

# RHI Magnesita

## Bottom Lining Considerations

TC 11

Cavaillon 20 December 2023

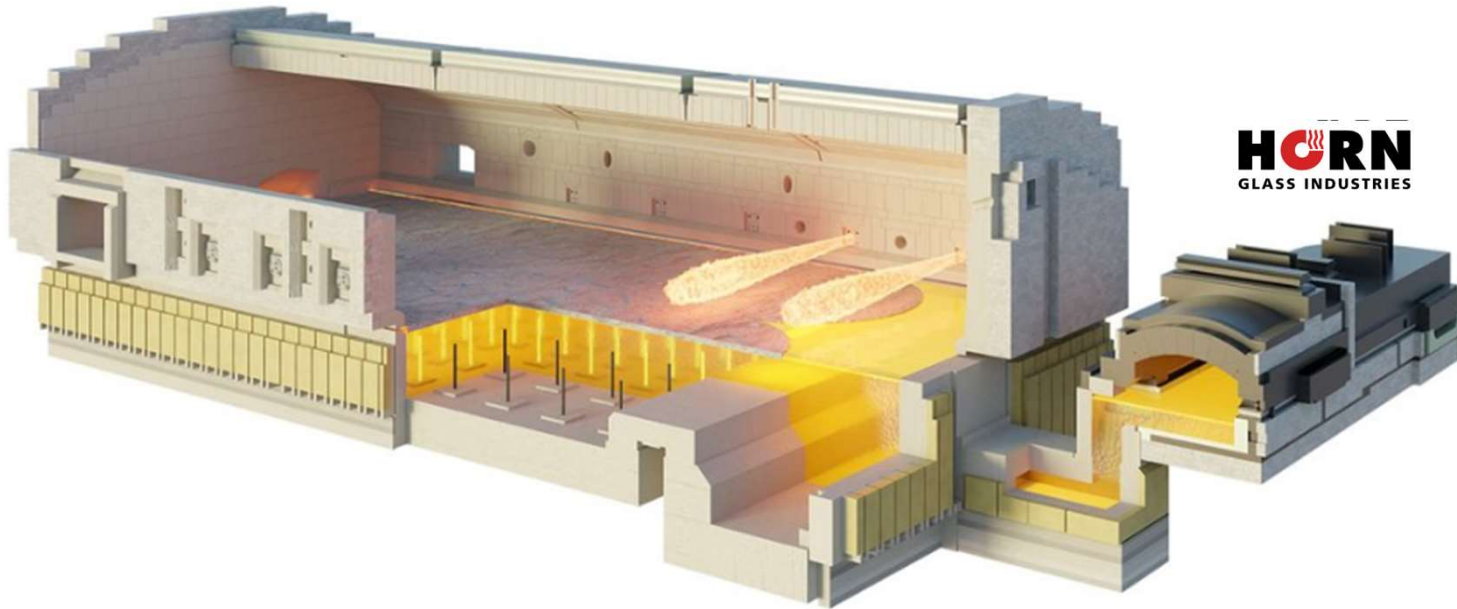


# Content



- Bottom Requirements for standard operation
- Bottom expected improvements for highly boosted bottoms

# Bottom paving wear



[www.hornglass.com/melting-conditioning/melting Hybrid furnace](http://www.hornglass.com/melting-conditioning/melting-Hybrid-furnace)

Hybrid furnace model from Glass Service

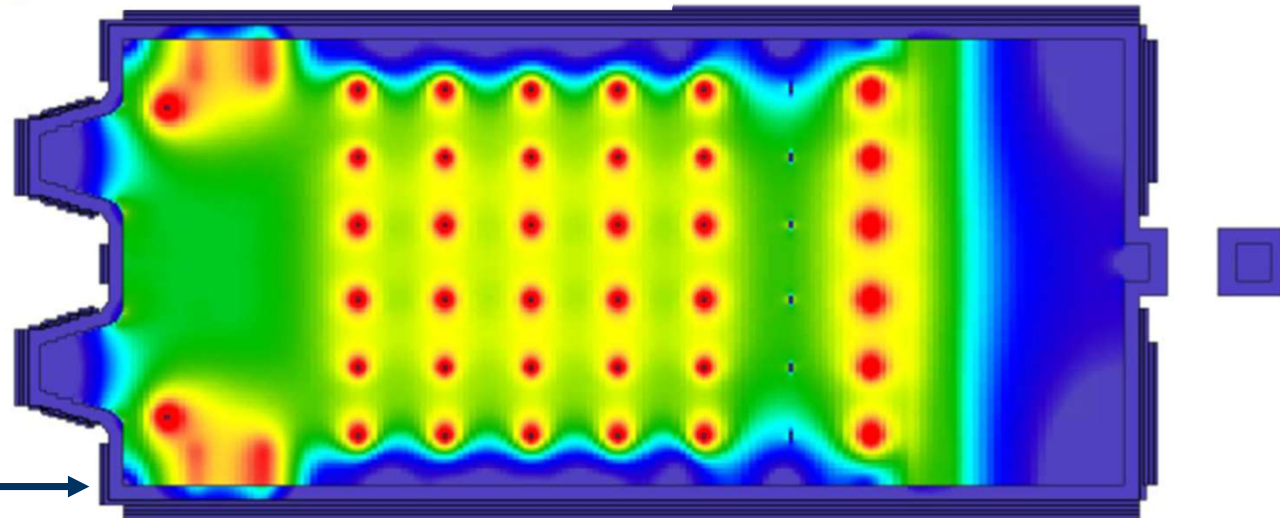


## Glass Model

Higher bottom temperatures  
Higher glass temperatures in the riser)



+ 100°C expected  
Higher forced convection



# Upper Layers Requirements

## The Upper Layers: Paving, monolithic and safety layers

- ◆ **Corrosion resistance** against glass
- ◆ Resistance against **metal drop drilling**
- ◆ **High refractoriness**

### **Glass Corrosion Resistance:**

Fused Cast AZS and bonded zirconia mullite grades are the traditional grades to be used in glass contact.

Chrome Corundum tiles and mixes are also alternatives in case of colored glass.

### **Metal Drop Drilling Resistance: two approaches**

**Metal Encapsulation;** Zirconium silicate grades are the preferred choices due to their metal encapsulating capabilities

**Metal Drilling Resistance;** Chrome Corundum Grades are extremely corrosion resistant against metal drill. As alternative for flint glasses Bonded Zirconia Mullite can be considered

