

GLASS MELTING TECHNOLOGY

INNOVATION ENGINEERED IN GERMANY

HORN GLASS INDUSTRIES

Presentation

17th Conference on electric melting of glass

on 10th of September 2019 / UCT Prague

Electrical heating systems for glass conditioning

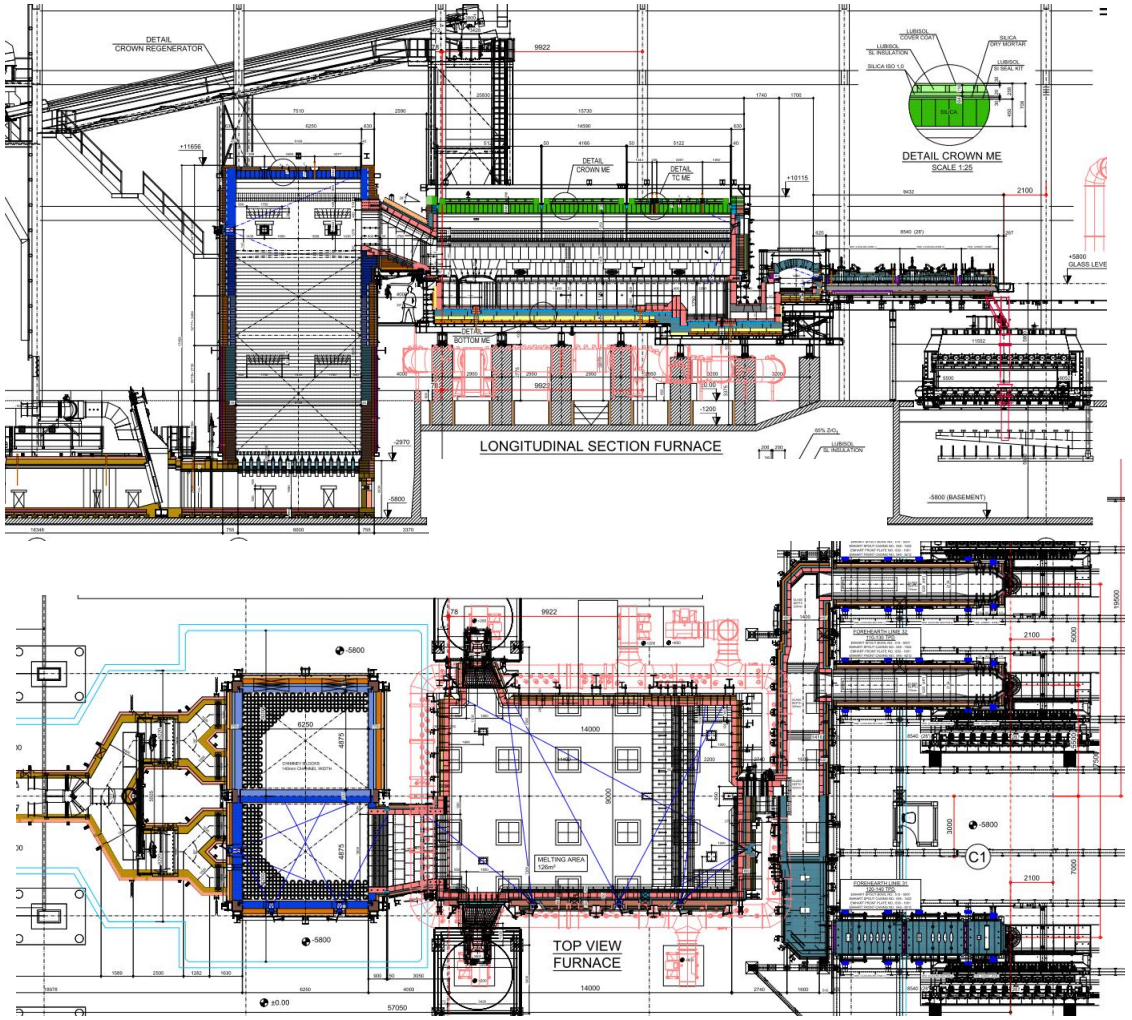
Lecturer: Dipl.- Ing. Joachim Gesslein

Glass conditioning

CONTENT

- basics and overview for glass conditioning
- basics for direct heated glass conditioning systems
- EQS boosting for improving TH index
- EQS boosting installation- and operation examples
- direct heated glass conditioning systems
- indirect heated glass conditioning systems
- comparison of all electric and fuel heated systems
- advantages, disadvantages, limits, operation
- special applications (overview)

Glass conditioning - basics





Example of a regenerative end fired furnace for container glass with 3 production lines

Glass conditioning - basics

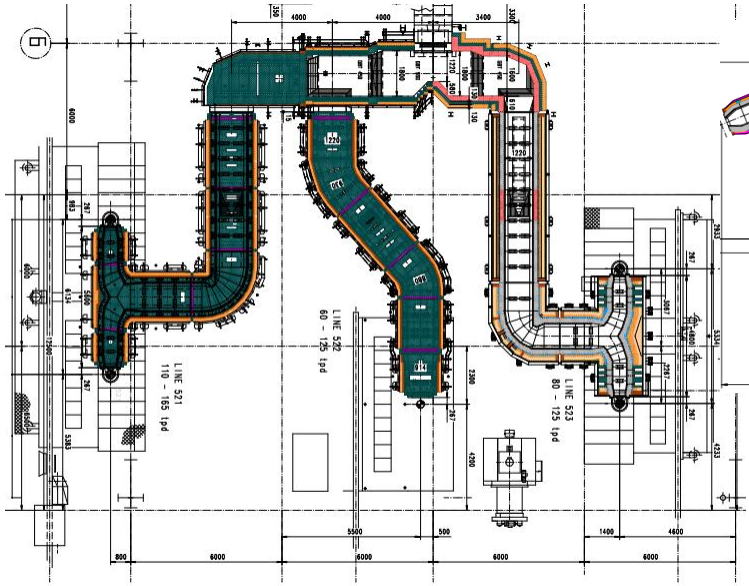
What are the most important requirements for glass conditioning ?

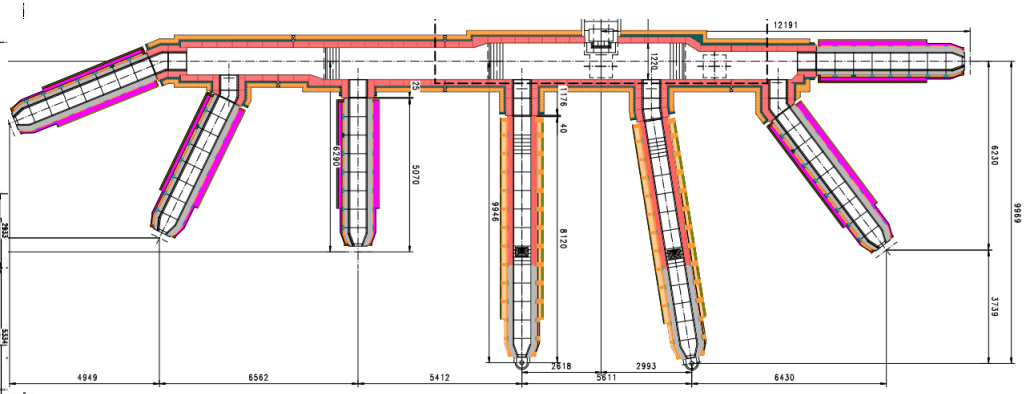
- main task for glass conditioning is the transport of the glass to the several gob points
- adjust the glass temperature to the necessary range for the forming process
- stable glass temperatures at the end must be reached (+/- 0,5 K)
- high thermal homogeneity especially for press & blow process is required
- high pull range up to a relation of 1 : 5 with generally pull ranges between 5 … 200 tpd
- multi gob production at the same IS machine possible (SG / DG / TG / QG)
- up to 800 gobs per minute with weights from 10 gram to 2500 gram are generally possible
- high job change frequency up to 3 times weekly with job change time up to 2 hours
- high thermal flexibility is required with fast reaction of cooling and heating systems
- colour changes up to 3 or 4 times yearly
- high requirements to the gob shape-, weight and temperature distribution
- by the way a less maintenance and energy consumption is additional required





Glass conditioning - basics





layout for container glass production **layout for table ware production**

- glass conditioning covers the area between the melting and the forming process
- very complex layouts are possible, depending on the production and available space
- energy consumption is around 10–20 % additional to the melting, up to 40 % are possible
- mainly heated with gas-air mixture systems (for mass glasses)
- in some cases electrical heated or additional electrical heating systems are necessary

