Sustainable Refractory Solutions for Long Life Throat Glass Furnace Supported by Corrosion Numerical Simulation

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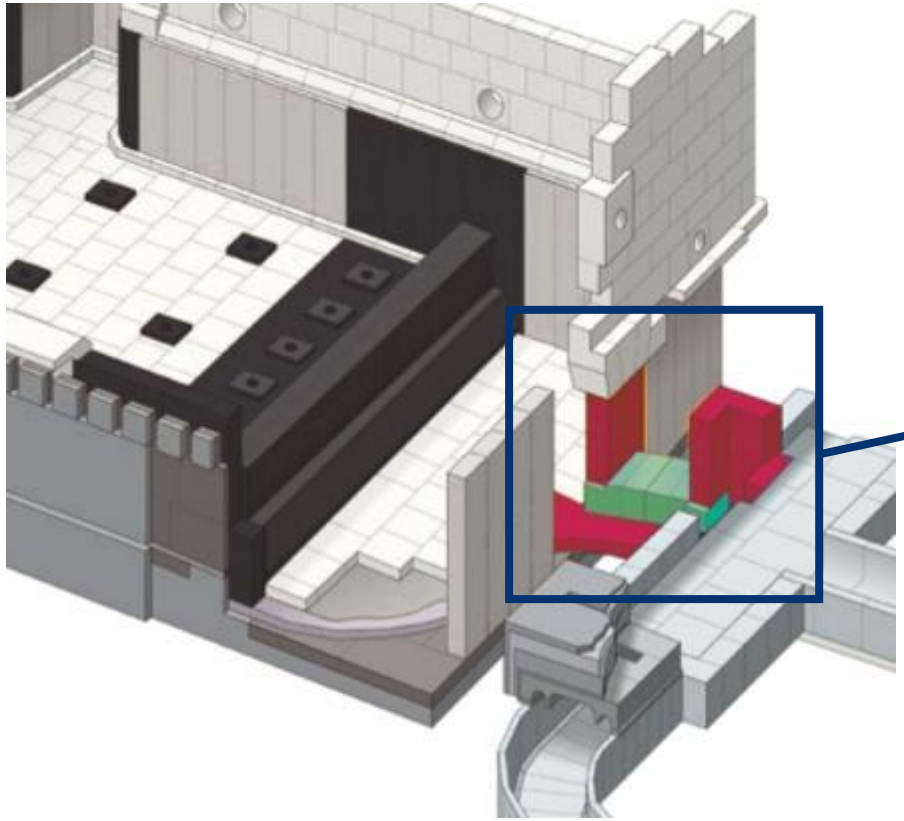
AGENDA

Introduction

- Glass furnace throat corrosion problems
- Refractory Solutions for different type of glass
- Throat corrosion simulation using FEM model
- Conclusion

The THROAT… a critical area

Increasing pull rate and/or extending glass furnace lifetime require to improve corrosion resistance on high solicitation areas such as the throat



