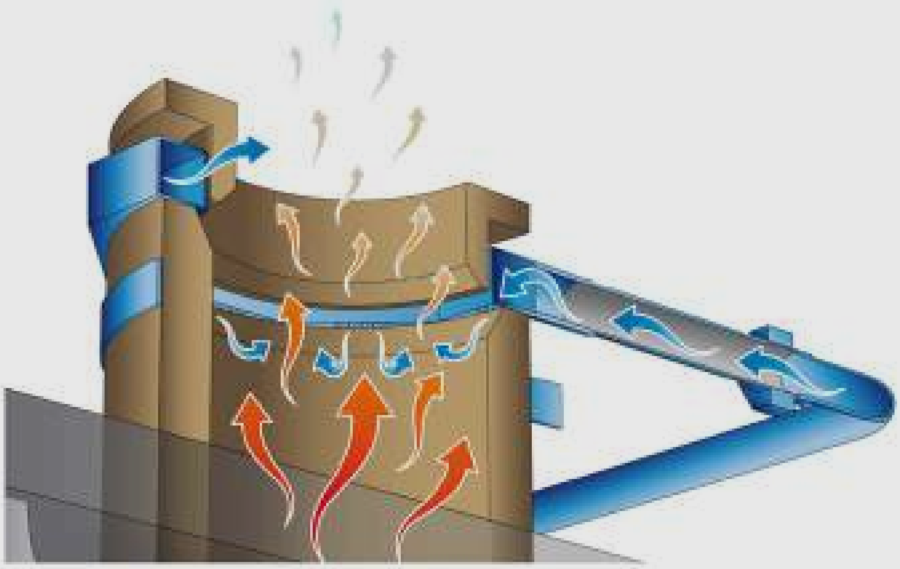

**COMBUSTION ROOF BLOCK COOLING**

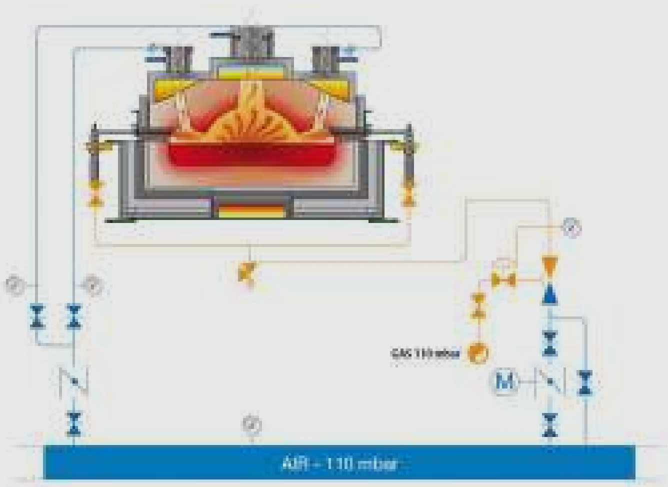
Over the superstructure is installed a small refractory channel that runs parallel to the foreheart axis. When cooling air is blown along this channel, the upper surface of the roof block is cooled. This reduces the temperature of the lower surface of the tile and energy is removed from the glass bath by radiative heat transfer to the cooled tile. The cooling air travels in the direction of the glass flow and is exhausted, together with the combustion gases, through the centrally located cooling air exhaust.
The volume of the cooling air blown along the channel is adjusted to vary the cooling effect, that is controlled by the flow regulation of the cooling air stream. The automatic control system will control heating and cooling functions within each independent zone.