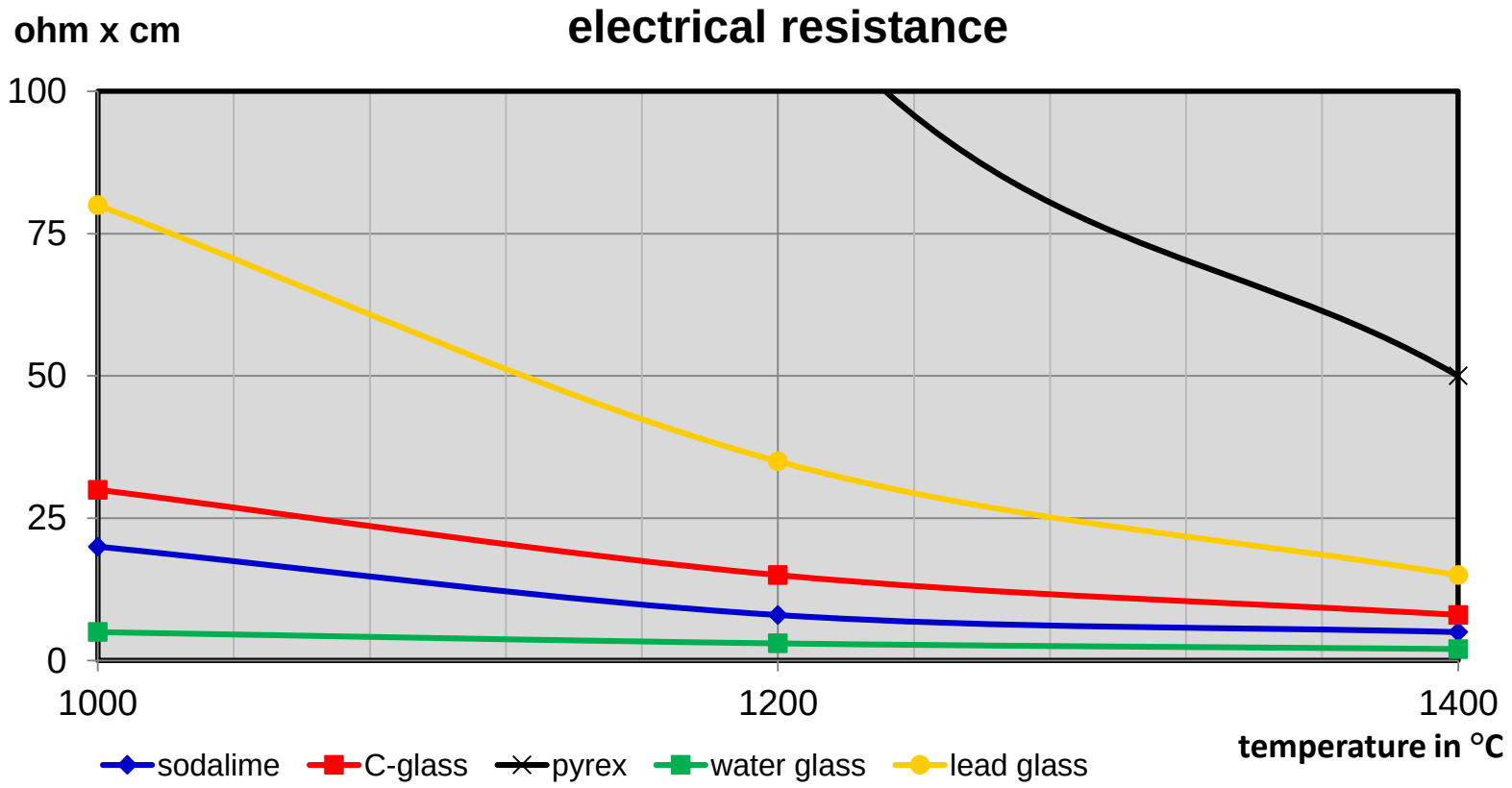
Glass conditioning - basics

example for a typical FH – type HORN GCS 301



Basics - direct heated systems

What are the necessary preconditions for direct heated systems?



The electrical current flow is achieved by ion conduction. An important pre condition is a high electrical conductivity or low resistance in the temperature range of glass conditioning system!

Basics - direct heated systems

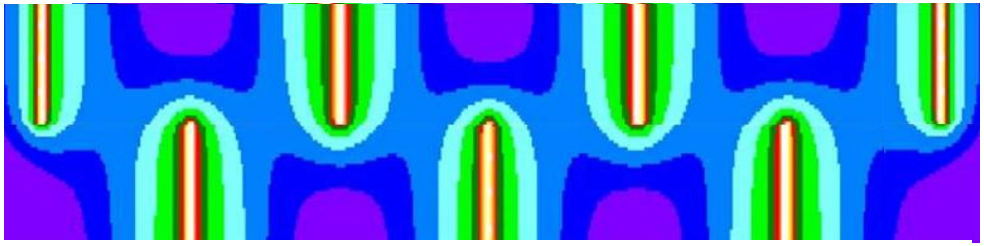
What kind of electrode material are available ?

	molybdenum	tin oxide	platinum
possible specific load	max. 0,5 A/cm²	max 0,7 A/cm²	max. 2,0 A/cm²
density	10,30 kg/dm³	6,95 kg/dm³	21,45 kg/dm³
advantage:	low costs easy installation	oxidized glass no reaction	normally less reaction potential
disadvantages:	sublimation over 450 °C	low thermal shock resistance	normally high (1-10 kHz) freuqency required
	reaction with oxidized glass	high voltage necessary	reaction possible with reduced glass
	chemical reaction (limits see below)	high corrosion over 1350 °C	
application:	soda lime glass C-glass borosilicate glass (lower quality)	lead crystal glass	borosilicate glass (high quality)
recommended limits:	Na_2SO_4 $NaNO_3$ AsO_3+Sb_3O_4	max. 5,0 kg/t sand max. 3,0 kg/t sand max. 0,25 kg/t sand	

Basics - direct heated systems

How we make the engineering for direct heated systems?

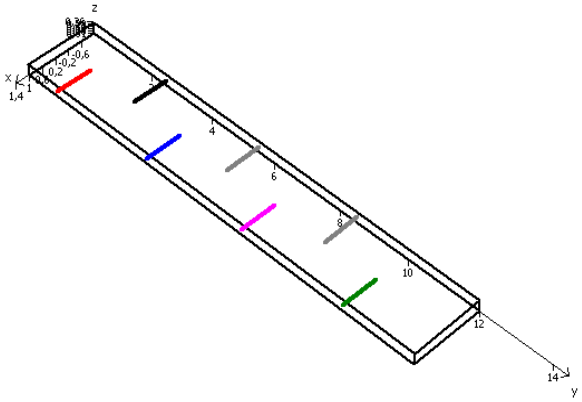




example C-glass FH

Berechnungsergebnisse

Elektrode	System	Elektroden-strom A	Phasenwinkel El.-strom Grad	Elektroden-stromdichte A/cm²
Elektrode 1	System 1	423	17,90	0,131
Elektrode 2	System 1	613	156,67	0,190
Elektrode 3	System 1	623	-92,97	0,194
Elektrode 4	System 1	561	30,05	0,174
Elektrode 5	System 1	624	152,95	0,194
Elektrode 6	System 1	612	-96,57	0,190
Elektrode 7	System 1	444	41,35	0,138



Systemleistungen

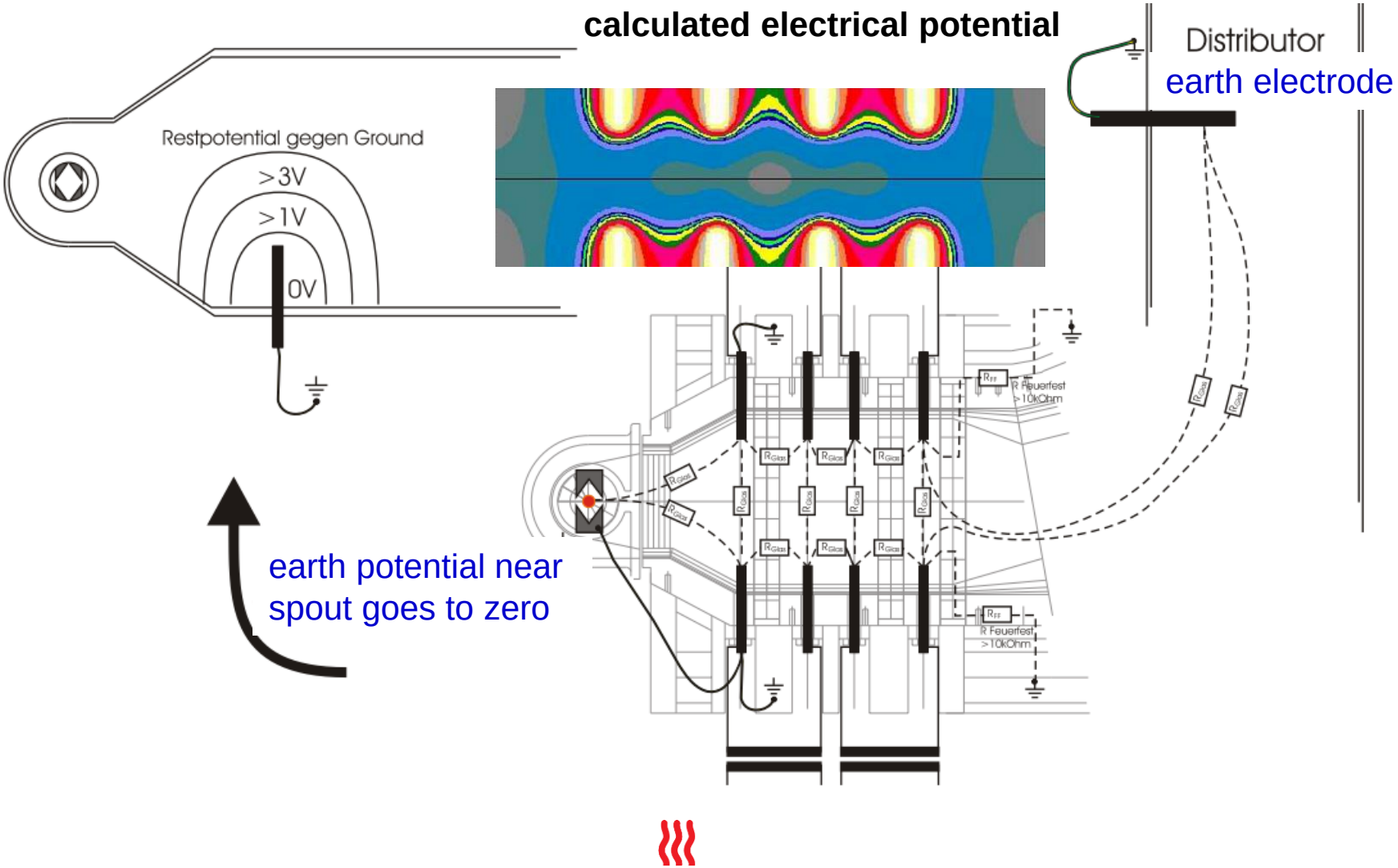
System	Leistung W
System 1	2,3474547E+05
Gesamtleistung	**2,3474547E+5**

with a special calculation software is it possible to calculate the main important electrical parameters and the 3D potential field together with additional validation of existing installations!



EQS Boosting

How does an EQS boosting system works?