For different glass composition ,Throat corrosion can affect Furnace life time

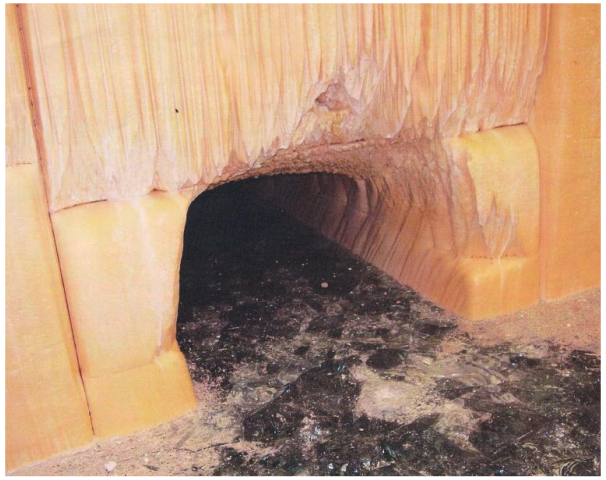
Opale Glass

Borosilicate Glass

New throat

After months

Sodalime Glass



Critical area for glass leakeage

High wearing zone

High temperature glass melting

Throat lifetime can be influenced by 3 main parameters

Refractory material

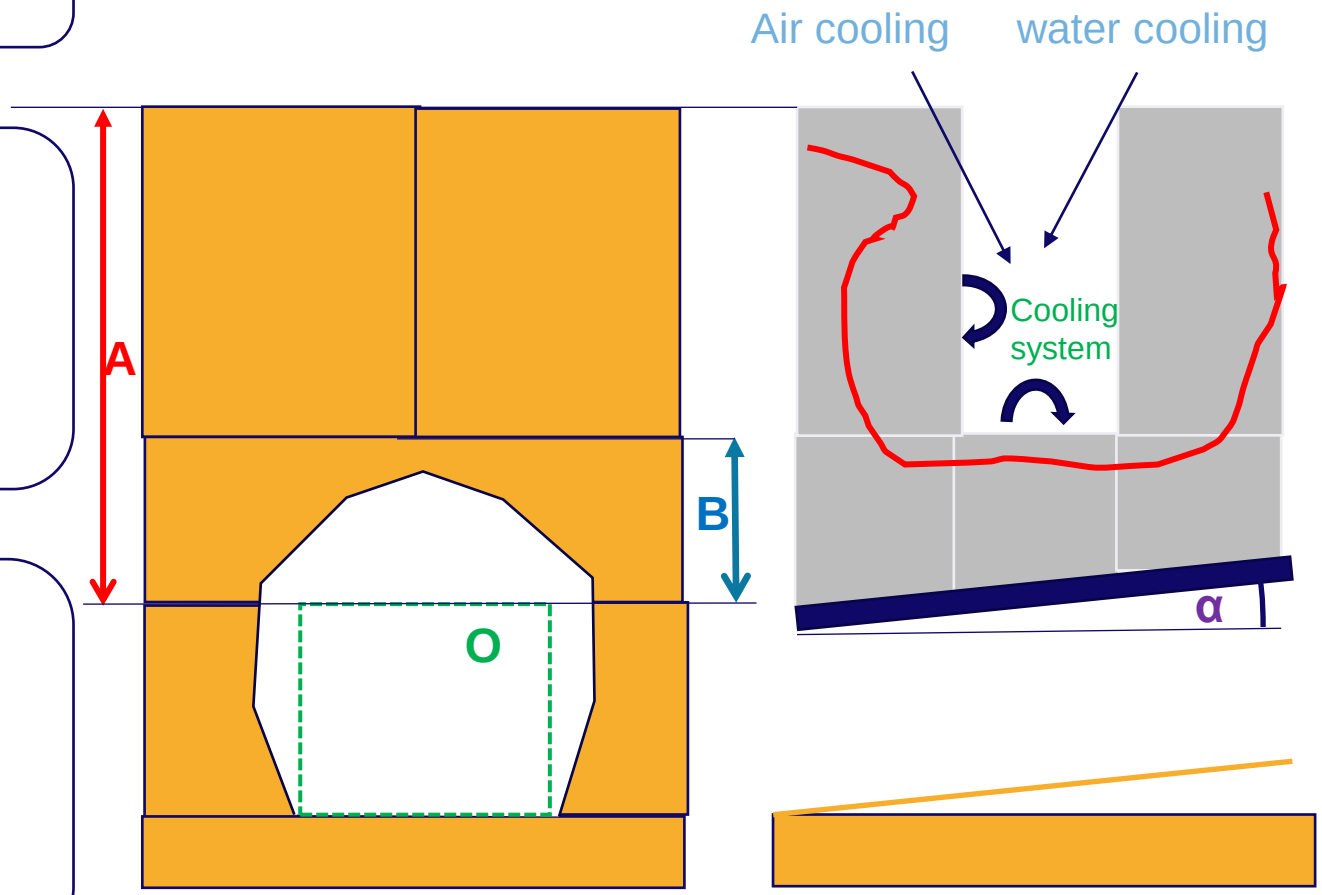
- FC AZS
- CHROMIC OXIDE
- HZFC

Throat Structure

- Roof Height **A**
- Roof thickness **B**
- Opening / glass flow **O**
- Cooling methods (air / water jacket)
- Inclined (**α**)

Furnace operation

- Glass temperature
- Pull rate
- Glass color / composition /transition

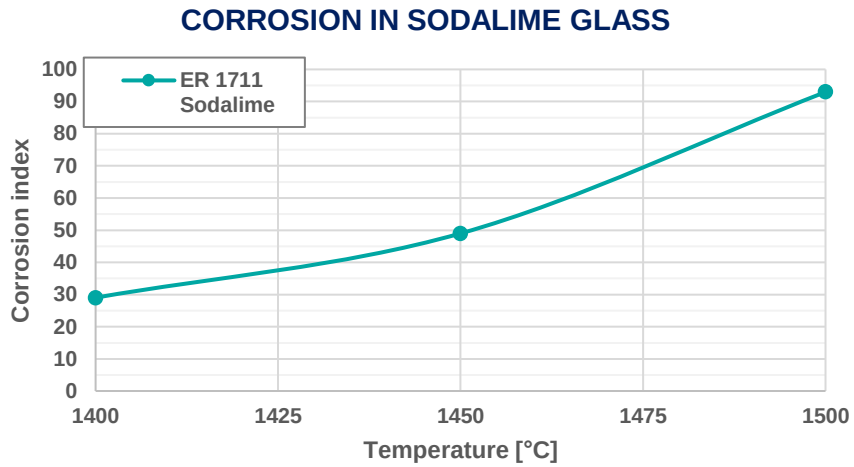


Throat corrosion process : combination of phenomenon

1) Refractory interface Dissolution :

- High influence of glass temperature T° & glass composition
  1380°C sodalime, 1500°C opal, 1550°C borosilicate

- Positive Impact of thermal cooling by reducing glass – refractory interface temperature

