HOW HIGH ELECTRICAL BOOSTING WILL AFFECT GLASS FURNACES' REFRACTORY MATERIALS

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GLASSMAKING: A CARBON INTENSIVE ACTIVITY…

Worldwide, glass manufacturing produces at least **86 million tonnes** of carbon dioxide every year

Legislators (and customers) are pushing for sustainability and carbon footprint reductions

Paris Agreement

Target: substantially reduce global greenhouse gas emissions to **limit the global temperature increase** in this century to 2 degrees Celsius while pursuing efforts to limit the increase even further to 1.5 degrees

Source: United Nations

… EVOLVING TO BE MORE SUSTAINABLE

STEP 1: Improvement of existing furnace

- Higher energy efficiency of regenerative glass furnace
- Improved thermal insulation
- Furnace monitoring for process optimization

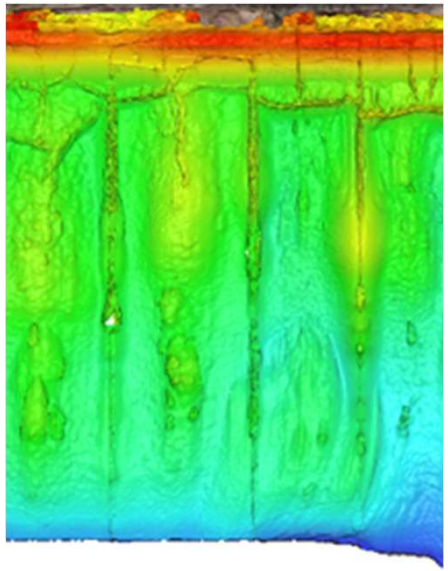
STEP 2: Technology evolution

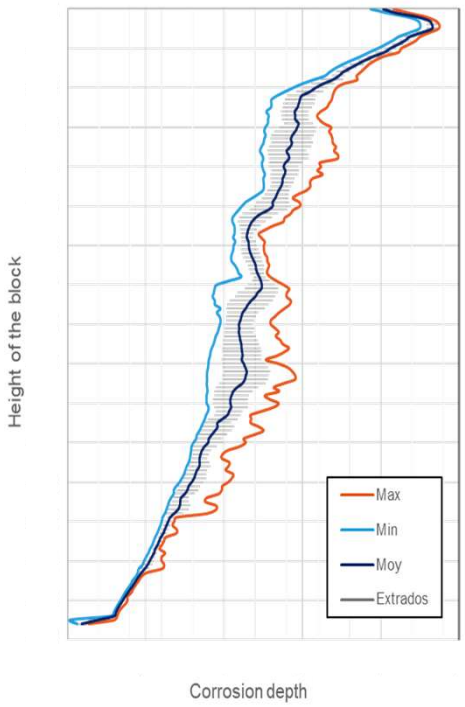
- Electrical melting: *From boosting to 100% e-furnace*
- Alternative fuel combustion: *Biofuels, H_2…*
- Carbon capture

CONSEQUENCES OF ELECTRICAL BOOSTING IN GLASS FURNACES

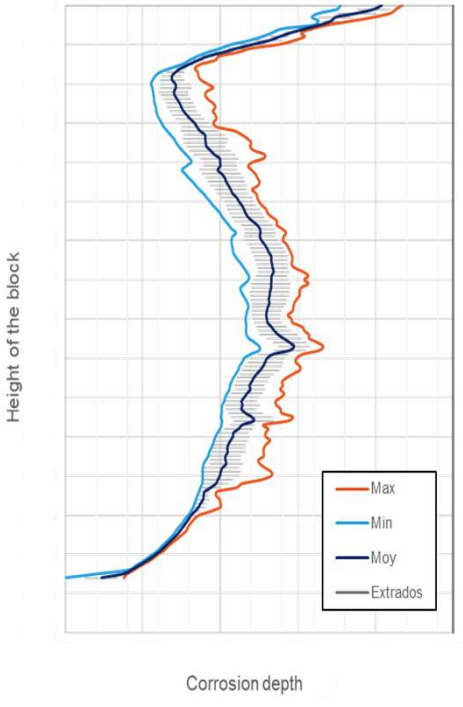
Significant effect on **refractory materials corrosion**