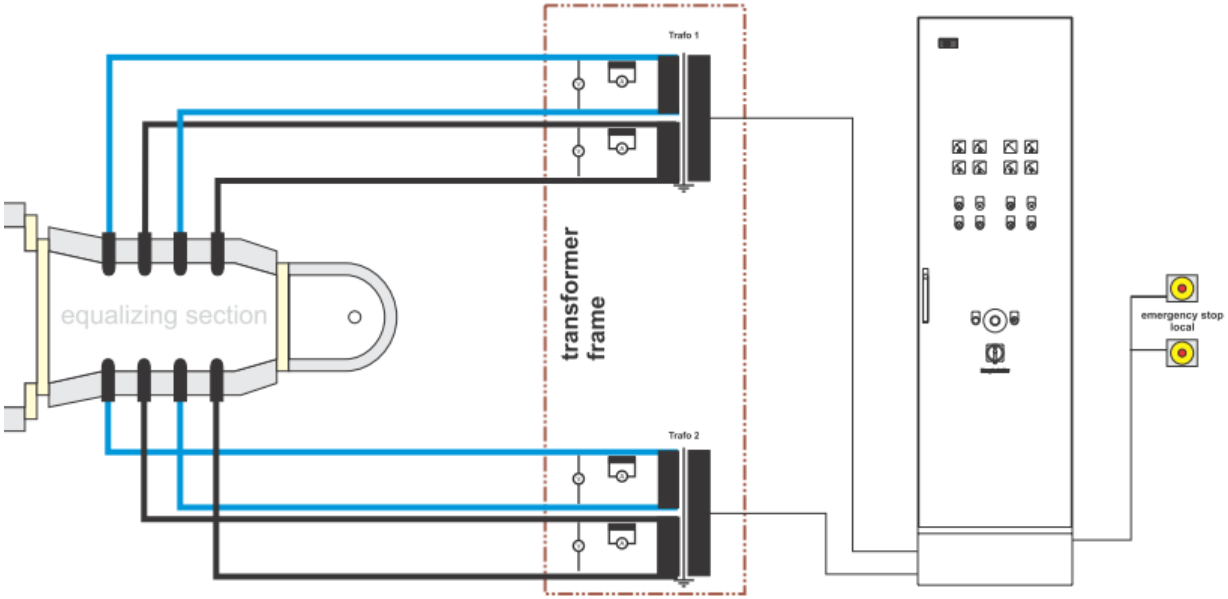


EQS Boosting

What are the installation basics?

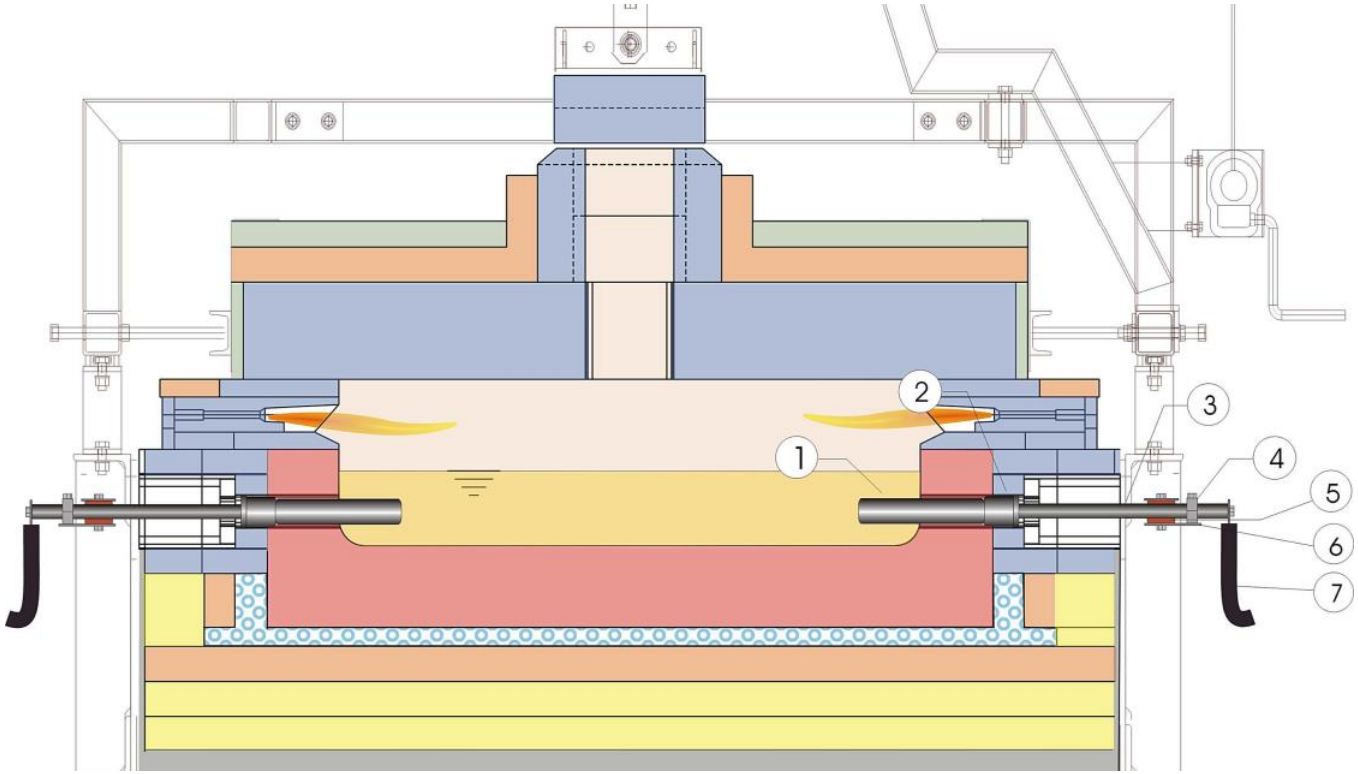
EQS standard boosting transformer data:

- transformer type 2 phase dry transformer
- installed power 2 x 20 kVA (total 40 kVA)
- primary voltage 400 VAC with 50…60 Hz
- secondary voltage 2 x 100 V AC
- secondary current 2 x 100 A



EQS Boosting

Which equipment is necessary ?



1 molybdenum electrode
2 electrode sealing
3 connection rod heat resistant steel
4 mechanical fixation
5 electrical connection
6 electrical insulation
7 power cable

EQS Boosting

What are the installation basics?

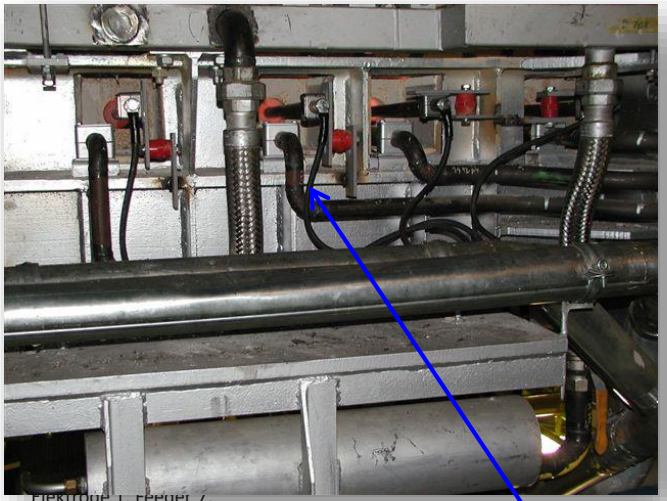
HORN standard EQS boosting system installation basics:

- normally 2 x 4 molybdenum electrodes with 2 transformers (left and right)
- transformer dry type with 2 phase connection and thyristor power control
- transformer with 1 primary and 2 secondary windings with 2 x 20 kVA
- real consumption is around 5 … 10 kVA depended on operation conditions
- manual power or current control is possible
- in HORN PLC it is possible to control the outside EQS temperature (middle/bottom)
- extended versions with more electrodes for high pull FH's is also possible
- later installation during hot operation is also possible in case of a need
- channel blocks should by designed in high quality glass contact material (ZM20 / KR95)
- for high quality and high temperatures is 32 % AZS void free quality recommended
- for hot FH's (small glass articles) HORN recommend the installation of cooling air
- for special glasses (borosilicate, C-glass) HORN recommend air cooled holders

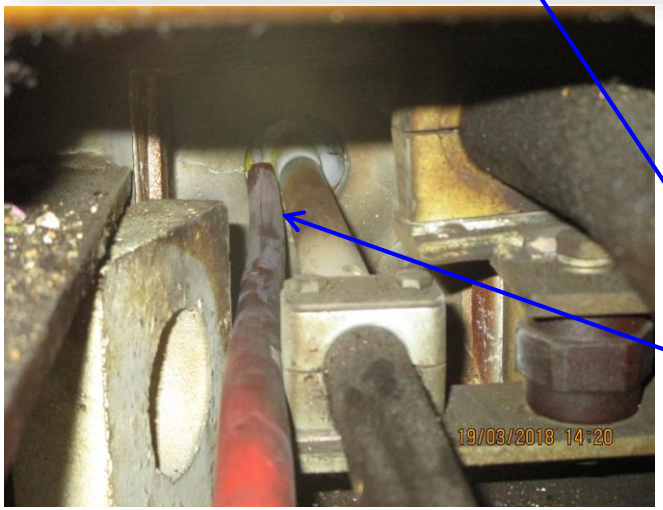
HORN supplies all heating parts including electrodes, transformers and control systems!

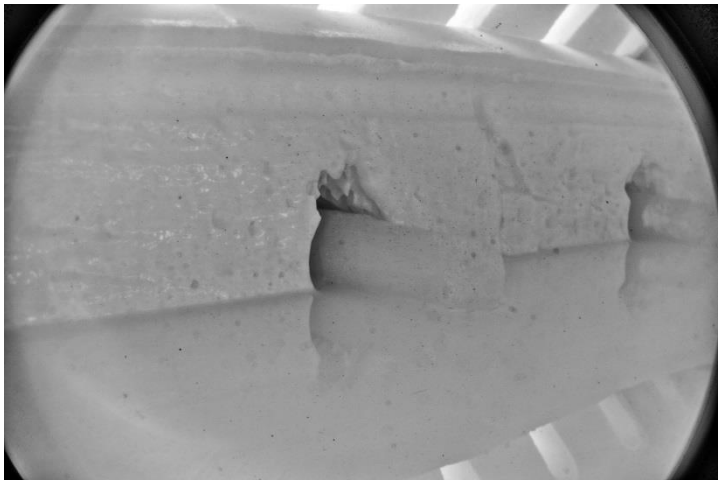
EQS Boosting

Installation examples



Elektrode 1, Feeder 7,
19.03.2018





hot inspection amber glass FH

- approx.1260°C in EQS
- glass contact material is ZM
- low corrosion after 6 years in operation

air cooling to avoid glass leakage

EQS Boosting

What are the general recommendations ?