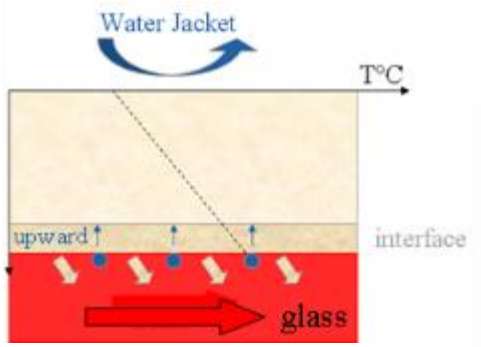


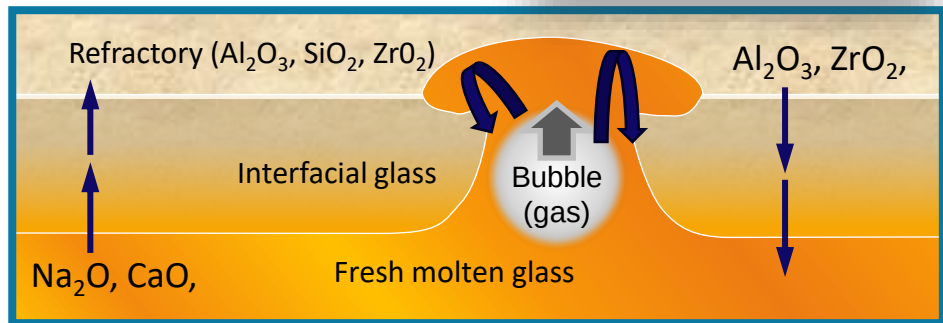
2) Interface renewal :