# Bottom Paving - AZS

## Fused Cast Grades

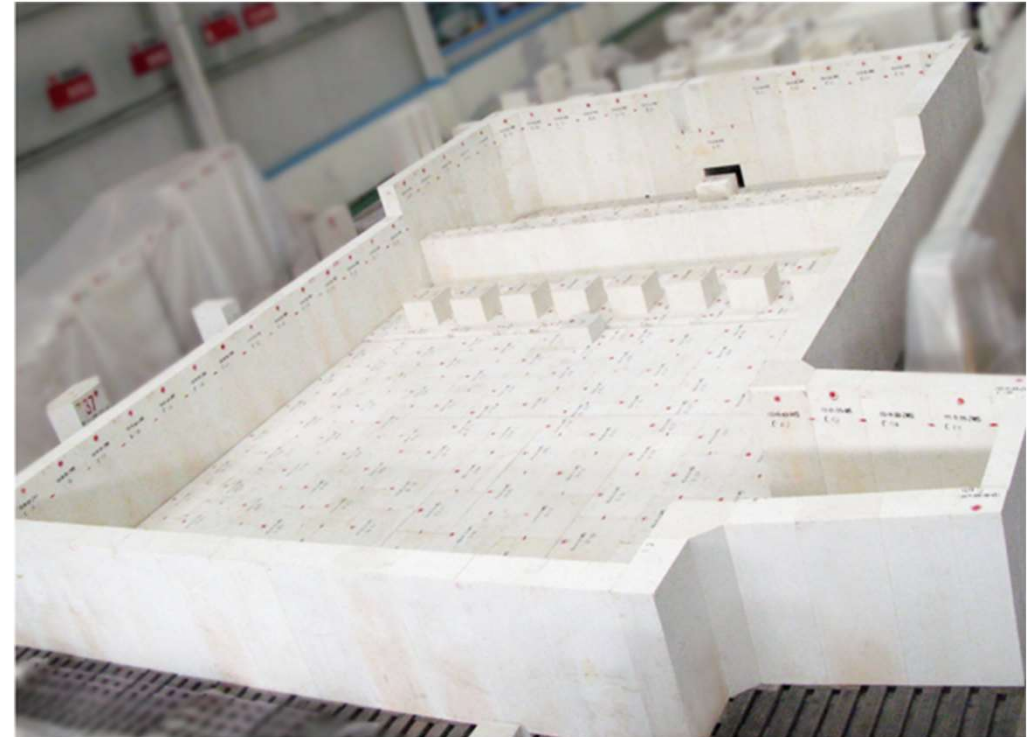
AZS33 void free / >32% ZrO<sub>2</sub>

AZS36 void free / >36% ZrO<sub>2</sub>

AZS41 void free / >40% ZrO<sub>2</sub>

## Thickness

- 75 mm: Low stressed situations, short campaign, deep refiner, working end , etc.
- 120 mm: Bottom temperature up to ~1330°C, strong bottom insulation, standard furnace lifetime expectation
- 150 mm: > ~1330°C bottom temperature, areas near electrode/bubbler blocks, highly boosted bottoms, highly stressed situations (grade upgrade; AZS41)



Two Paving layers are NOT recommended due to an enhanced upward drilling risk

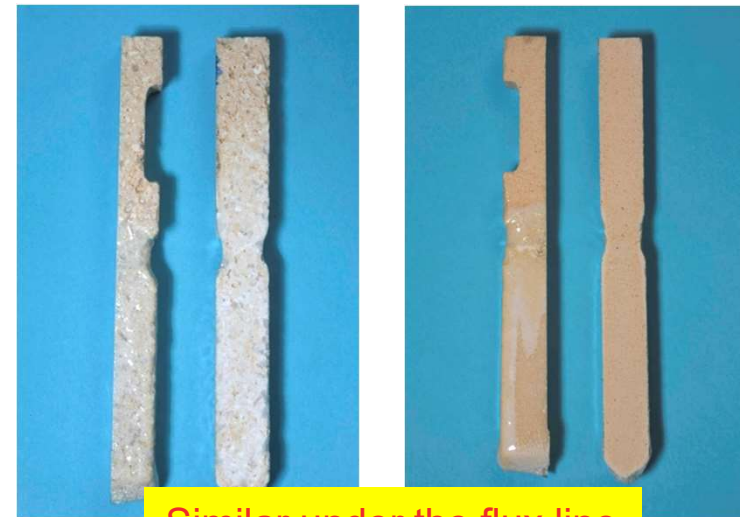
## Highly boosted furnaces

- more resistant materials to glass corrosion (due to higher temperatures)
- high electrical resistivity would be desired to reduce the risk of overheating and premature wear.
- Thermal expansion stability in case of thermal cycling like in hybrid furnaces, to avoid uncontrolled joint opening and/or paving movement

# Bottom Paving - Bonded Zirconia-Mullite

- ◆ No glassy phase to exudate;
  - Lower risk of **cat scratch** glass defect
- ◆ Lower thermal conductivity;
  - Lower glass temperature under the paving
  - Less attack on the layers under the paving
- ◆ Homogenous tile;
  - Good corrosion resistance across the tile thickness
- ◆ More stable expansion behaviour
  - Less or no shrinkage during heat up = less glass penetration through the joints and higher stability in case of thermal cycling

Bonded Zirconia-Mullite



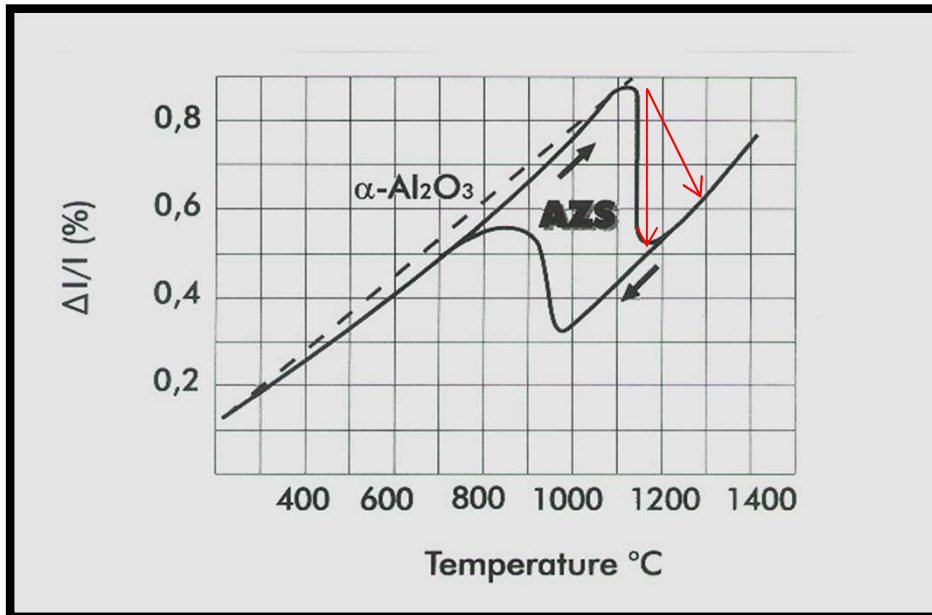
Similar under the flux line

Corrosion test with soda lime glass 1400°C – 24h



# Bottom Paving - Bonded Zirconia-Mullite

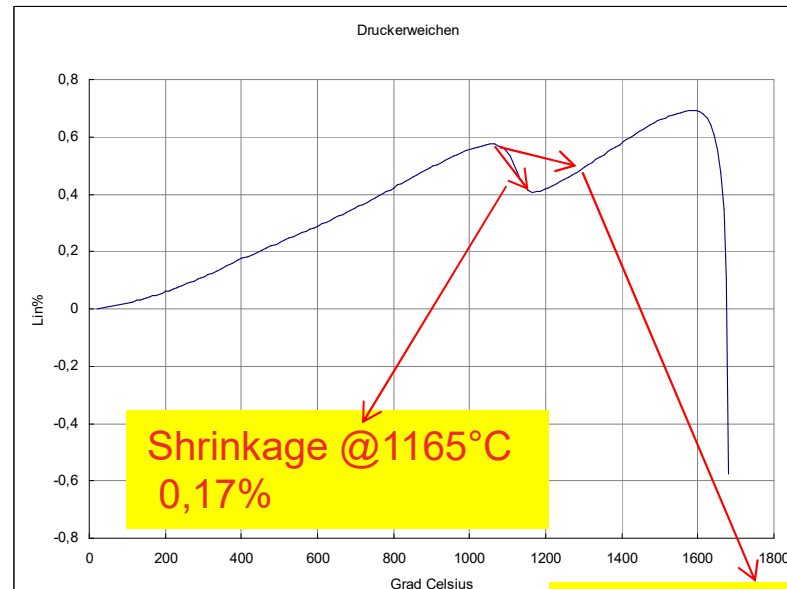
## Fused Cast AZS



Shrinkage @1165°C  
0,35%

Shrinkage @1300°C  
0,25%

## Bonded Zirconia-Mullite



Shrinkage @1300°C  
0,08%

FILE: 475-06.DE  
NUMMER: 015962-13-1  
DATUM/ZEIT: 21.6.2006 11:06  
LAST /MPa: 0,2

DMAX /Lin%: 0,691  
T0 /°C: 1586  
T0,5 /°C: 1673  
T1 /°C: 1679  
T2 /°C: >1682  
Z1682 /Lin%: -1,267