EQS boosting recommendations from HORN:

- for glasses with low thermal conductivity (amber & green)
- for multi gob production (TG / QG …) with high THI requirements
- for press & blow forming processes
- for high flexible FH systems with a wide pull range and often job changes
- for multi colour glass conditioning systems
- for more accurate temperature adjustments in front of spout
- improve the THI from existing FH installations with inadequate performance
- installations in flint glass only partially recommended
- normally it is installed from the beginning of a furnace campaign
- it is designed for normal furnace lifetime (>10 years are possible)
- no change or push in during the normal operation required
- this is achieved by low specific current load at the electrode surface max. 0,50 A/cm²
- during the operation it must be ensured the molybdenum is always covered with glass!

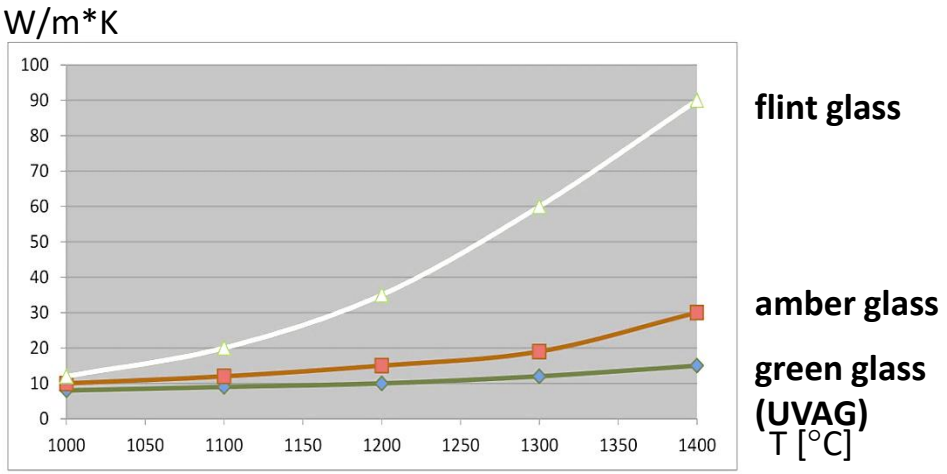
Please attend that flint glasses with high oxidizing redox state and high SO_3 content the sulfur can react with the molybdenum. This can lead into a formation of bubbles and corrosion of the molybdenum electrodes!

EQS Boosting

Why is EQS Boosting necessary?



thermal conductivity f(T)



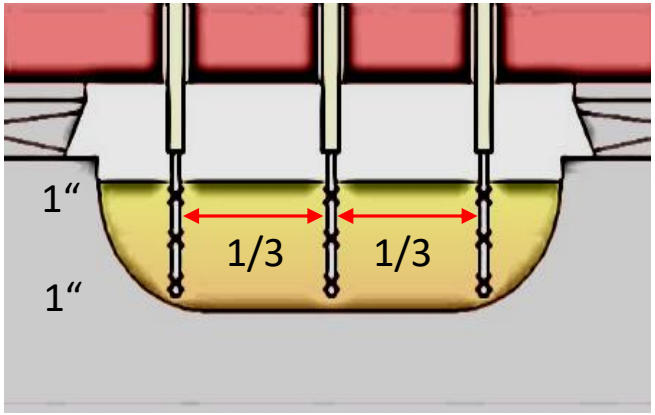
- heat transfer and temperature equalizing occurs mainly about radiation
- thermal conductivity depends on concentration of Fe and Cr and the redox state
- amber and reduced green (UVAG) with high Fe content is most difficult

Low radiation conductivity creates higher temperature differences!
Low radiation conductivity needs slower cooling velocity and longer equalizing time!

EQS Boosting

What is the thermal homogeneity and how is the calculation?

Calculation method by HORN (Original from OI / Emhart)



vertical differences

difference 1-3 = 3

difference 4-6 = 1

difference 7-9 = 8

horizontal differences

difference 1-4 = 0 K

difference 2-5 = 3 K

difference 3-6 = 2 K

difference 4-7 = 1 K

difference 5-8 = 4 K

difference 6-9 = 8 K

example for FH THI calculation:

#1 = **1169**	#4 = **1169**	#7 = **1168**
#2 = **1167**	#5 = **1170**	#8 = **1166**
#3 = **1166**	#6 = **1168**	#9 = **1160**

summary of all differences = 30 K

hottest temperature centre line = 1170 °C

THI = 100 – 30 / 1170 = **97,4** %

EQS Boosting

What are typical requirements to the thermal homogeneity ?

The thermal homogeneity index (THI) is measured in front of the spout with an 9 point TC grid and calculated with a mathematical formula (100 % means that all temperatures the same) It is an important precondition for a good gob shaping, gob fall and the forming process. The requirements to the thermal homogeneity depends mainly from the number of gobs and the forming process.

lower requirements are necessary for blow & blow process:

- typical THI range is between **90 …..93 %**

higher requirements are necessary for press & blow process:

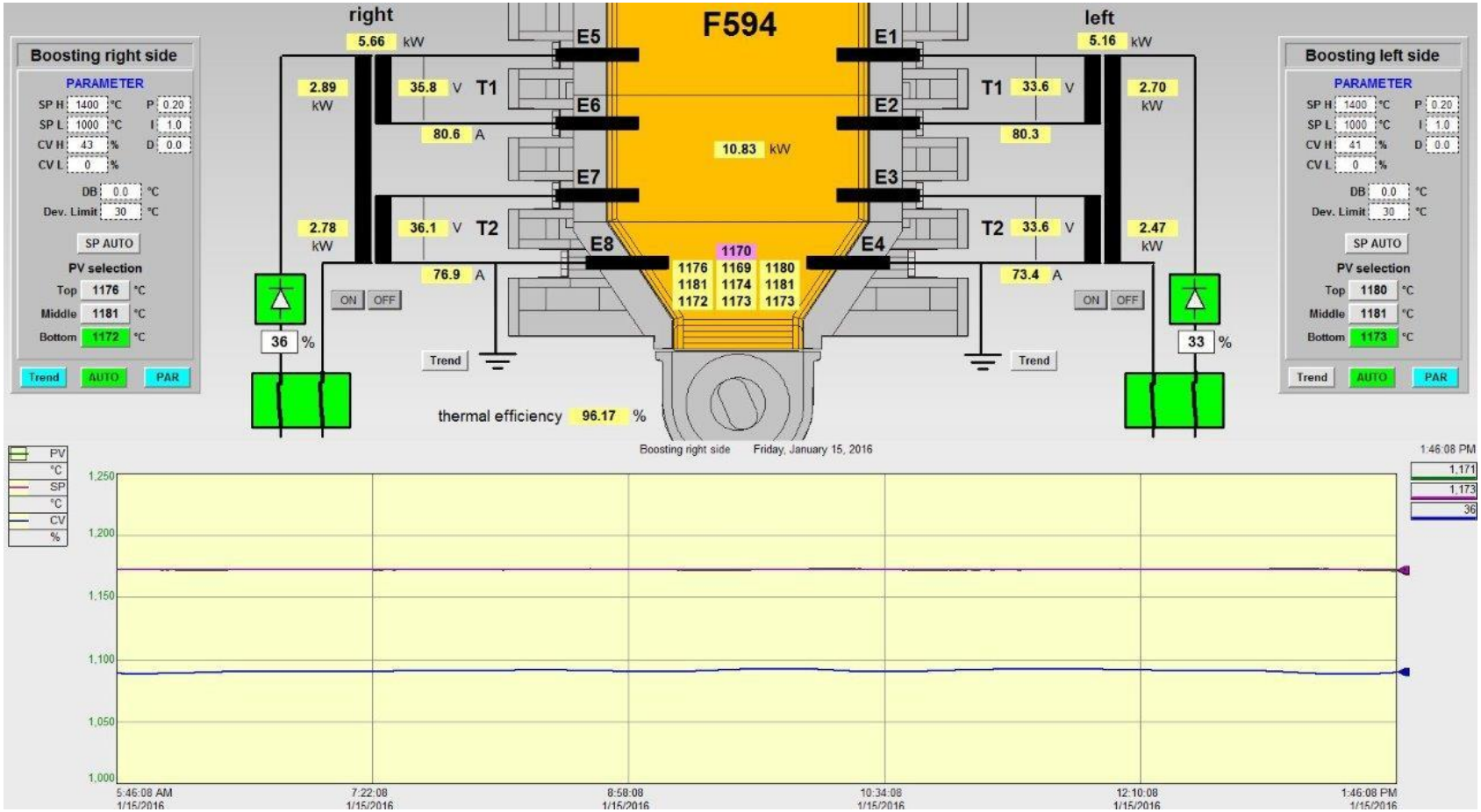
- typical THI range is between **93 …..96 %**

For multi gob feeding systems are higher values necessary to be sure, that all gobs have same weight and shape and can be achieved only with small plunger and tube adjustments !

Highest requirements are necessary for TG/QG IS machines and for press & blow processes! With EQS boosting systems the TH index and the job change time can additional be improved!