- Marangoni phenomenon (driven by $\Delta\gamma$) due to bubbles trapped

- interface layer density / Viscosity vs glass

- High influence of glass flow rate close to the refractory interface

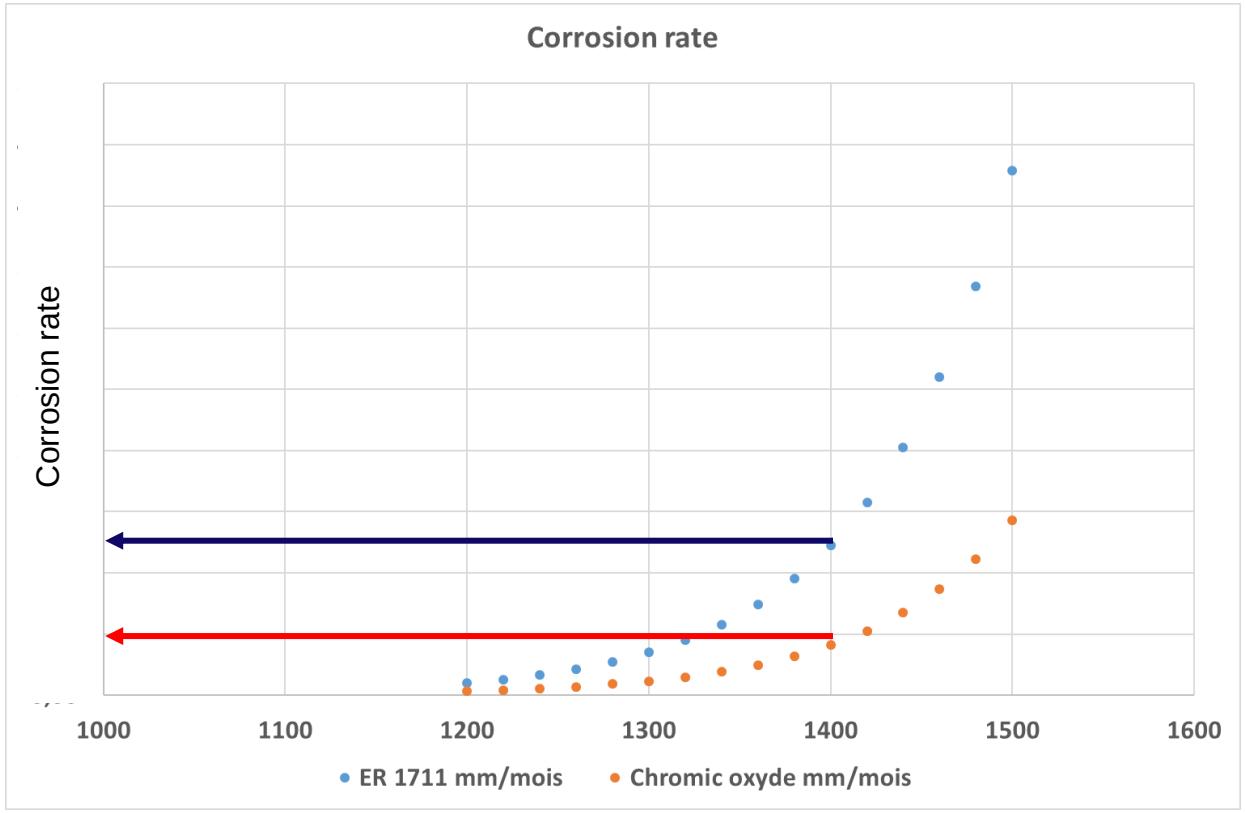


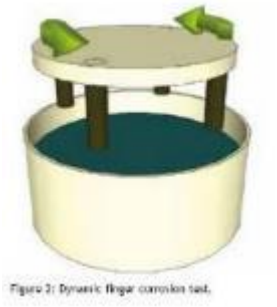


Throat corrosion : refractory material solution for sodalime glass

Sodalime Glass

High dependence to temperature of corrosion rate

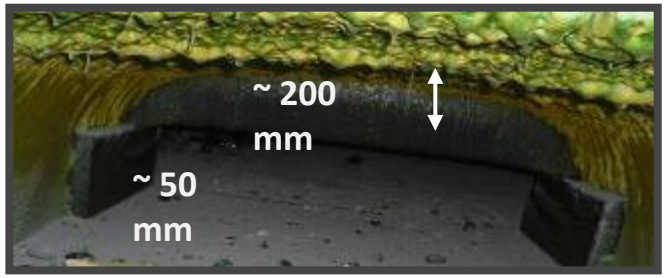




Corrosion resistance **~ 3 times higher** vs ER 1711

Index at 1450 °C :

- FC AZS (ER 1711)	100
- High chromic oxide Vibro-Cast (ZC85V)	**280**
- High chromic oxide Iso-pressed (C1221)	**330**



Industrial results

- throat Life improvement with alternative refractory choice / sodalime Glass

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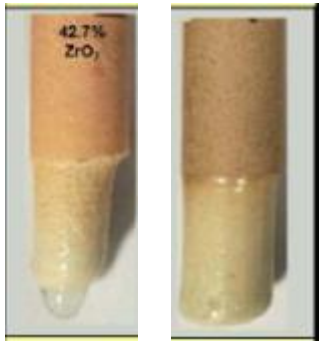
Throat corrosion : Refractory material solution for borosilicate glass

Neutral borosilicate Glass

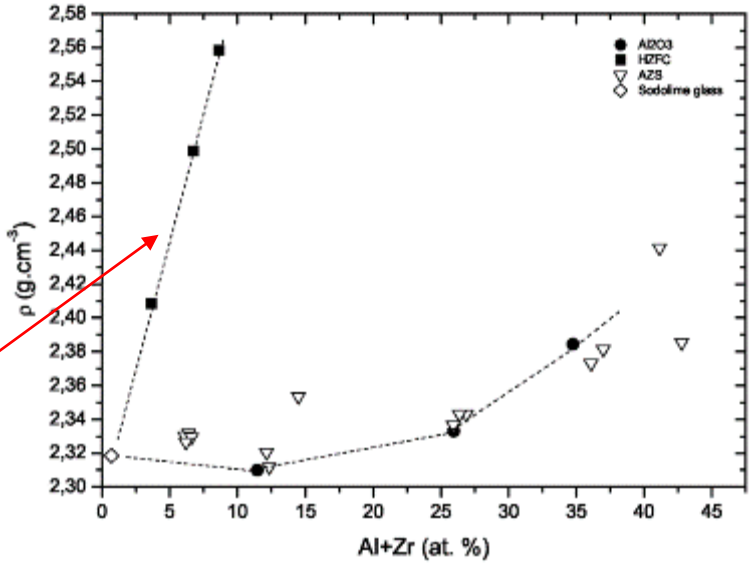
FC AZS HZFC



Corrosion	ER 1711	ER 1195
Cor volume	6.44	2.45
Index	100	262

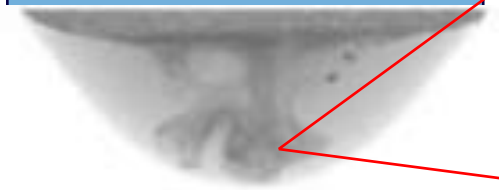
Glass density evolution at interface layer :