# AIR DAMPER
# SYSTEM

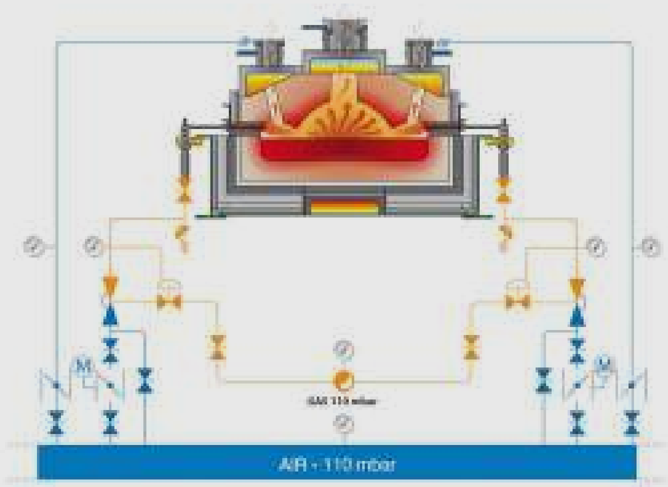
All exhausts are fitted with automatically controlled air dampers. The air damper is made of a series of internal concentric air jets creating an air curtain which is controlled to allow either cooling air enter into the superstructure or products of combustion to exhaust from the forehearth, depending on whether they act as a cooling air inlet or flue.
Air dampers represent an effective means of controlling forehearth pressure without the use on any moving parts, hence minimizing maintenance requirements.

The amount of cooling air entering the cooling channel and the position of the dampers are automatically regulated according to the cooling requirement of the forehearth.
The same actuator, that controls the cooling air flow, drives the air to be sent to the air damper to control the pressure into the forehearth superstructure in order to avoid fresh air infiltration through the chimney when the cooling is working at low capacity.






**STANDARD COMBUSTION**




**SIDE-BY-SIDE COMBUSTION**
(if required)

# EQUIPMENT

- Forehearth burner
- Eagle 3.1 - glass level
- Pneumatic - glass level
- Stirrer
- Measurement
- Working-end & forehearth control system
- Thermal map

# EAGLE 3.1 GLASS LEVEL MEASUREMENT SYSTEM

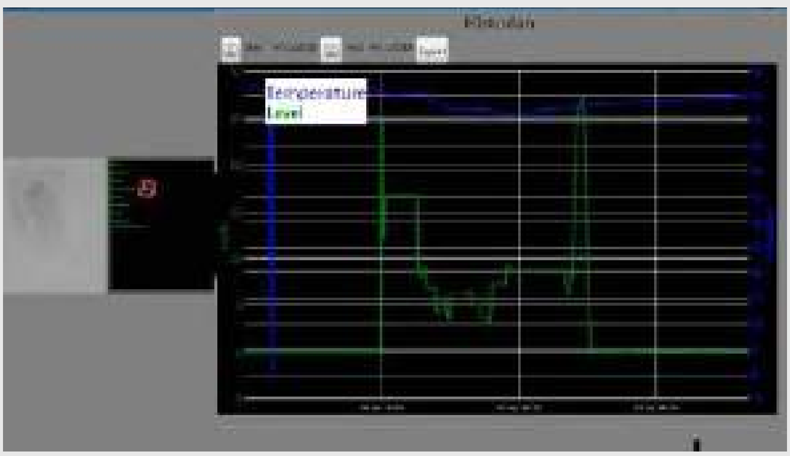
- No object in contact with glass or in the combustion chamber
- Nothing in movement
- Absolute level measure
- Easy to install
- Protective air curtain against dust
- Maintenance-free
- Self-calibrating
- Vibration proof

The new Generation Glass Level Measurement system. The system EAGLe 3.1 “Enhanced Absolute Glass Level” (Patented) allows to measuring the glass level through the optical reflection of a fixed pointer mounted out of contact with glass or the burner reflection. Innovative and technologically evolution of E.A.G.Le 2.0 and 3.0 is achieved: the new release 3.1 offers renewed features and improvements in the measurement and performance.

EAGLe 3.1 is composed of video camera placed in a rigid industrial casing and mounted at approx. 50 cm from the measurement point using a small hole (50x50 mm) in the furnace working end. A new protective air curtain is designed in order to avoid the possible dust coming out from the small hole. All the parameters of calibration and tuning can be read and set from whatever PC (Personal Computer) only one cable for data collection and power.

EAGLe 3.1 acquires and processes the images through advanced algorithms controlled by a system of Artificial Vision in an industrial computer equipped of a touch screen operator panel. The real pointer- reflected image or the burner reflection are acquired at high frequency enabling thus to establish the actual level of glass with absolute precision higher than ±0.01mm. EAGLe 3.1 is self-calibrating and vibration-proof. EAGLe 3.1, thanks to the characteristics described, is the most advanced glass level measuring device present on the market.