EQS Boosting

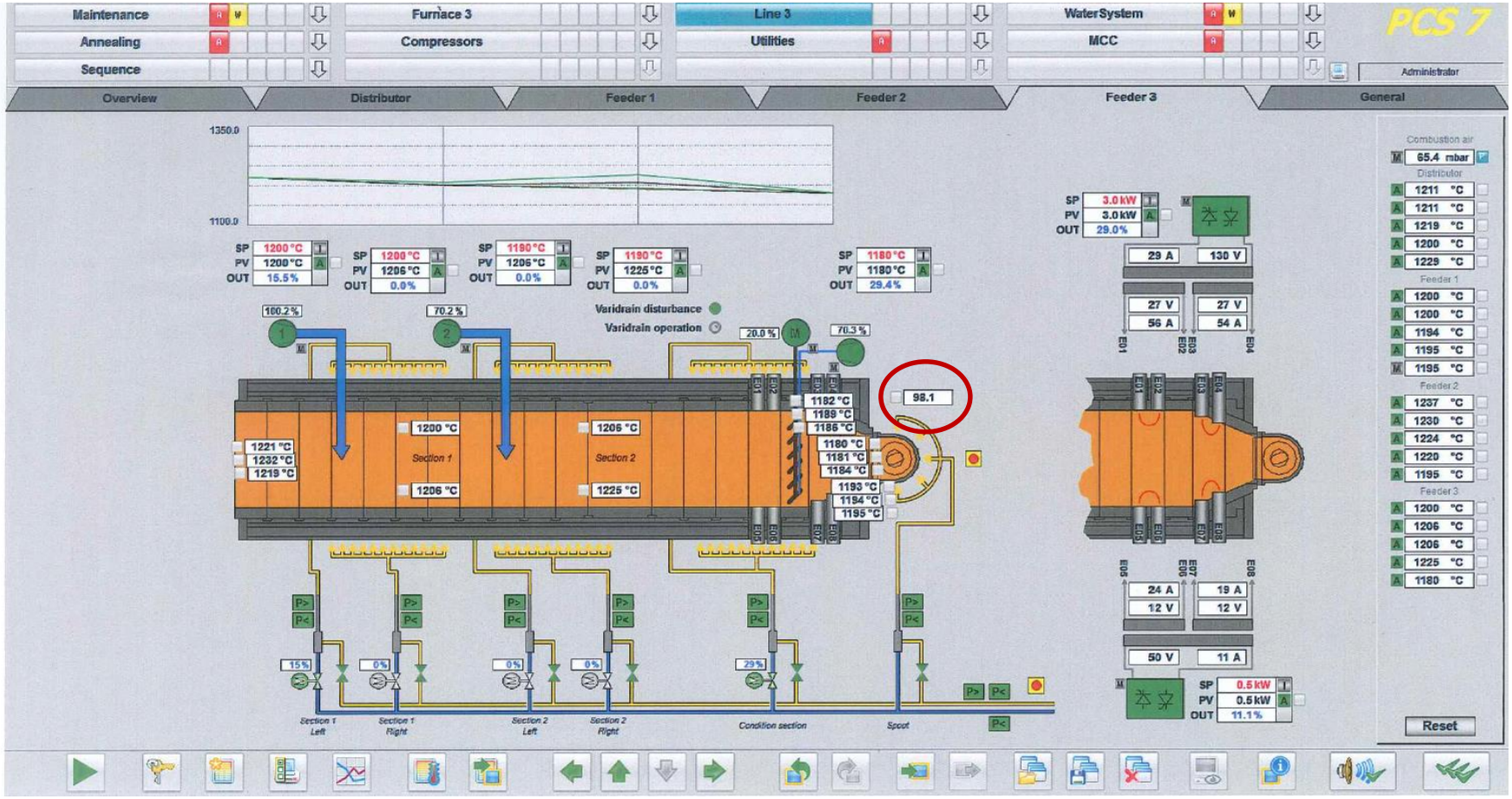
HORN operation examples



FH 140 tpd amber NNPB-Process THI = 95,4 % (Emhart formula) temperature controlled

EQS Boosting

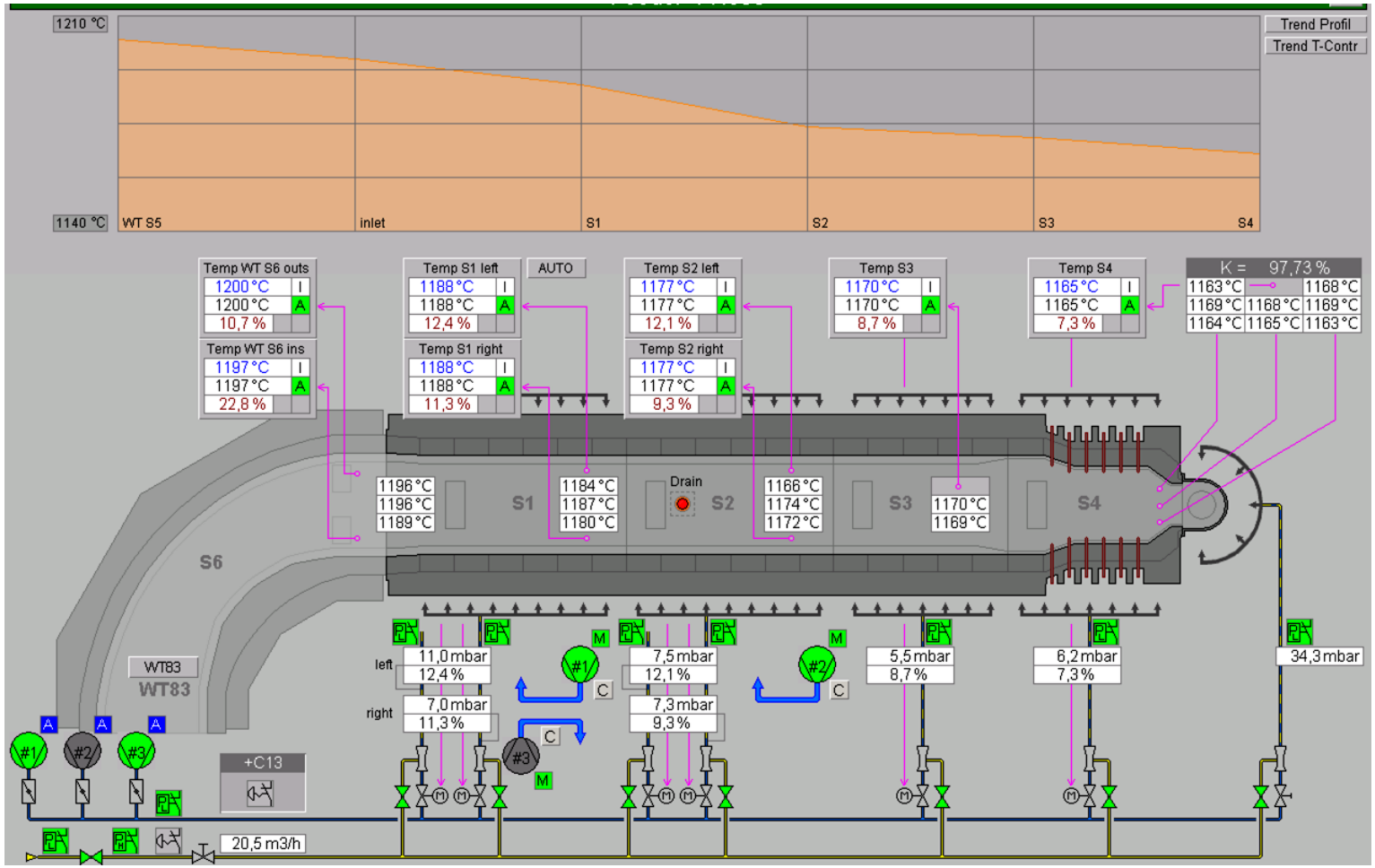
HORN operation examples



FH 127 tpd green NNPB-Process THI = 95,0% (Emhart formula)

EQS Boosting

HORN operation examples

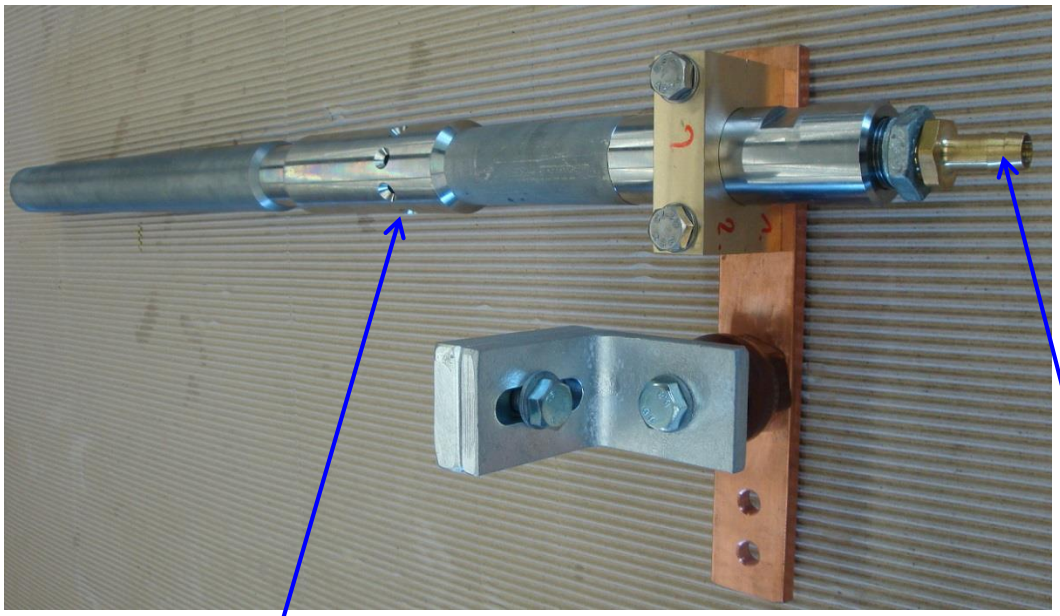


FH 150 tpd green THI = 97,7% (Emhart formula)