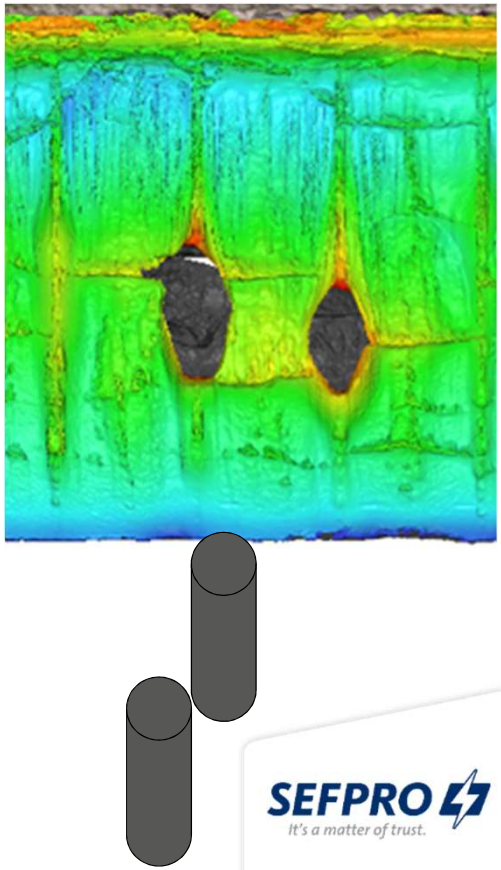
STANDARD PROFILE





ELECTRODE AREA

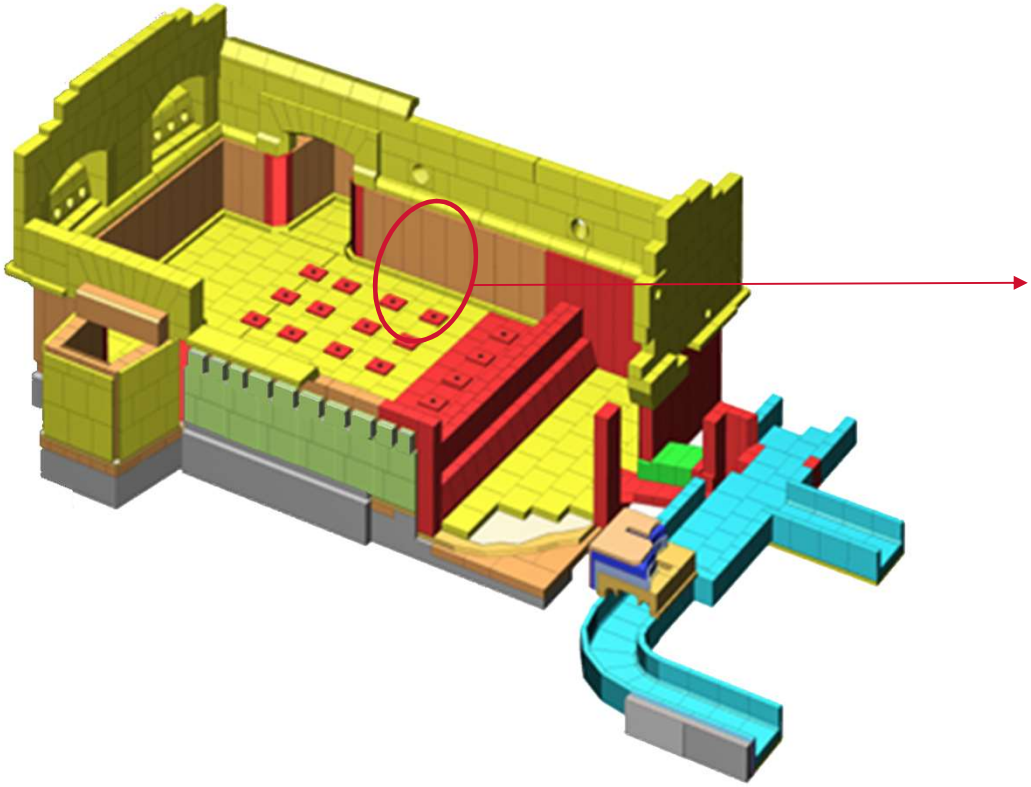


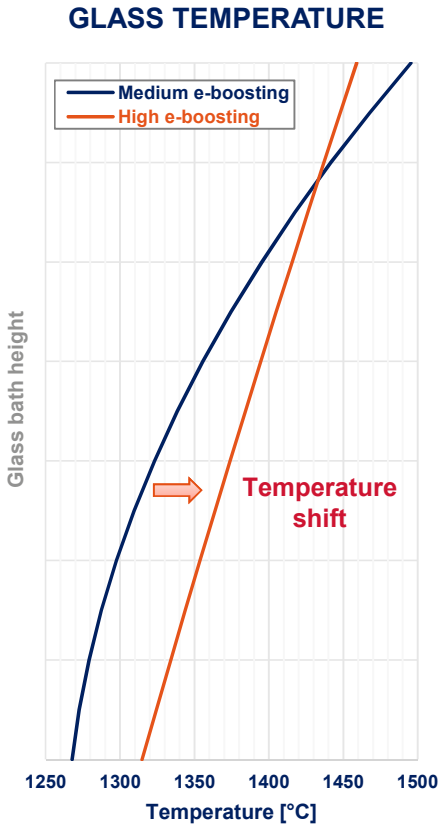


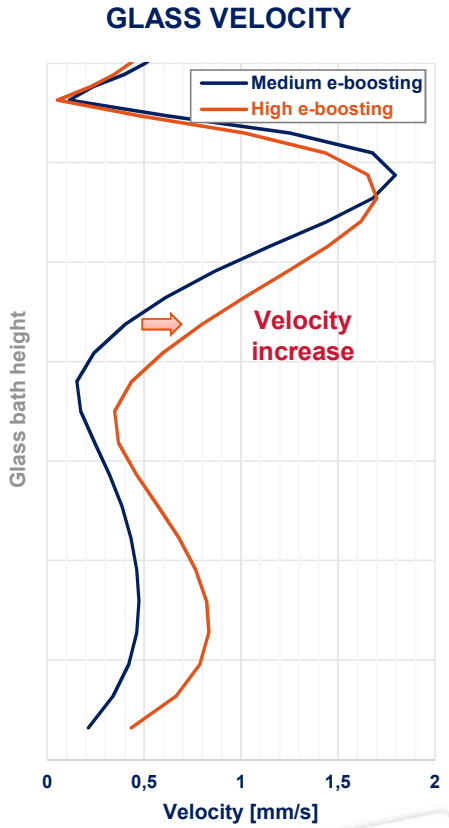
CONSEQUENCES OF ELECTRICAL BOOSTING IN GLASS FURNACES

New (or more intense) **energy source at the bottom** of glass bath.

Modifications in **glass temperature & velocity profiles**