high impact of Zro2 content

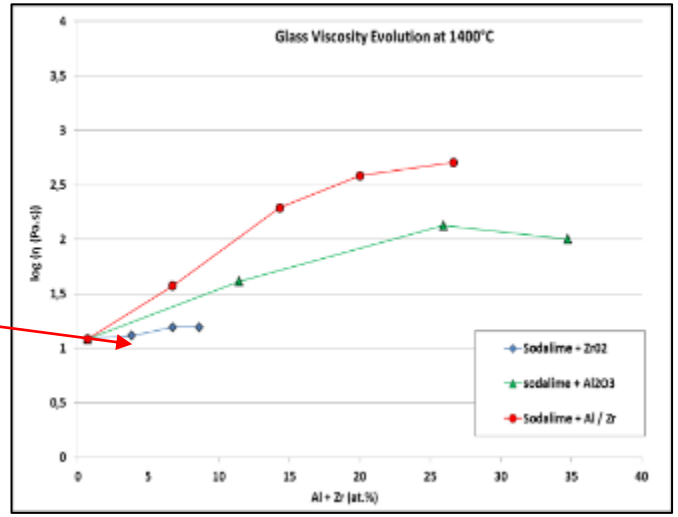


Xray tomography of

horizontal interface



Glass viscosity evolution at interface layer : low impact of Zro2 content

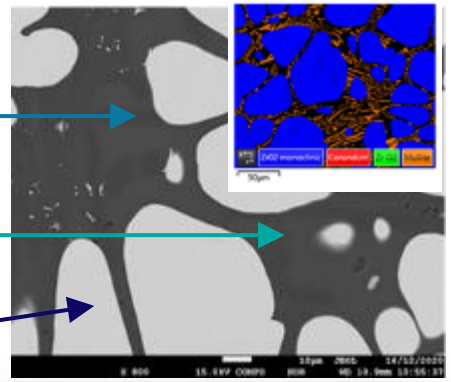


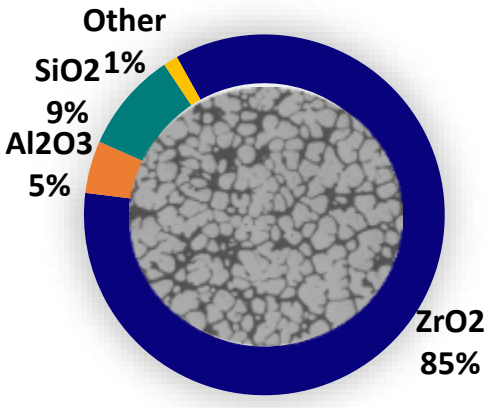
Throat corrosion : refractory material solution for borosilicate glass

Alternative HZFC Refractroy Solution

- **More protective layer with** a higher alumina content interface with higher viscosity
- **Lower ZrO2 solubility** at interface level to limit density increase

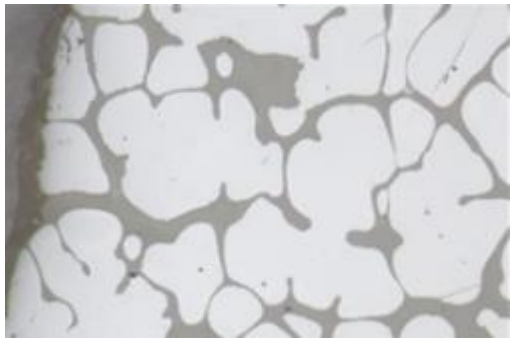
SEM / EBSD mapping



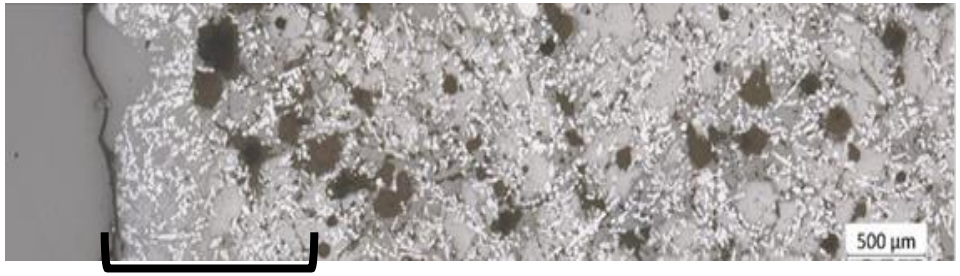


Advantage of HZFC in terms of glass defect

No interface layer



HZFC



interface layer

FC AZS

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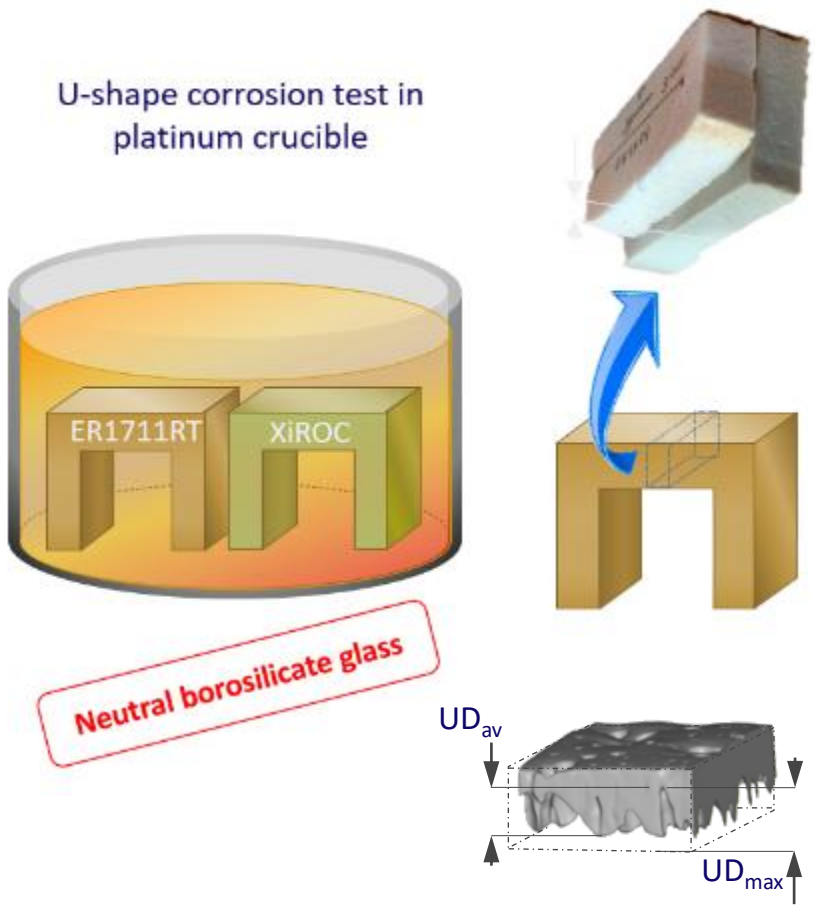
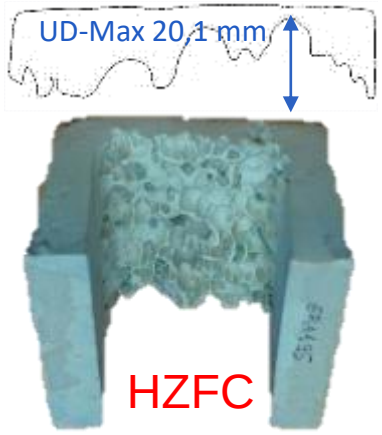
Laboratory test dedicated for throat corrosion process