Hysteresis:  
H1 /Lin% 0,574  
T\_H1 /°C 1054  
H2 /Lin% 0,407  
T\_H2 /°C 1165  
H3 /Lin% 0,691  
T\_H3 /°C 1586  
  
delta H1-2: -0,167  
delta H1-3: 0,117  
delta T1-2: 111  
delta T1-3: 532  
  
T\_H1/°C 1394  
delta T1-1' 340

Hysteresis starts with 24% ZrO<sub>2</sub> content in the brick

- ◆ Zirconia Mullite can be a reliable alternative to fused cast AZS as bottom pavings (low specific pulls)
- ◆ Working End paving alternative due to the less risk of glass defects
- ◆ Smaller CO<sub>2</sub> footprint – During production and application : 2,79 tCO<sub>2</sub>e/t prod

# Bottom Paving - Bonded Zirconia Mullite

Application results as Bottom Paving



## ◆ Application:

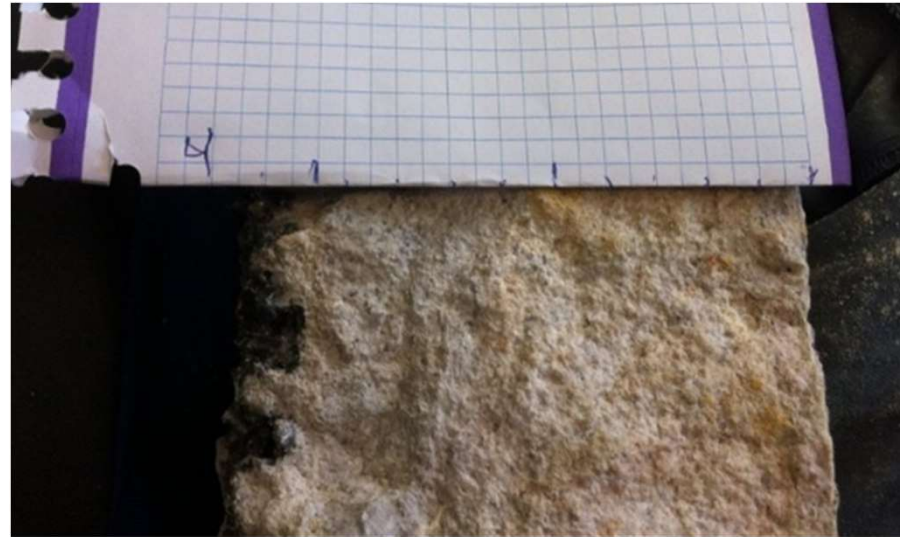
- Container furnace with 50m<sup>2</sup>
- Pull rate 140 t/d
- Campaign: 27 months

## ◆ Wear:

- Original thickness: 120mm
- Remaining thickness: 110mm

## ◆ “Metal drilling”:

- Max. 10 mm
- No upward drilling visible



# Monolithic Layer

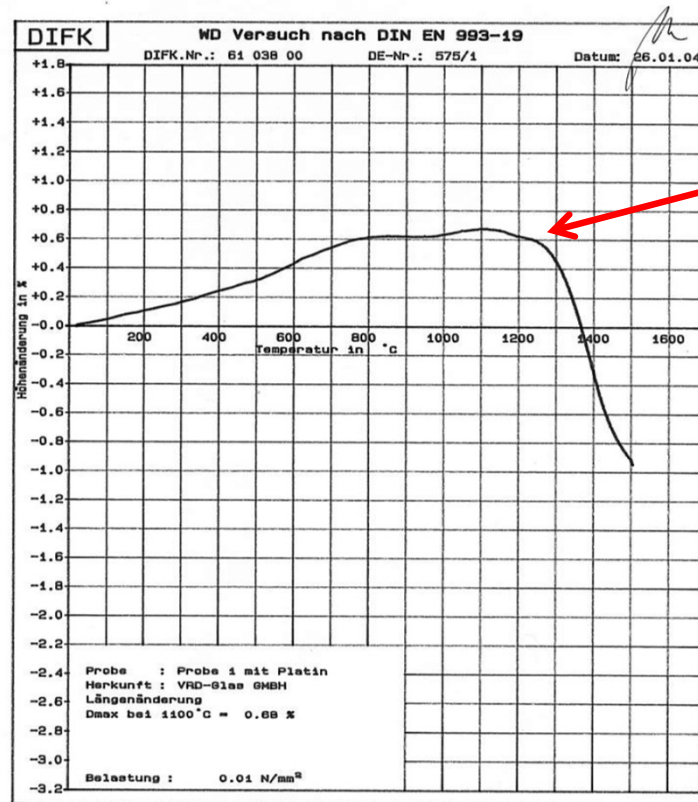


- **Purpose and Requirements** - Layer with *No Joints!*
  - *Avoids the presence of any gap through which glass can freely penetrate.*
  - It must show low shrinkage during heat-up to obtain a sealed layer with no gaps.
  - Requires good glass corrosion resistance to maintain the bottom's integrity.
  - Resistance against metal penetration is also helpful
  
- **Thickness**
  - Ramming Mixes: 35 to 50 mm single layers are suggested (minimum 25mm). It is possible to increase total thickness by installing multiple layers (it is labor intensive).
  - Castable: >40mm
  
- **Leveling Mortar**
  - Zirconia mullite based mortar provides good contact and air pocket removal between the paving and monolithic layer. This reduces glass infiltration and risk of upward drilling.