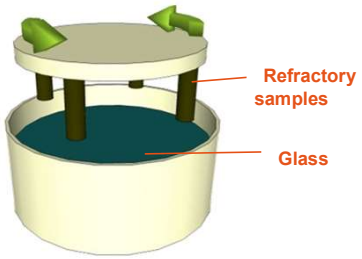


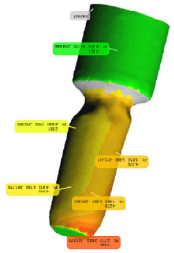


REFRACTORIES' CORROSION IN GLASS FURNACES

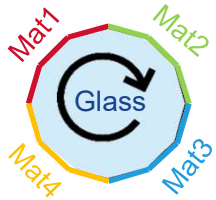
DYNAMIC CORROSION TESTS

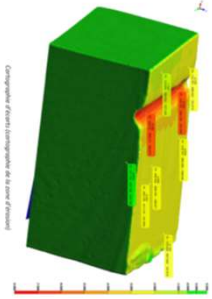
- MGR Test ("Merry-Go-Round")





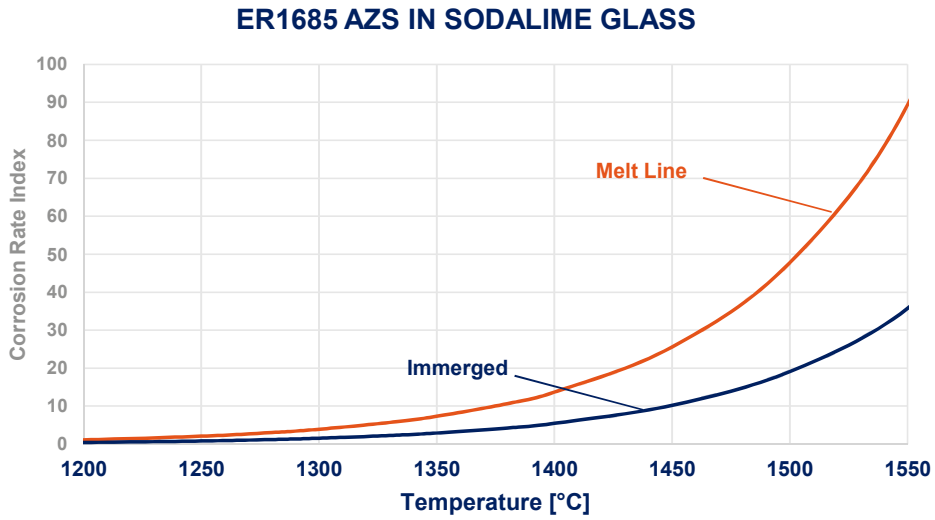
- SRF Test ("Small Rotating Furnace")