- To reproduce horizontal interface corrosion process

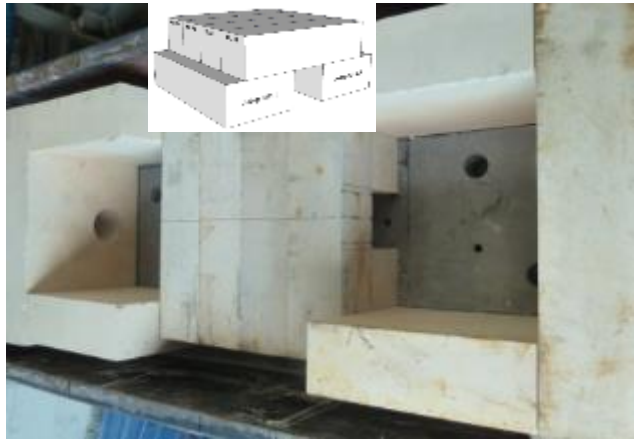
Static laboratory test





Lab test results

Dynamic Pilot Furnace



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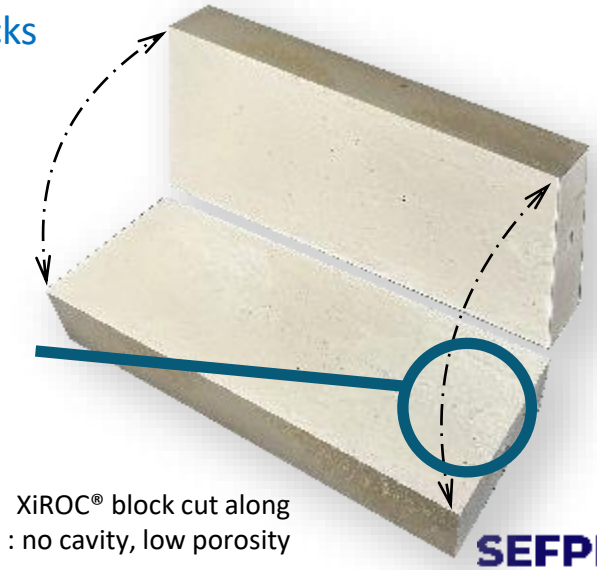
Industrial feasibility

Sidewall block

Throat lintel

Product Name :	**XiROC 95 RT**
Product category :	Void-free High Zirconia - all faces machine ground
Key features :	Density 4,9 g/cm^3
	No Chrome - Coloration free,
Industrial application :	borosilicate glass
	hard borosilicate flint glass
	Opal glass
Favorite application :	Throat lintel and throat cover blocks
	Distributors and feeder cover blocks