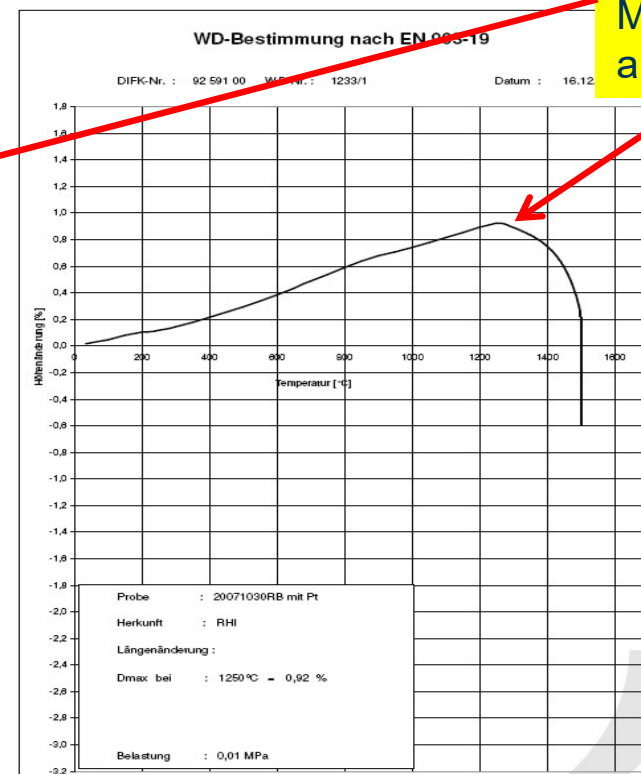
# Monolithic Layer

## Behavior of mixes during heat-up

### Thermal expansion Zirconia-Mullite Castable vs. Zirconia-Mullite Ramming Mix



Zirconia-Mullite Castable



Zirconia-Mullite Ramming Mix

Minimal shrinkage @1250°C application temperature

# Monolithic Layer



## We distinguish between:

### ● Corrosion Resistant Grades

- Casting mix based on Fused Cast AZS grog and synthetic Zirconia Mullite.  
A further improvement, consists in a mix variation with optimized self-flowing capability, for faster and easier installation, specially for highly boosted bottoms.
- Ramming mix, based on zirconium silicate sand and corundum, leads to volume expansion upon mullitisation, providing solid bonding with surrounding blocks and NO GAPS. Useful if a thinner layer is needed and bottoms containing less electrode blocks to allow an adequate rammed installation.
- Self flowing Chrome Corundum casting mix to be considered if a Chrome Corundum safety layer is installed.

### ● Metal Encapsulating Grades

- Ramming mixes based on zirconium silicate that provide metal encapsulation.
- Zirconium silicate based castable, that in addition allows the installation of thicker layers.

# Safety Layer

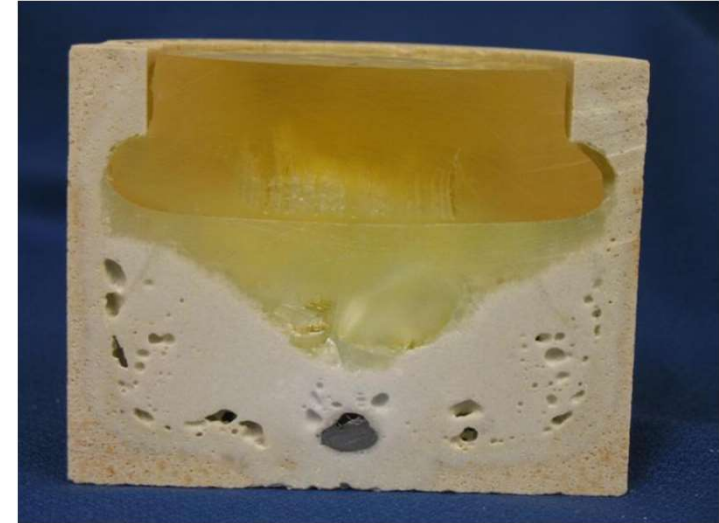
Its main purpose is to protect against penetration of metals and glass.

## Thickness

- 65 to 75mm layers

## ◆ Metal Encapsulation Approach

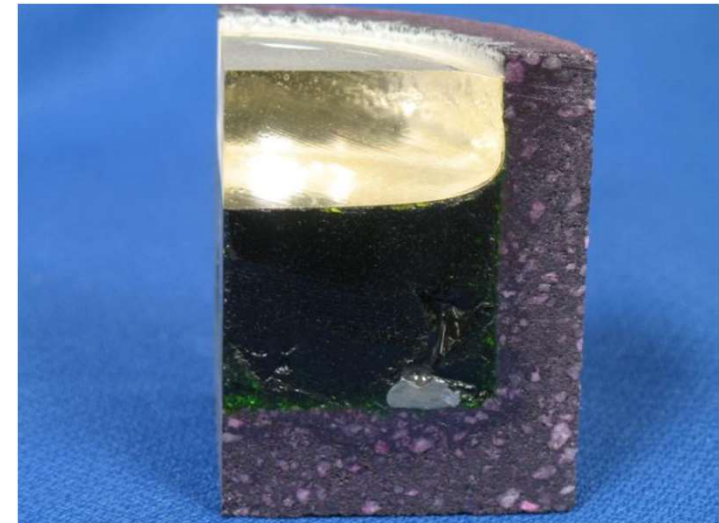
- **Zirconium Silicate** forms a foaming reaction which encloses the metal drops, interrupting the drilling mechanism. It is preferred to **avoid metal clusters** which can affect specially **electrical boosted bottoms**.
- Metal encapsulation in addition reduces glass defects like bubbles and coloration