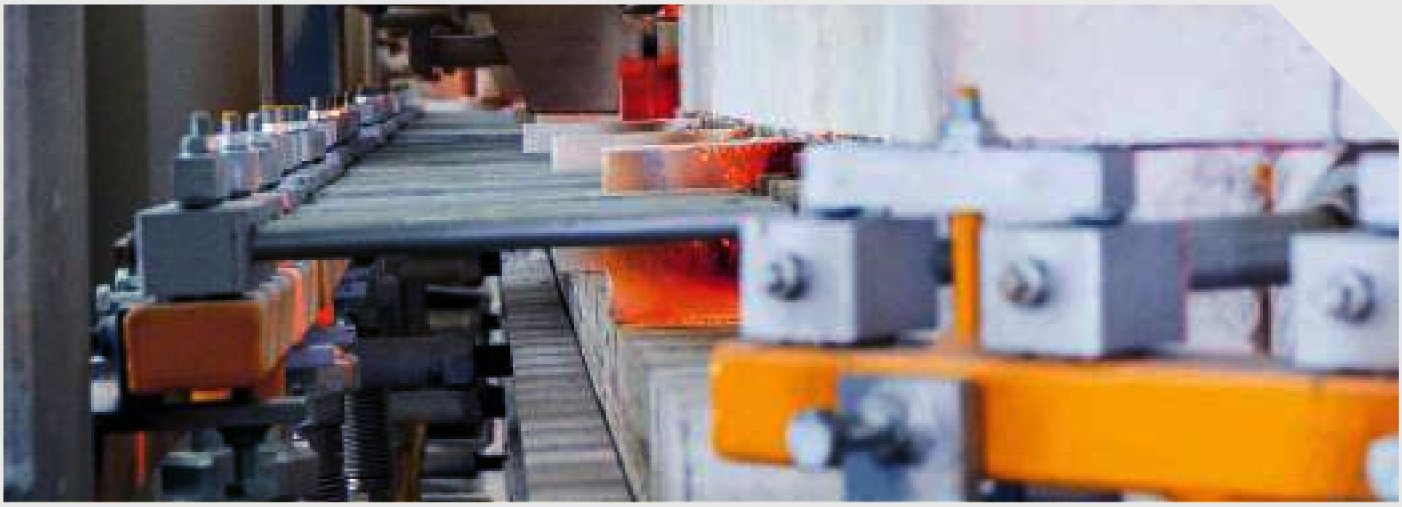
**Eagle 3.1** Supervision control system
Standard user-friendly supervision in operation



## BURNERS

The burners are installed on the forehearth sides and they are fed with an air-gas mix, that is introduced in the room over the glass and that burns thanks to the ambient high temperature.
The air-gas mix ratio must be kept constant, since any change compared to the optimal value could cause defects (most of all seeds and blisters).

Each nozzle has a working area calculated on the basis of the energy required in each zone, according to the outcome of the thermal balance calculation. In order to prevent any possible damage in case of backfiring, safety heads are installed, which purpose is to open in case the operating pressure exceeds the normal values.



## STIRRER

With BDF stirrer mechanisms it is possible to achieve better quality in glass homogenization and better production flexibility of coloring forehearths.

The system consists of a steel structure and a couple of mixing units typically installed on forehearths equalizing zone.
The mixing units, made of refractory material, are drawn with special profile, apt to improve the glass temperature homogeneity and thus contributing to reduce any possible defect, such as the “cat scratches”, by mixing mechanically the Zirconium in the molten glass.

- Sliding bracket motion for easy maintenance or refractory parts replacement
- Different configuration up to 4 stirrers
- Independent rotation for left/right 4-stirrer group
- Same rotation or counter rotation for each stirrer
- Remote electronic control for speed and direction