XiROC® block cut along its axis : no cavity, low porosity

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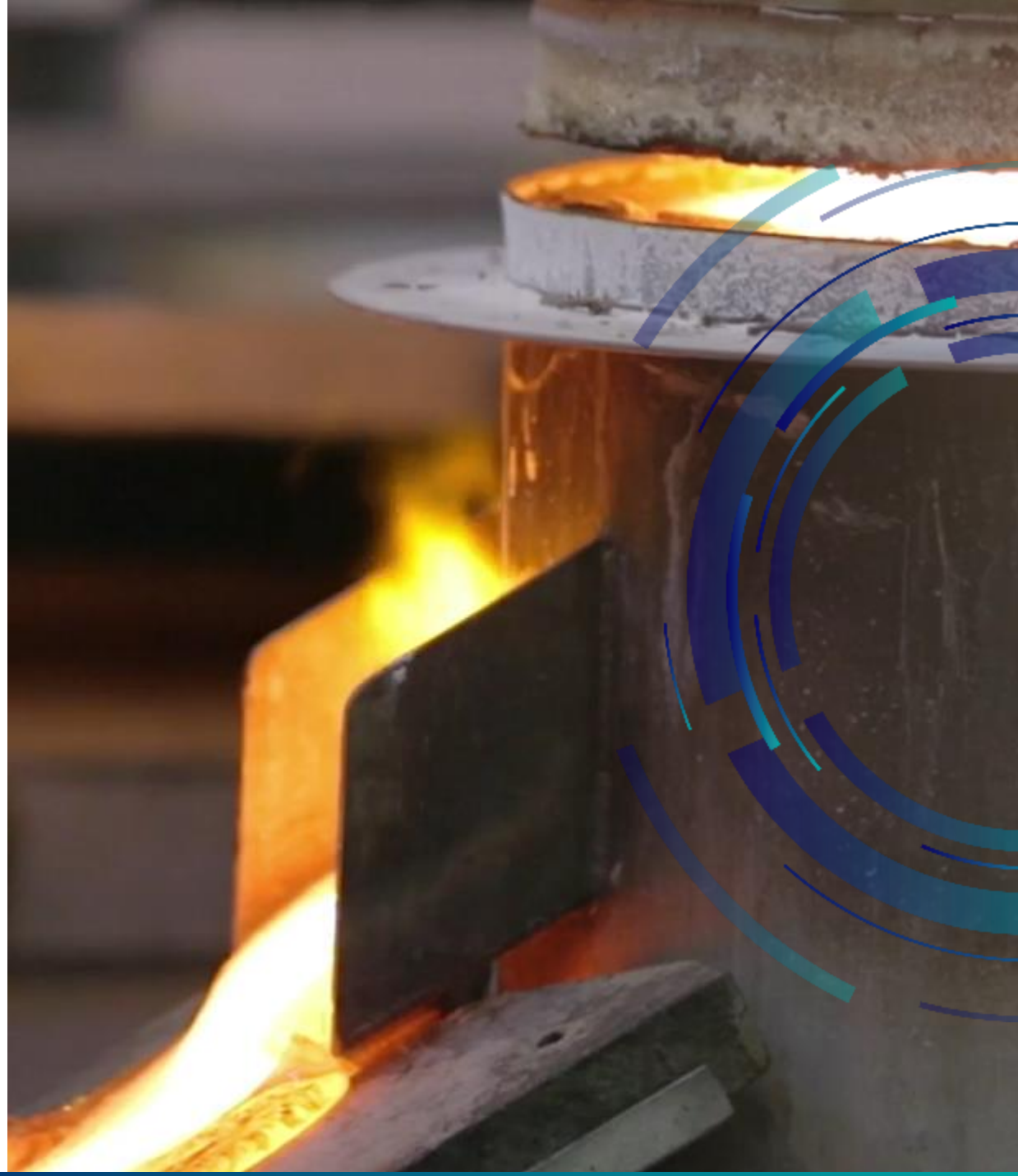
Numerical simulation of throat corrosion



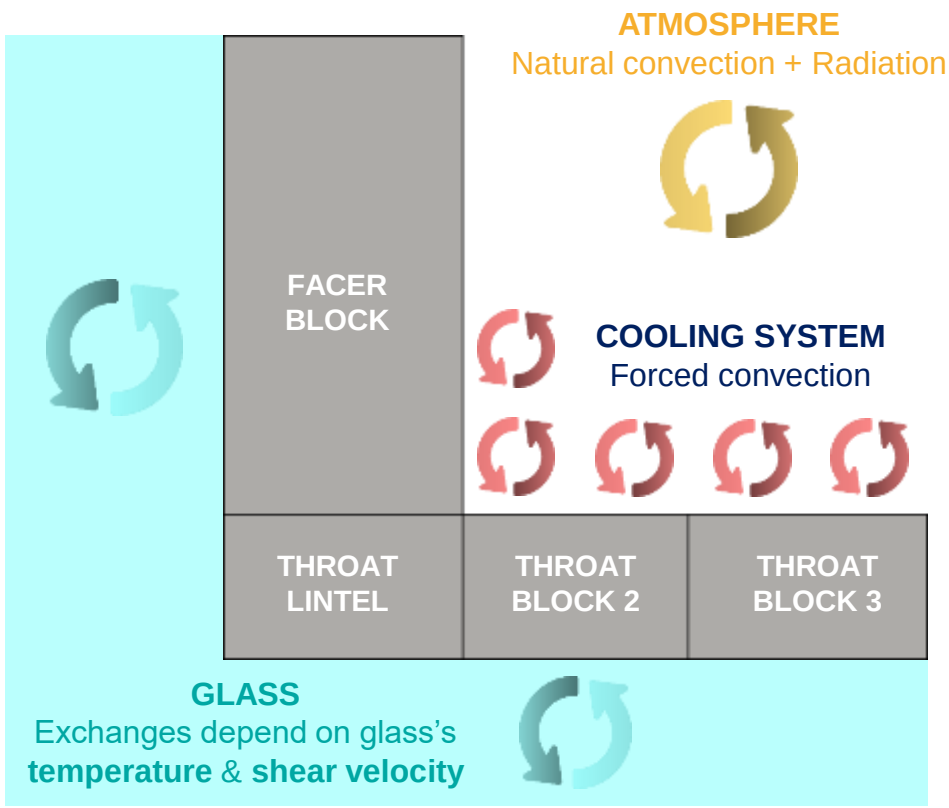
SIMULATION OF THROAT CORROSION

2D MODELING OF THROAT AREA WITH FEM MODEL

- 2D steady-state calculation with perfect thermal contact
- SEFPRO corrosion law of refractory material = f(T)
- Physical properties with temperature dependence