Zirconium Silicate

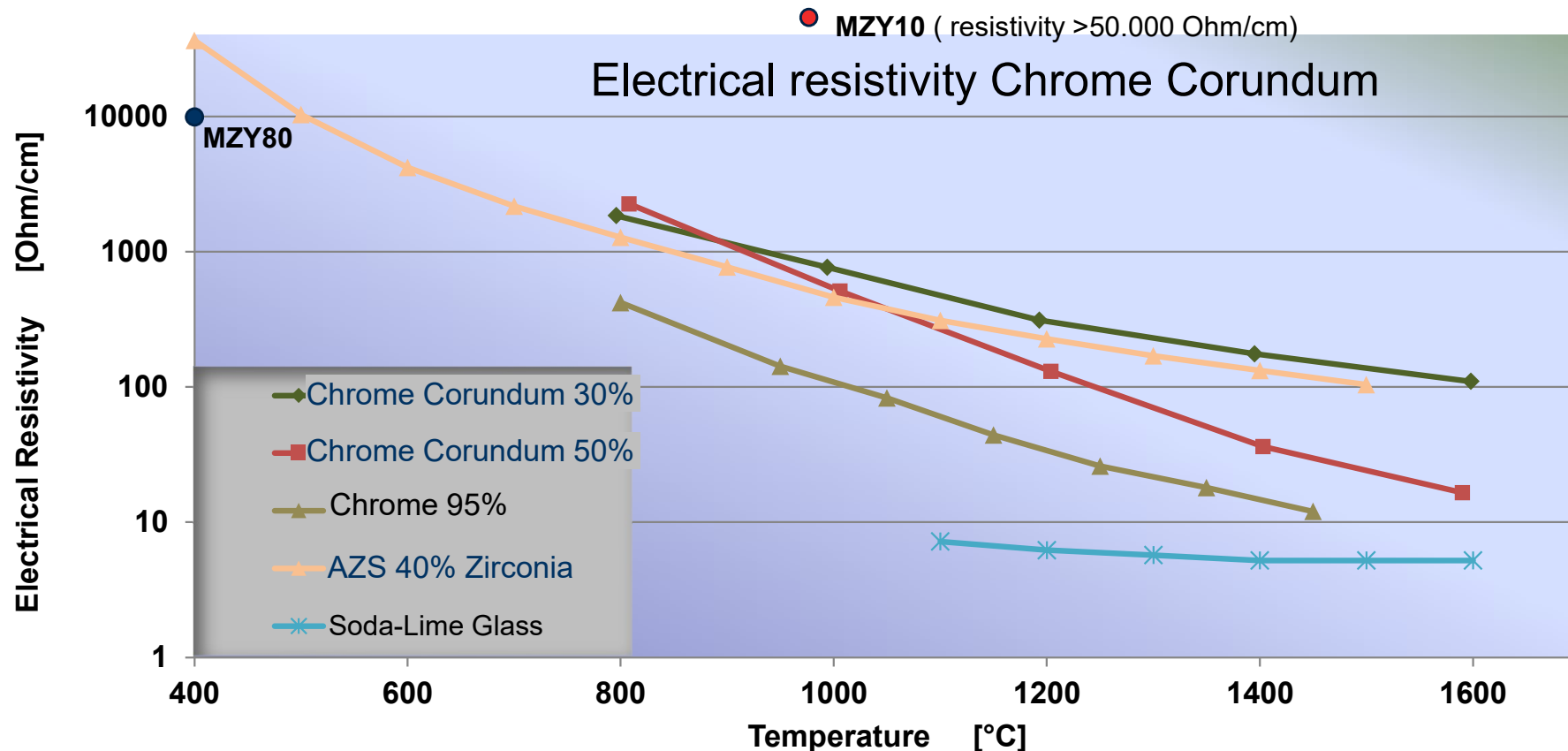
## ◆ Metal Drilling Resistance Approach

- A second approach is to stop the metals on the safety layer surface.
- It's an option in case of very low metal contamination is expected
- Zirconia mullite has excellent properties as safety layer
- Chrome corundum is a good alternative due to its extreme corrosion resistance to metal drops and glass melt, to the extent that the drilling mechanism doesn't even start in lab trials.



Chrome Corundum

# Safety Layer – Electrical Resistivity

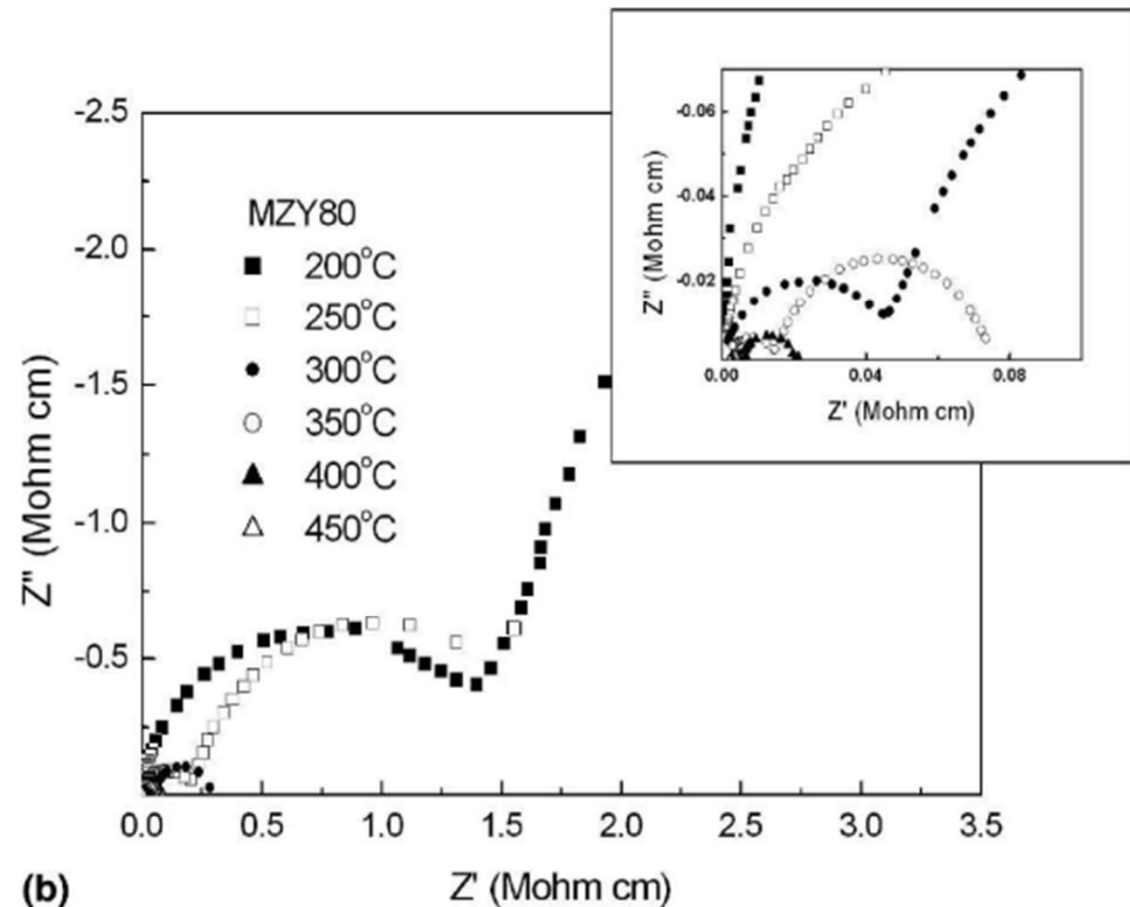
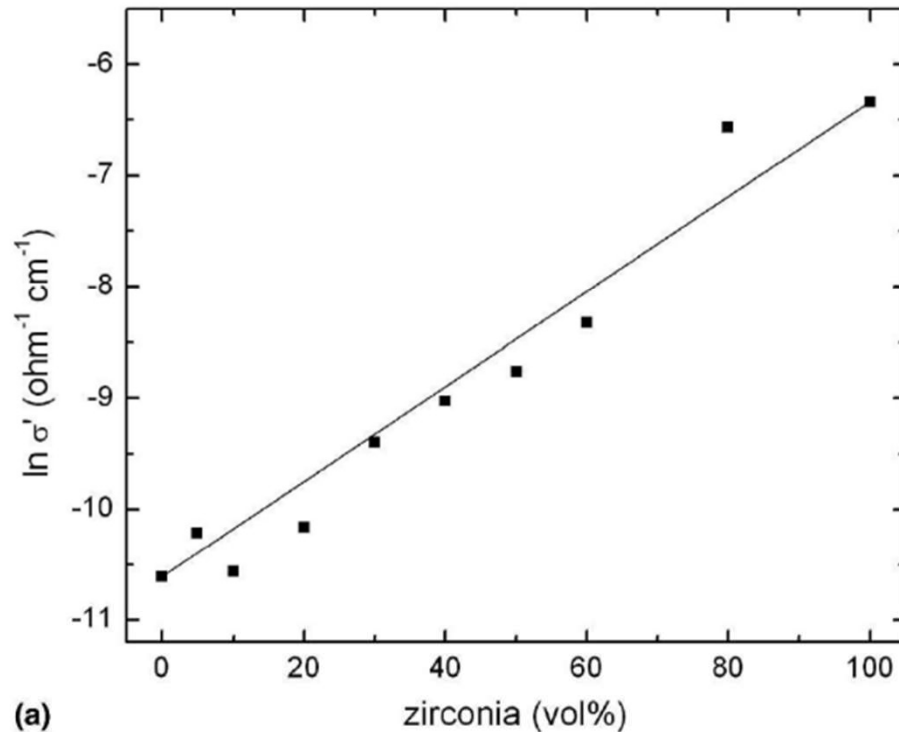


Chrome Corundum with 30% or less Chrome have a higher electrical resistivity compared to 40% Zirconia AZS.

**Note :** The electric resistivity is measured using Pt supports which are not contaminated by  $\text{Cr}_2\text{O}_3$ . Nevertheless due to the growing interest of characteristic 'electrical resistivity' and the different methods to determine it, RHIM has started to identify the most proper method, to build it up in TC Leoben and to start systematic investigation on the refractory materials of interest for glass application. First part is done and we expect to present first results in Q1/2024.