# SCADA SOFTWARE

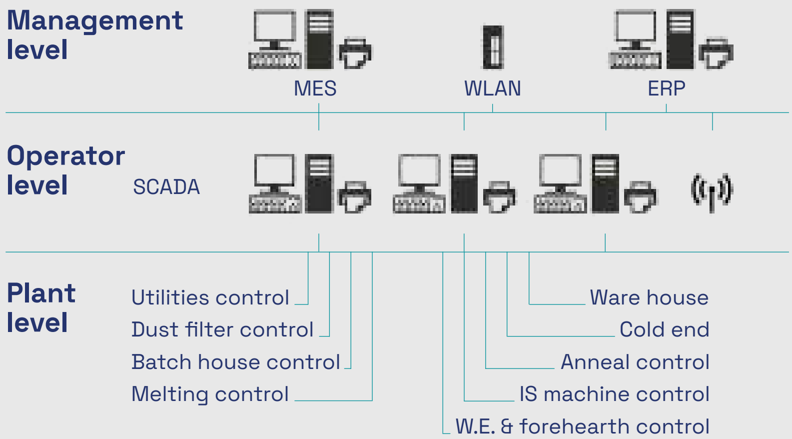
BDF SCADA system is completely open since is based in Ignition™ to other devices also as smartphones and tablet.

User management and also trend control is really simple and reliable and very useful for diagnostic in plant or by remote.

BDF also propose a Data collecting Historian product called PANORAMA. PANORAMA is oriented to fulfill all the requirements of the Industry 4.0 giving our customer the possibility to concentrate and synchronize all the BDF equipment in a single historian archive, to manage and edit report, to redirect and manage alarms (even to SMS or mail) and possibly to add manual entry (as Pull or Pack to Melt) for statistical reason.

Control cabinet

## GENERAL PROCESS CONTROL ARCHITECTURE




Control systems focused on key- performance factors to grant:

- Minimum Energy Consumption and Operation Cost
- Glass Quality
- Low Polluting Emission
- Furnace Life-Time
- Reliability elaboration of Trend Process

The System allows effective, reliable control and recording of real time or historical data during the whole furnace campaign.

Continuous monitoring and control of parameters such as:

- Pilot Temperatures
- Combustion
- Electric Energy and Energy Consumption

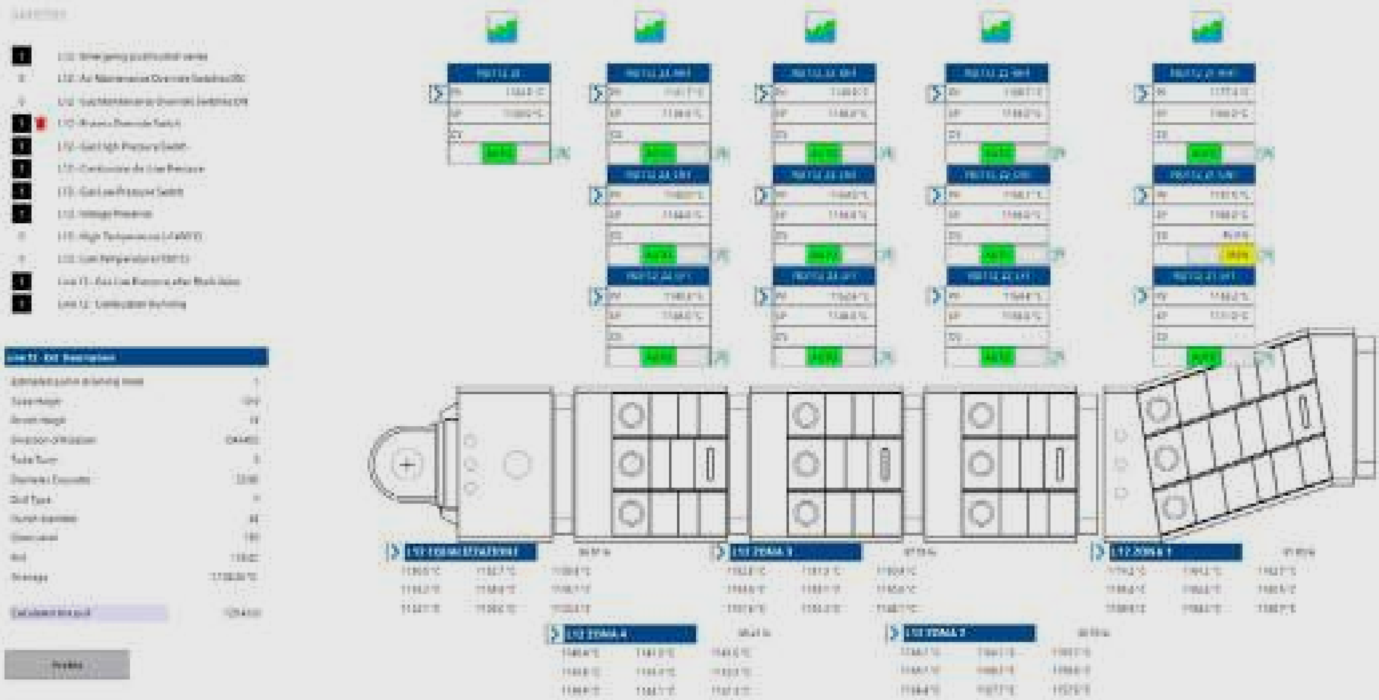
Flexible application:

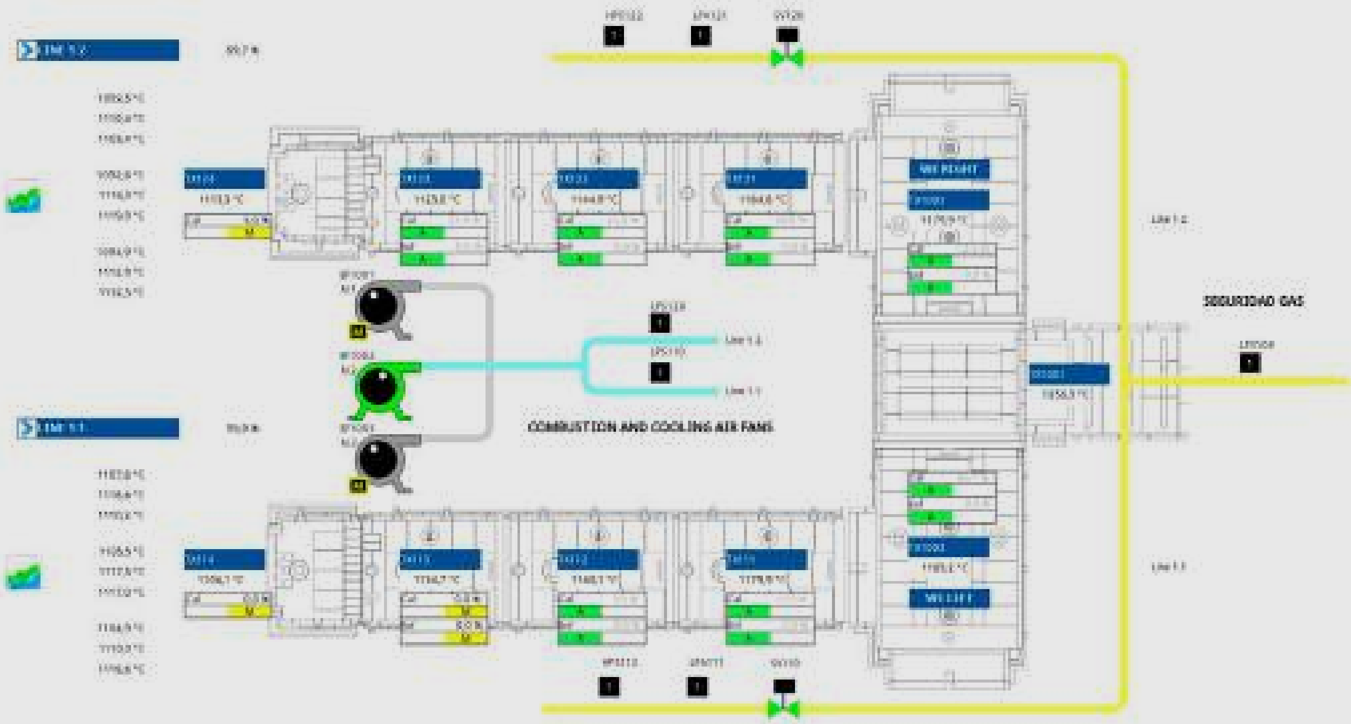
- Full supply or integration with most best-known PLC brands.
- Integration with glass plant Supervision via SCADA system (Supervisory and Data Acquisition).

The application of a SCADA acquisition system creates a multi-terminal network for a fast access to required information and grants a constant overview of:

- Process
- Centralized Controls
- Historical
- Trend
- Correlation between different areas of the plant process.

Access from different places and with hierarchies levels is available to ensure a proper flexibility and safety managing.




COMBUSTION AND COOLING AIR FANS
SEGURIDAD GAS

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