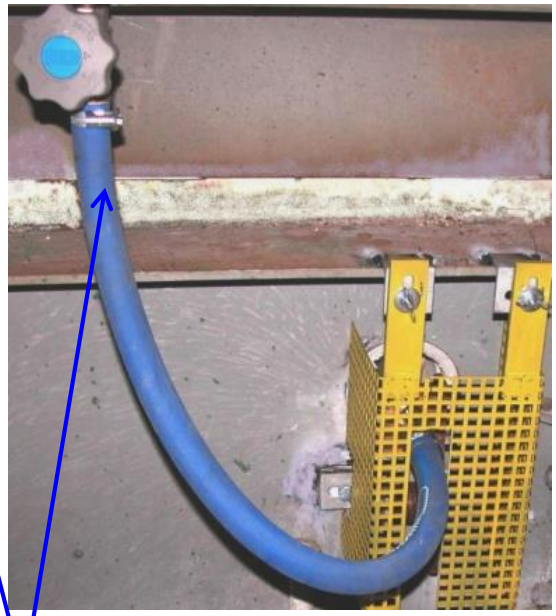
Direct heated systems

Molybdenum electrode for high temperature applications

FH electrode VEL 48 with direct air cooling - preassembled



cooling air outlet

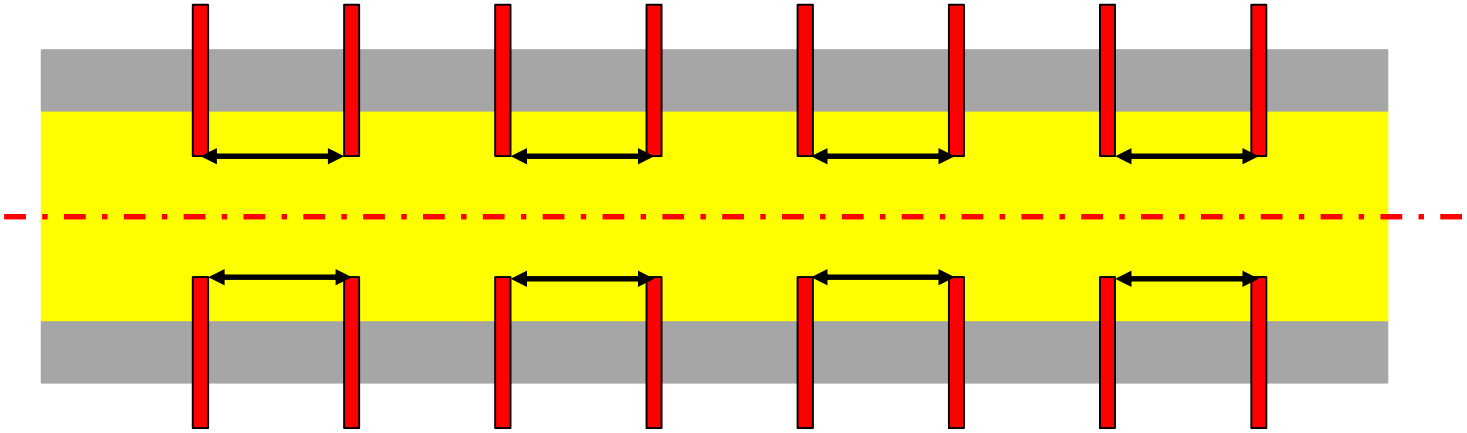


cooling air inlet

This electrode type is recommended for special glass applications with a higher cooling effect in the connection area to the molybednum and the surrounding refractory!

Direct heated systems

heating systems with sidewall molybdenum electrodes

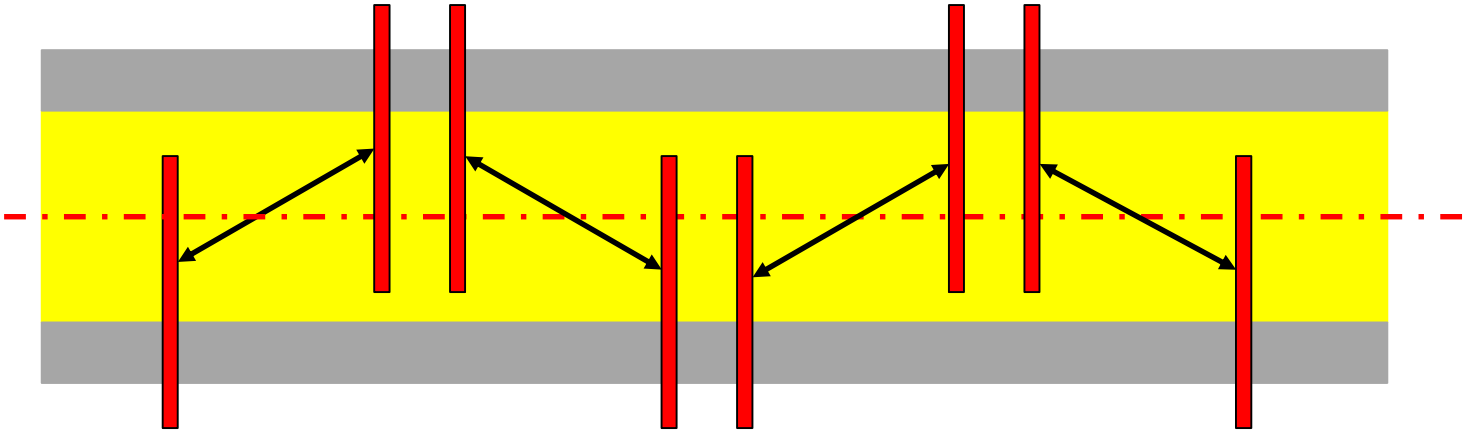


example 1 **full electrical FH designed for soda lime glass**

- typical application in soda lime glass when no heating gas available
- superstructure is similar to normal installations
- for heating up a special system with additional burners are required
- water plug system or electrode protection during commissioning required
- good heating of outer glass areas possible
- very high thermal homogeneity
- fast reaction und good control behaviour
- problems with glass defects can be occur in oxidizing glasses

Direct heated systems

heating systems with sidewall molybdenum electrodes

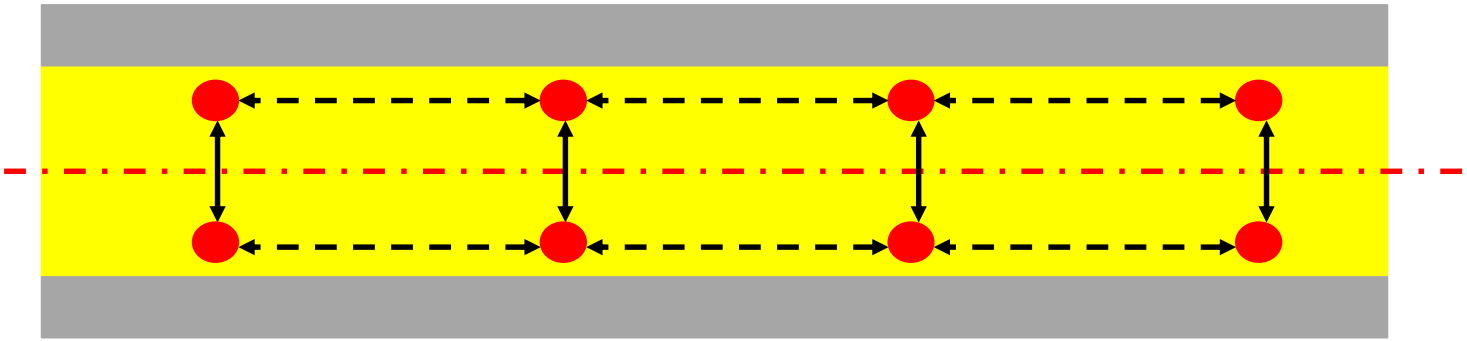


example 2 **full electrical FH designed for C - glass / borosilicate glass**

- typical application for glasses with high evaporation potential
- superstructure is similar to normal installations or with closed surface
- additional firebox especially for borosilicate glass recommended
- reduced number of electrodes possible (half of example 2)
- for larger channels also 2 electrode levels recommenden
- for heating up a special system with additional burners are required
- water plug system or electrode protection during commissioning required
- fast reaction und good control behaviour

Direct heated systems

heating systems with molybdenum top electrodes

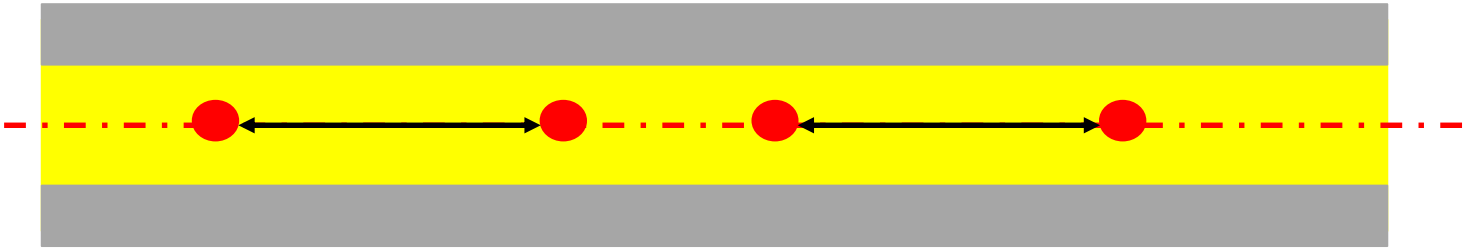


example 3 **full electrical FH designed for high quality special glass**

- typical application for glasses with high quality requirements
- heating along or cross to glass flow direction
- superstructure is with closed surface without firebox
- installation of top electrodes (water cooled recommended)
- for heating up is a special technology required
- fast reaction und good control behaviour

Direct heated systems

heating systems with molybdenum top electrodes

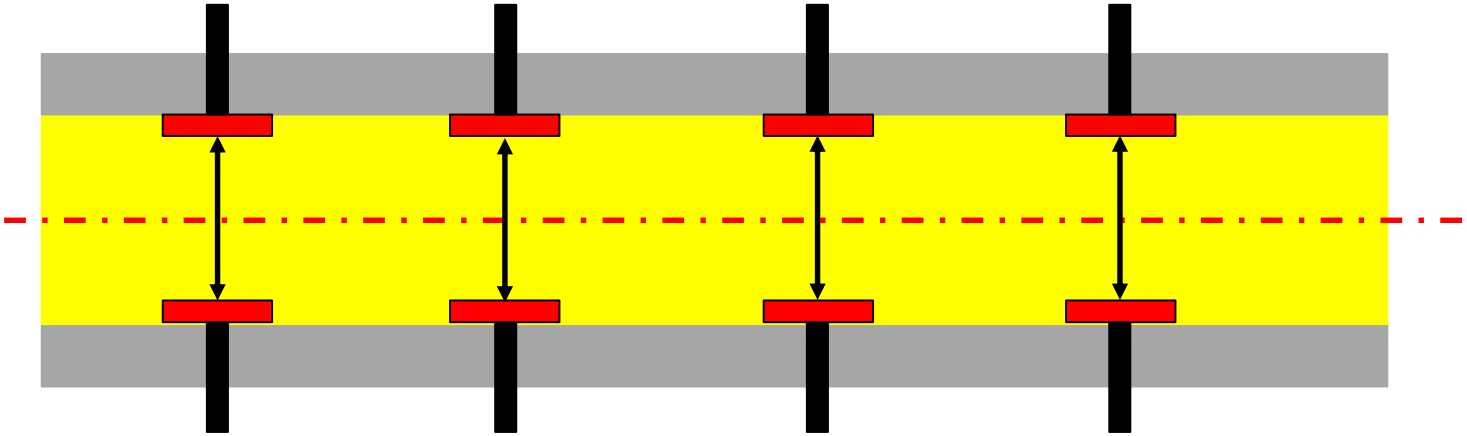


example 4 **full electrical FH designed for high quality special glass**

- typical application for glasses with high quality requirements
- designed for less pull with a smaller and deeper channel design
- heating along to glass flow direction
- superstructure is with closed surface without firebox
- installation of top electrodes (water cooled recommended)
- for heating up is a special technology required
- fast reaction und good control behaviour