# Safety Layer – Electrical Resistivity

## Electrical conductivity of Bonded Zirconia-Mullite



The data taken from the literature (\*) show that the higher the content of Zirconia, the higher the conductivity

(\*) **J. Material Research Vol 23 n.8 August 2008** «Effect of Zirconia content on electrical conductivities of mullite/zirconia composites measured by impedance spectroscopy»  
Hong Da Ko and Chieng Cheng Ling Kuo-Chuang Chiu

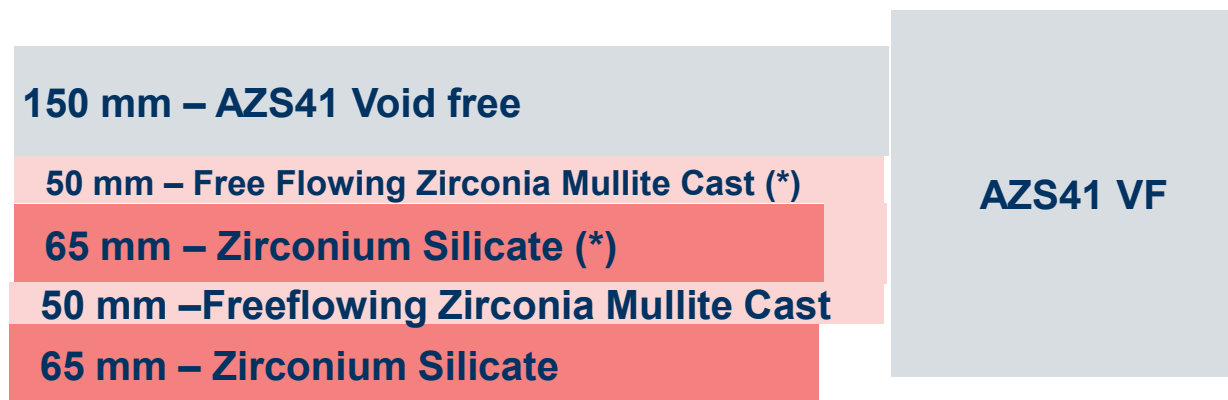
## Upper Layers Concept – Highly boosted bottoms

For increased bottom boosting it is crucial to reinforce the bottom and avoid glass penetration.

- Higher glass temperature and lower viscosity allows easier movement between layers.
- Increase of Glass Currents amplifies the corrosion mechanisms.

**A second Monolithic Layer is suggested for highly boosted bottoms and for extreme cases even a second Safety Layer can be considered.**

- The second monolithic layer is intended to stop glass infiltration. Situated at a lower temperature it would perform better towards more viscous glass.



(\*) The alternatives previously discussed can be considered as needed

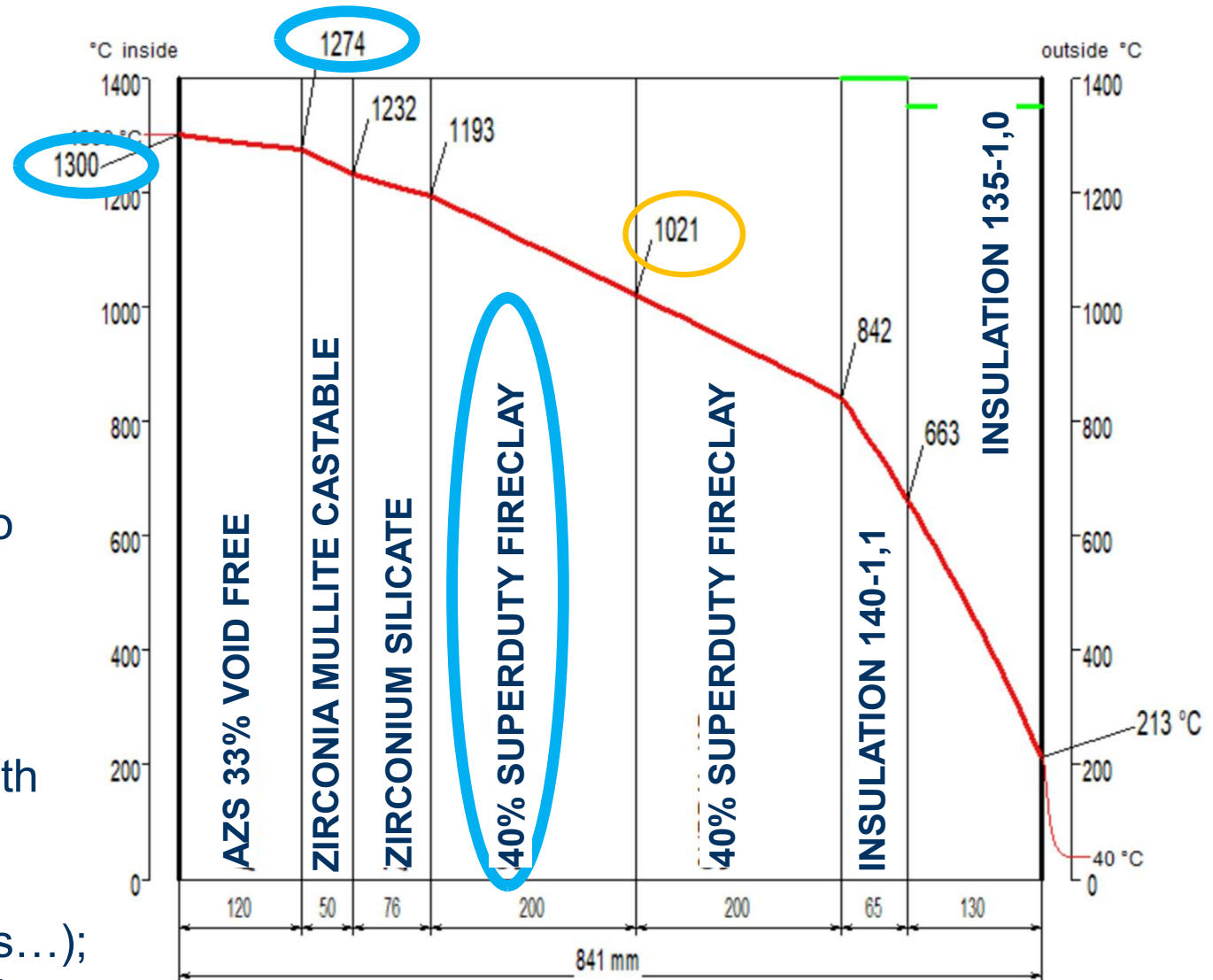
# Lower Layers Concept – Standard operating condition

Standard operating condition  
with bottom glass  $T=1300^{\circ}\text{C}$

Heat Loss :  $1189 \text{ W/m}^2$

This thermal profile, calculated for a standard concept, is able to permit a furnace campaign of 8-10 years (glass containers)

40% Fireclay can be replaced with Sillimanite if a more temperature resistant layer is required (Clear glasses, highly insulated bottoms...); the thermal profile is not affected.