- Corrosion calculation
  - 2D Corrosion of Throat lintel
  - 1 month time increments

- 2 glass contact areas
  - Furnace (vertical interface)
  - Throat (horizontal interface)



Numerical simulation of throat corrosion

FEM model for dynamic corrosion interface study

Metal line

$\Phi = 0$

T_{verre}= 1535 °C

h_{chf} variable

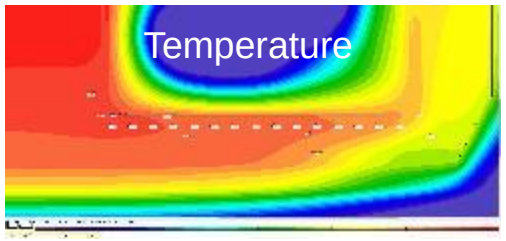
y

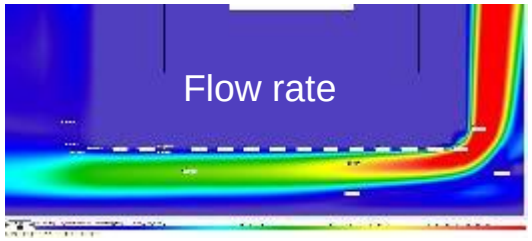
x

h_{ccf} heat exchange coefficient

Cooling efficiency

➢ Refractory material





CFD Modeling

➢ Glass temperature profile and glass velocity profile at the interface from CFD Model

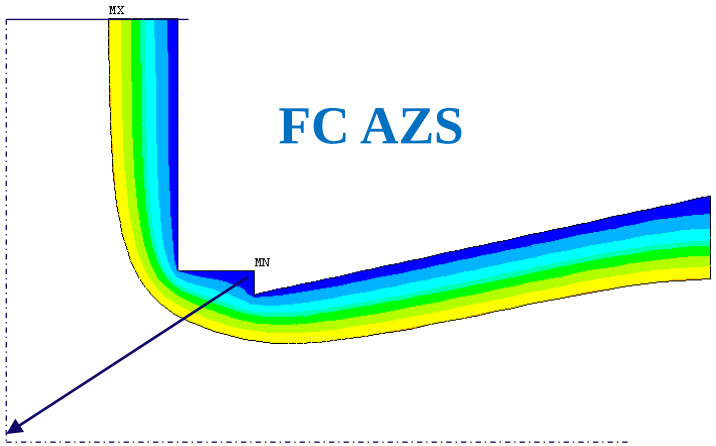
➢ Cooling system and efficiency

- air tempertaure / Air flow rate
- Water tempertaure / Water flow rate

Numerical simulation of throat corrosion by loop calculation on FEM model

Corrosion profile after 1 year

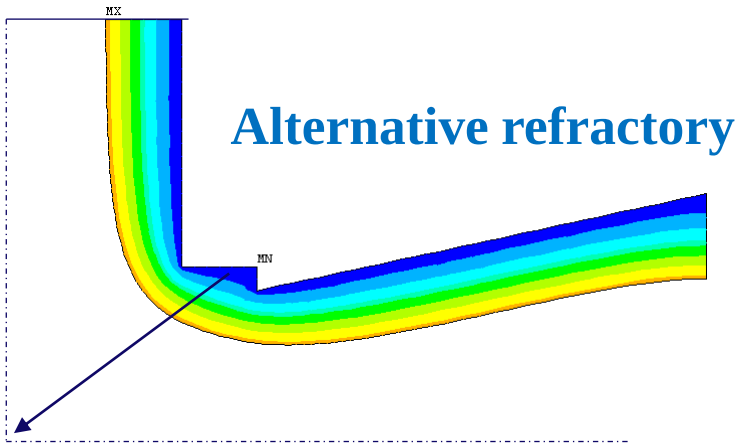
After 1 year



FC AZS

Erosion

d = 377 mm

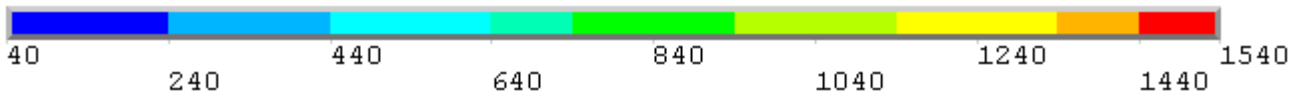


Alternative refractory

Erosion

d = 363 mm

Température (°C)



We can test and compare many different solutions :

- Refractory material
- Cooling system
- Refractory thickness
- Glass flow rate and temperature

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CONCLUSION

- Throat corrosion is a concern for glass furnace lifetime

- When comparing throat campaign duration, different parameters must be taken into account, such as :
  - refractory material
  - throat design
  - furnace running parameter

- To face hard corrosion conditions, alternative refractory solutions can be considered
  - chromic oxide for sodalime glass (depending on glass color)
  - new high zirconia FC material for borosilicate (under industrial testing)

- Numerical simulation of throat corrosion are under development and can help to compare different solution/design, to reach the suitable throat lifetime

Thank you for your attention !

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