Direct heated systems

heating systems with platinum plate electrodes



example 5 **full electrical FH designed for high quality special glass**

- typical application for glasses with high quality requirements
- superstructure is with closed surface
- high frequency converter system required (up to 10 kHz)
- for heating up is a special technology required
- fast reaction und good control behaviour
- very expensive system
- alternatively is a direct heated platinum tube possible

Indirect heated systems

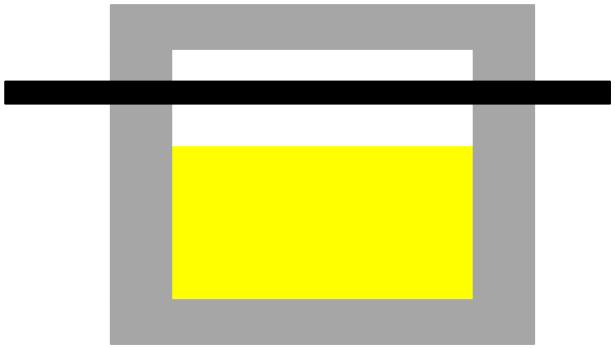
What kind of heating material is when recommended?

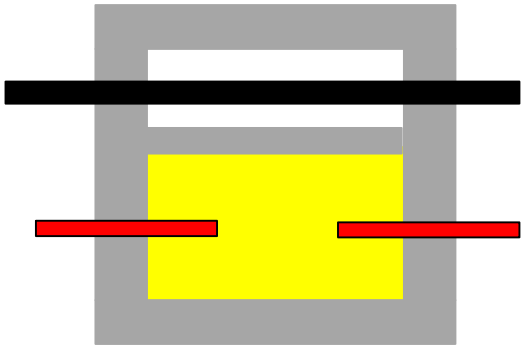
material:	**siliconcarbide SiC**	**molybdenumdisilicid $MoSi_2$**
application:	up to 1.600°C	up to 1.800° C
life time:	approx. 1 – 3 years	approx. 3 – 6 years
advantages:	easy installation	long lifetime
	different design available	constant resistance
disadvantages:	aging	high superstructure design required
	changing resistance	
	voltage reserve necessary	high risk of mechanical breaks
	complete change of a zone recommended	very expensive

This heating systems are mostly recommended in closed superstructure FH‘s!
In glass contact this materials can create big problems! An application in open superstructures are possible but a careful maintenance is strictly recommended!

Indirect heated systems

What kind of design is possible?





SiC with open surface

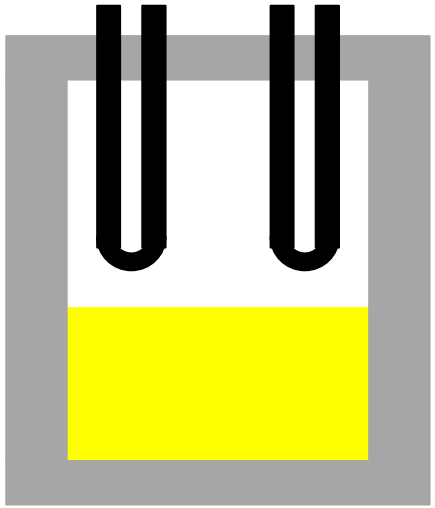
- for glasses with low evaporation
- high risk of glass defects
- high energy efficiency

SiC with closed surface

- for glasses with high evaporation
- no risk in case of a break
- lower energy efficiency
- combination with direct heating possible

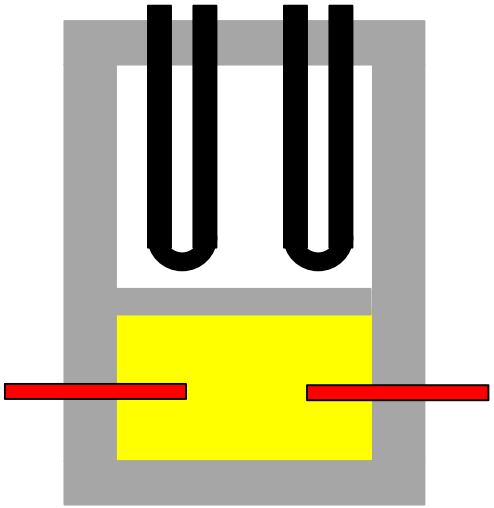
Indirect heated systems

What kind of design is possible?



$MoSi_2$ with open surface

- for glasses with low evaporation
- high risk of glass defects
- high energy efficiency



$MoSi_2$ with closed surface

- for glasses with high evaporation
- no risk in case of a break
- lower energy efficiency
- combination with direct heating possible

Indirect + direct heated systems

Comparison of fully gas heated and electrically heated systems

	gas heated	direct heated	indirect heated
energy consumption	high	low	middle
estimated consumption	20 - 40 kW/m	5 - 15 kW/m	5 – 25 kW/m
energy costs	high	low-middle	low-middle
investment costs	low	middle	high
maintenance costs	low	middle	high
typical applications	mass glasses	special glasses	special glasses

For each application HORN recommends a comparison of the investment and operation costs to work out the best technical and economical solution for the customer!

Indirect + direct heated systems

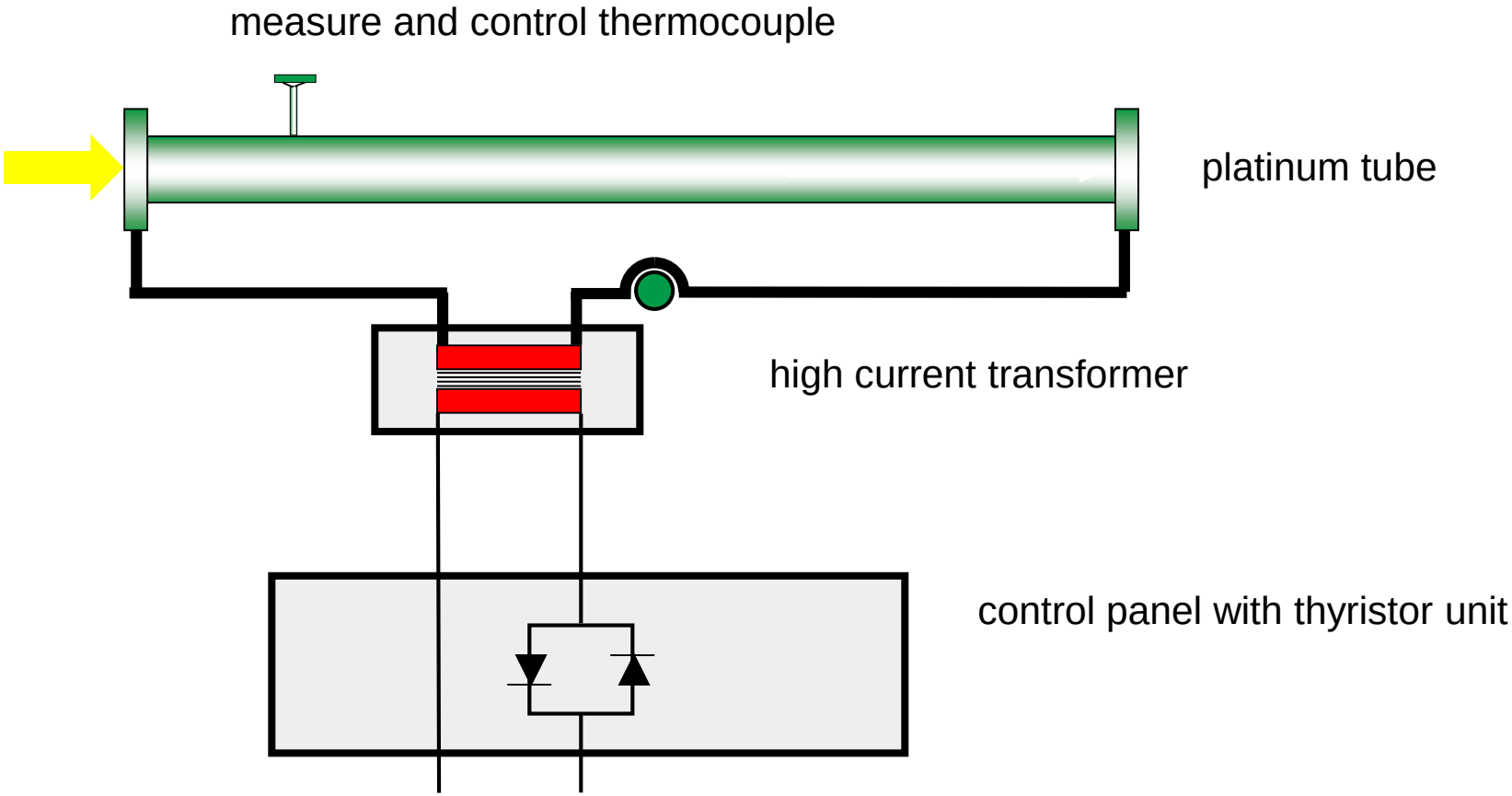
When is which solution recommended?

- the indirect and direct heated systems can be applied in a wide range
- at first it must be considered what is the main focus of the production
- what kind of glass should be produced and what is the required glass quality
- what is the glass composition, the FH pull and temperature range
- what is the available space for the FH's and the distributor
- what are the necessary channel dimensions (depth and width)
- dependent on glass resistance the optimal electrode configuration must be considered
- the engineering must be determined for each project in detail
- what kind of energy is available (without power breaks)
- what is the price for gas and electricity
- in case of often electrical power breaks is additional a gas heated firebox recommended
- in addition, fireboxes can be used for heating up and temperature control

Based on different applications it is not possible to apply standard solutions!