# Lower Layers Concept – Highly boosted furnaces

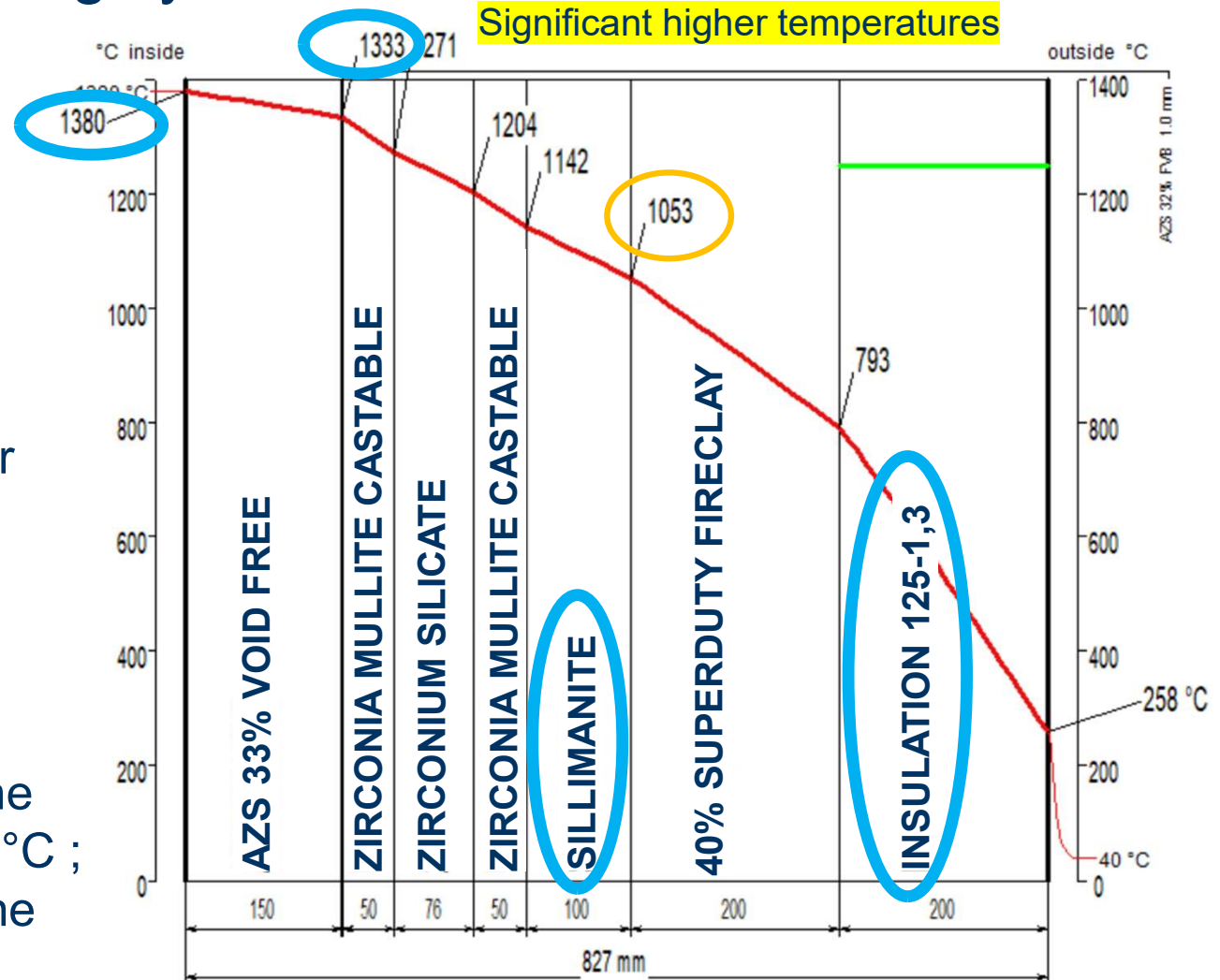
Expected bottom glass  
**T=1380°C**

**Heat Loss :1730 W/m<sup>2</sup>**

This thermal profile brings to higher temperatures inside the AZS increasing the corrosion velocity

40% Fireclay is replaced with Sillimanite since we are close to the temperature limit of Fireclay (1250°C ; the selection must consider also the conditions of a worn bottom).

The insulating layer applied is a less insulating grade to have a better control on the thermal profile



# Lower Layers Concept – Highly boosted furnaces

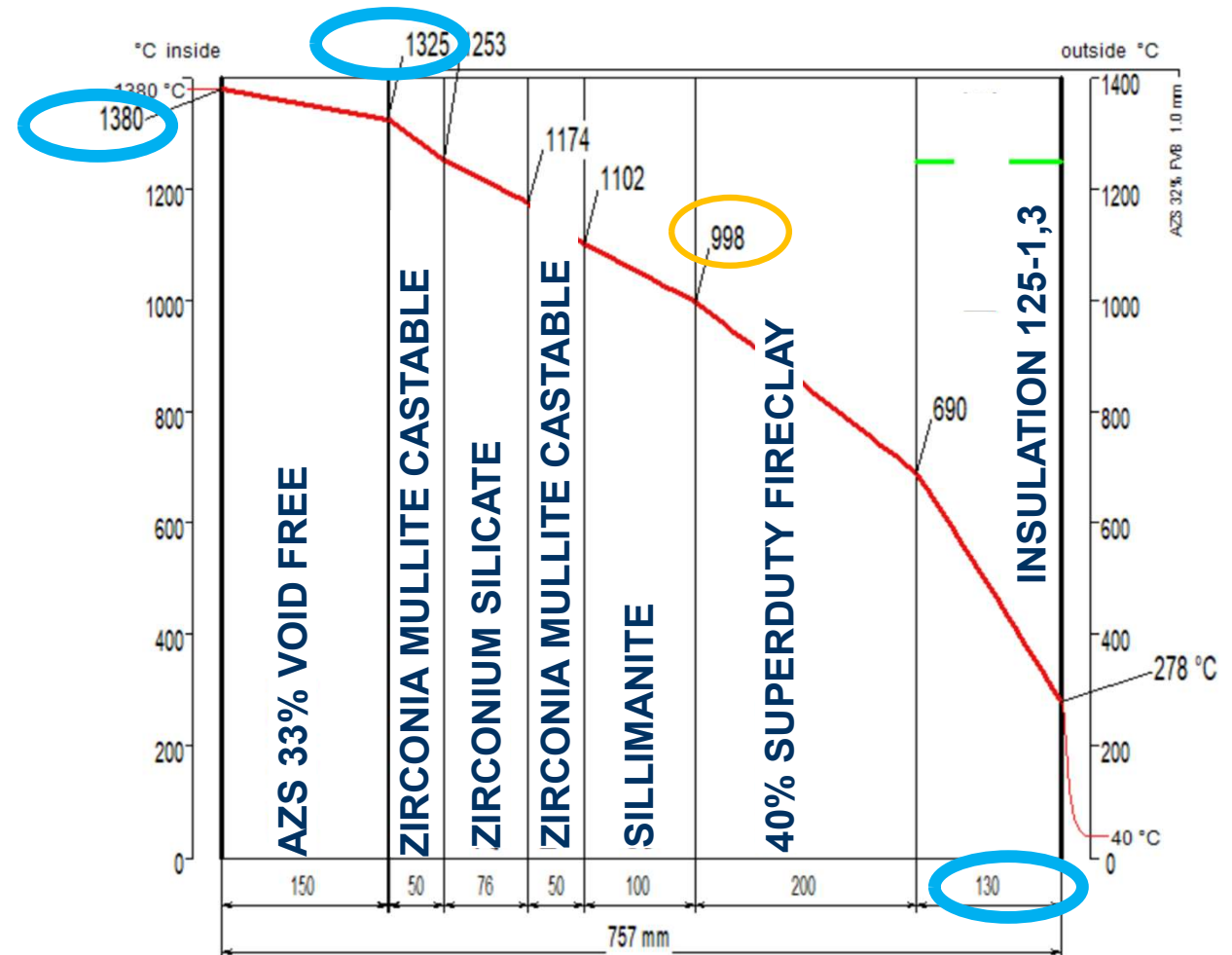
Alternative with lower insulation

Expected bottom glass

**T=1380°C**

**Heat Loss :2017 W/m<sup>2</sup>**

The thermal profile has been improved reducing the temperature at the interface with the monolithic layer, providing a better control on the corrosion velocity. This result has been achieved by reducing the thickness of the insulating layer

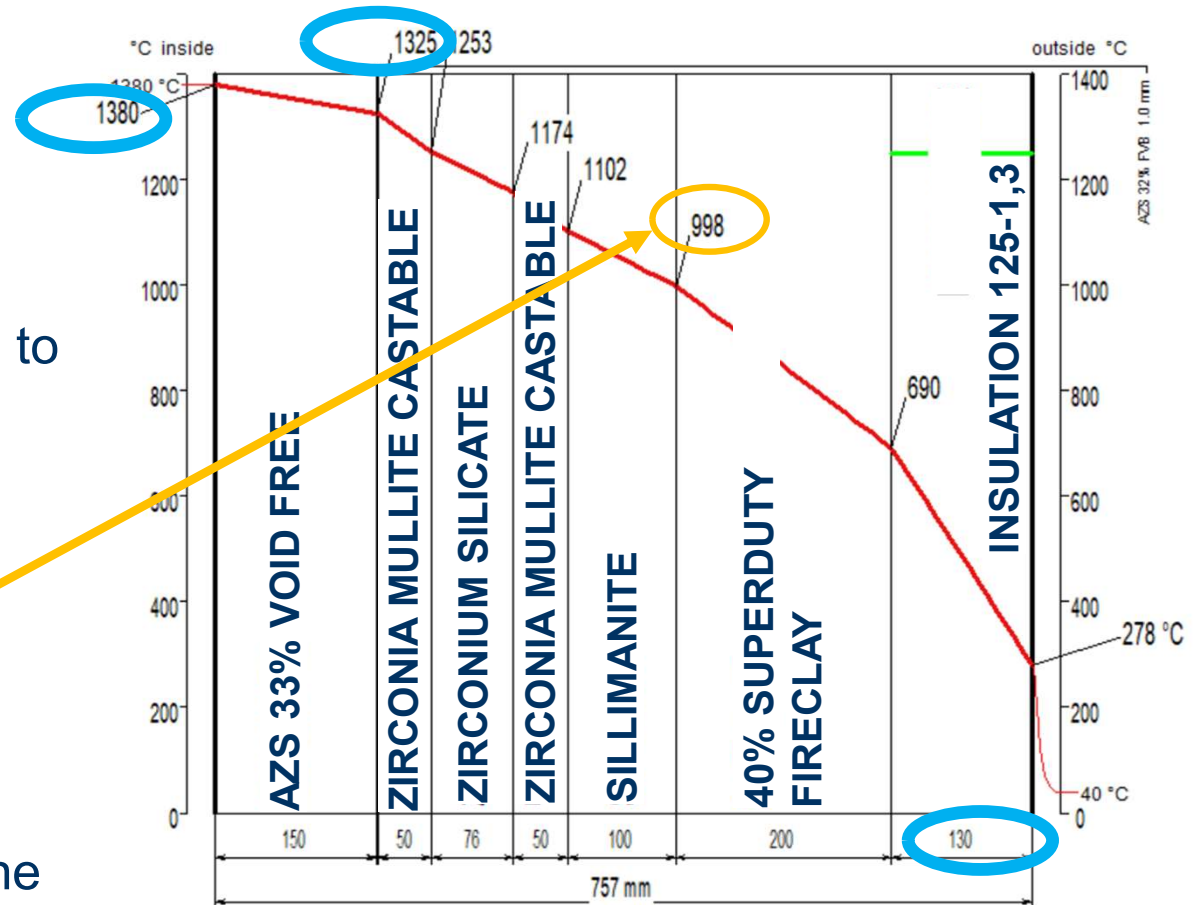


More alternatives can be developed combining the bottom thermal loss with the calculated temperature profile

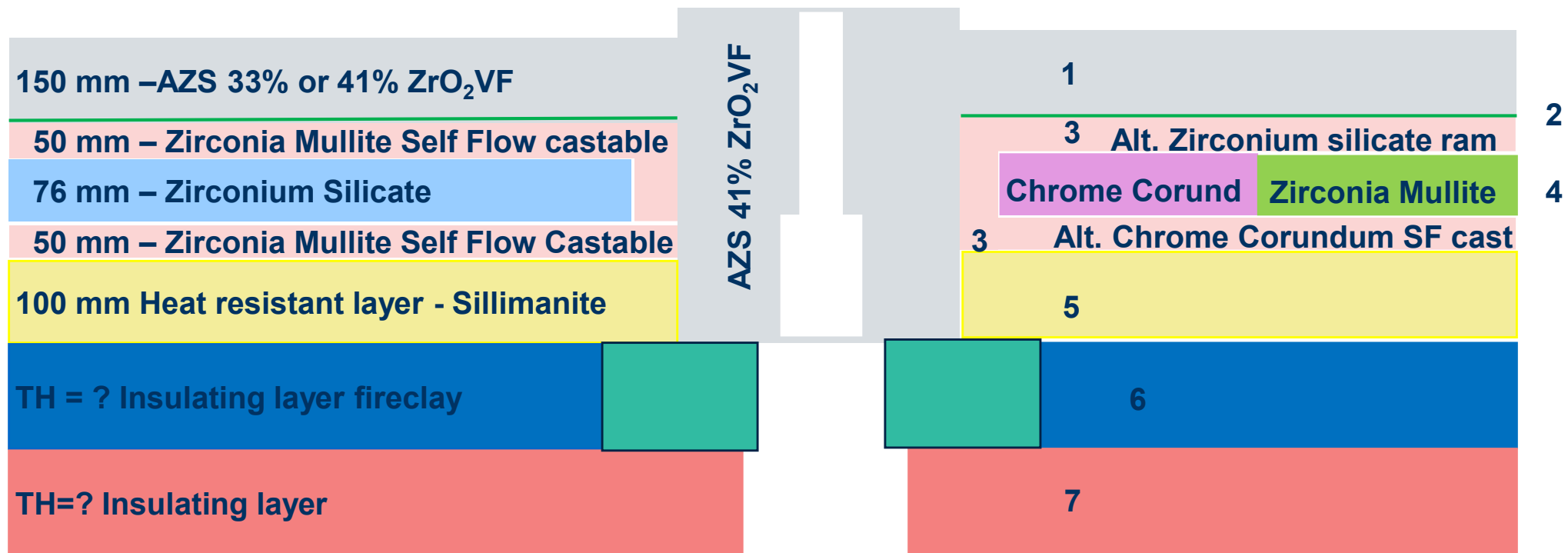
# Lower Layers Concept – Highly boosted furnaces

## Conclusive Remarks

- Higher heat loss expected/is reality; optimum need to be figured out)/ possible to reduce insulation to come to standard temperatures at monolithic layer? → no , challenge! → need for adapted concept!!
- Temperature at the interface between the sillimanite and fireclay layers: Should be kept around (or below) 1000°C ; in case of glass infiltration the temperature will “freeze” the glass or will highly increase its viscosity preventing a fast bottom lower layers collapse/corrosion



# Bottom paving– Lining Concepts



1 2 3 4 Upper Layers – Glass corrosion resistant materials

5 6 7 Lower Layers – supporting and insulating materials

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