Special applications

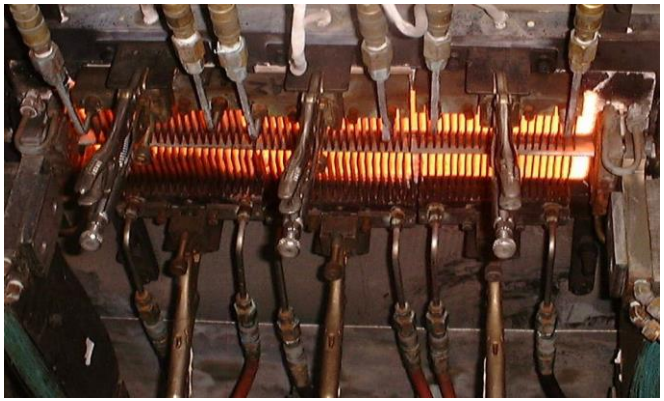
Direct heated platinum tube for special glass FH systems



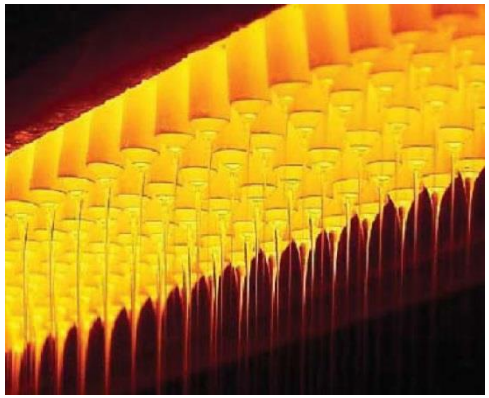
Application is mainly recommended for high quality special glasses, design is in principal possible as tube, stirrer cell or refiner tube!

Special applications

Direct heated platinum bushings and drains for special glass







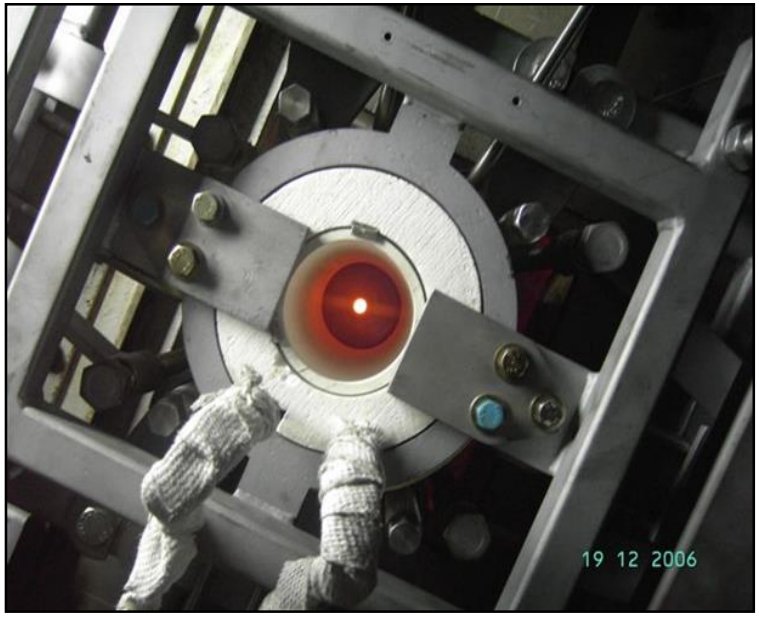


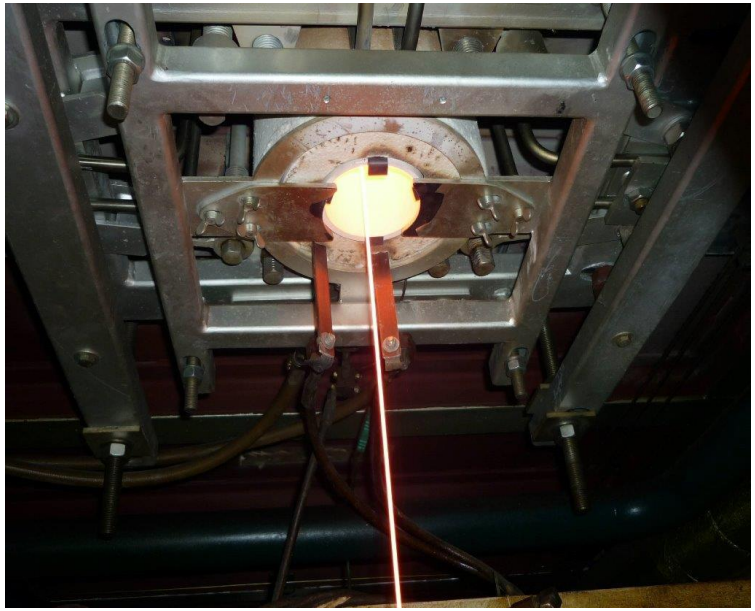
- Pt bushings especially for fibre glass applications textile fibre (endless) and fibre wool
- up to 600 bushing tips possible

- Pt bottom drains for special glass

Special applications

FH drain systems – VARI DRAIN





- indirect electrical heating system
- removal of contaminated bottom glass
- avoid glass defects by “cat scratches”
- installation of a drain channel block in front of equalizing section recommended
- continuously and temporary operation are possible
- system works without a molybdenum counter electrode in the glass

Special applications

Indirect heated spout





The application is foreseen for standard spouts. The heating elements will be added before spout installation take place.

Application is mainly recommended for low pull FH's with high gob temperature.
The heating system is compensating more or less the energy losses through the walls.
In this way it is possible to stabilize the gob temperature!

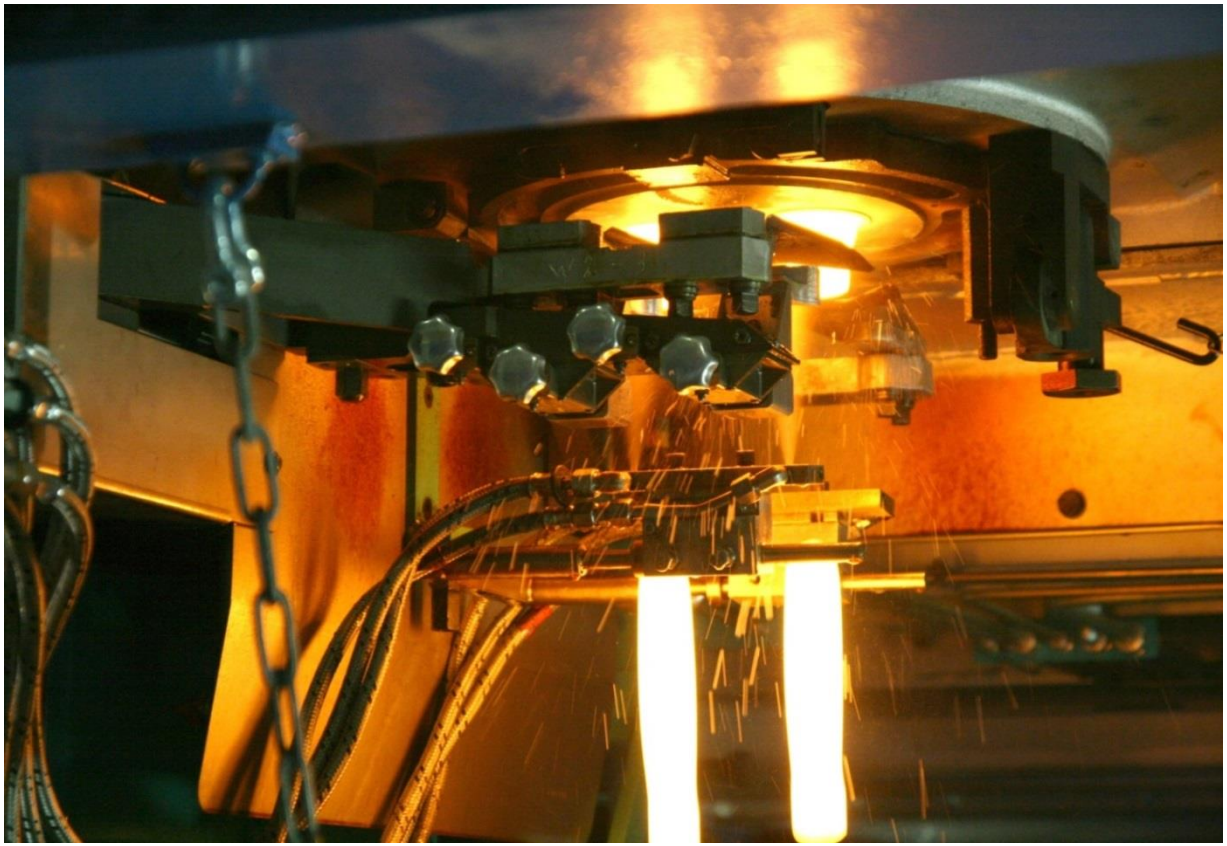
Conclusions

When selecting suitable heating systems, it is particularly important to have a precise knowledge about the planned production and the technology. The technical and economical boundary conditions must be taken also into account to apply all the available know-how in a right way and work out the best solution for the glass producer. Even a high quality and durable final product, the highest possible production efficiency together with a low energy consumption and a long lifetime of the equipment is also a small contribution for the sensible using of energy- and raw material resources.



This is my personally contribution as an engineer!

Glass conditioning



MANY THANKS FOR YOUR ATTENTION!
I WISH YOU GOOD LUCK & SUCCESS FOR YOUR GLASS PRODUCTION AND BUSINESS!

Glass conditioning

Author:

Dipl.- Ing. Joachim Gesslein

engineering / conception / service / customer support
glass technology, -melting & conditioning

contact:

HORN Glass Industries AG
Bergstrasse 2
95703 Ploessberg / Germany
Phone: +49(0)9636 9204 -114
Mobile: +49(0)151-20409636
Fax: +49(0)9636 9204 10
E-Mail: j.gesslein@hornlgas.de
Web: www.hornglas.de

Vorstand: Stephan Meindl (Vorsitzender)
Aufsichtsrat: Dr. Hans Wehrmann (Vorsitzender), HRB 2146 Amtsgericht Weiden