TEMPERATURE DEPENDENT CORROSION LAW

- Based on SEFPRO's database
- Compiling decades of lab testing & industrial experience / measurements



STRONG TEMPERATURE DEPENCY OF CORROSION RATE

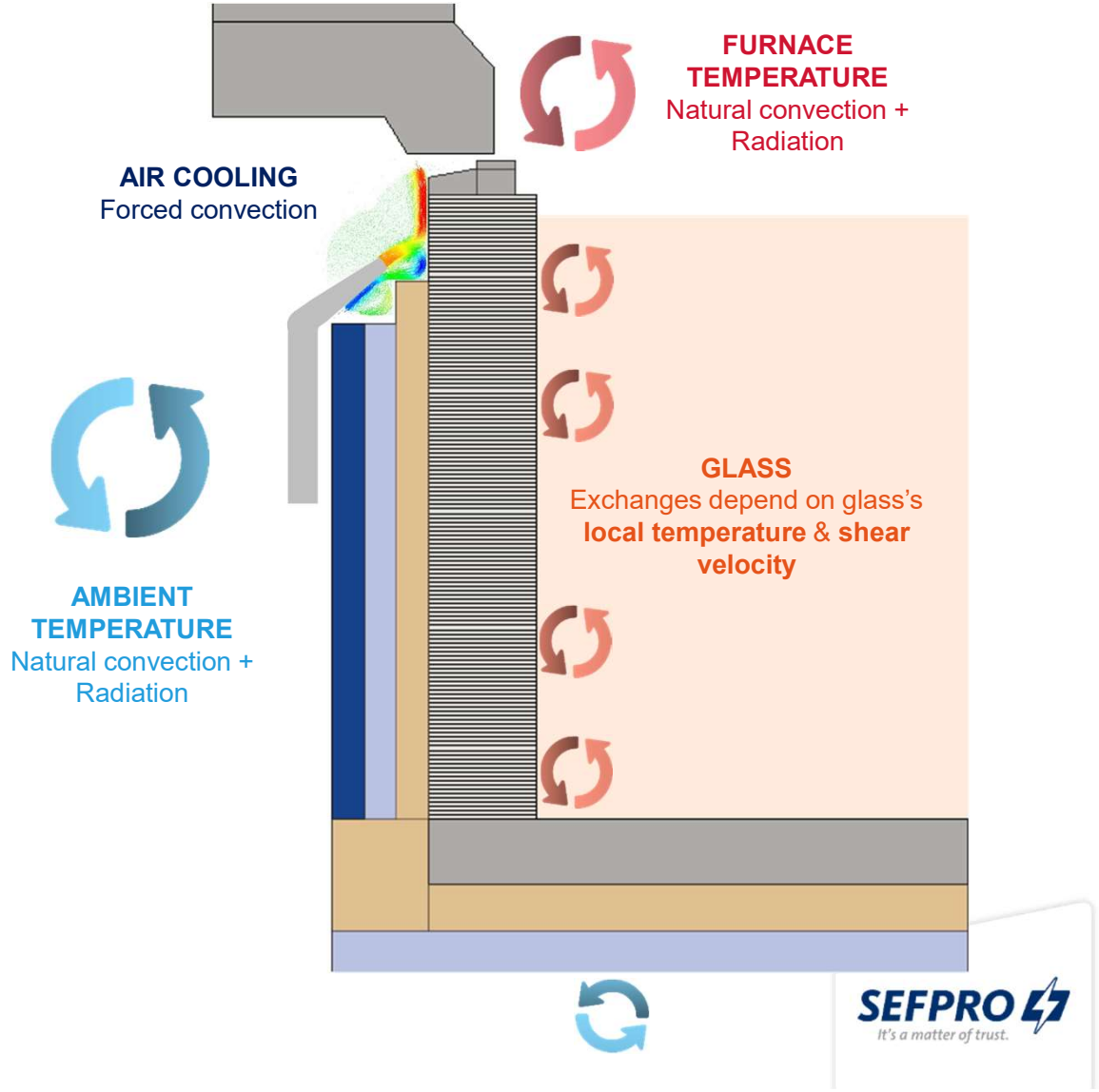
GLASS VELOCITY

- *Interface renewal / protective layer removal*
- *Increased heat transfers*

SIMULATION OF SOLDIER BLOCK'S CORROSION

2D MODELING OF INDUSTRIAL FURNACE

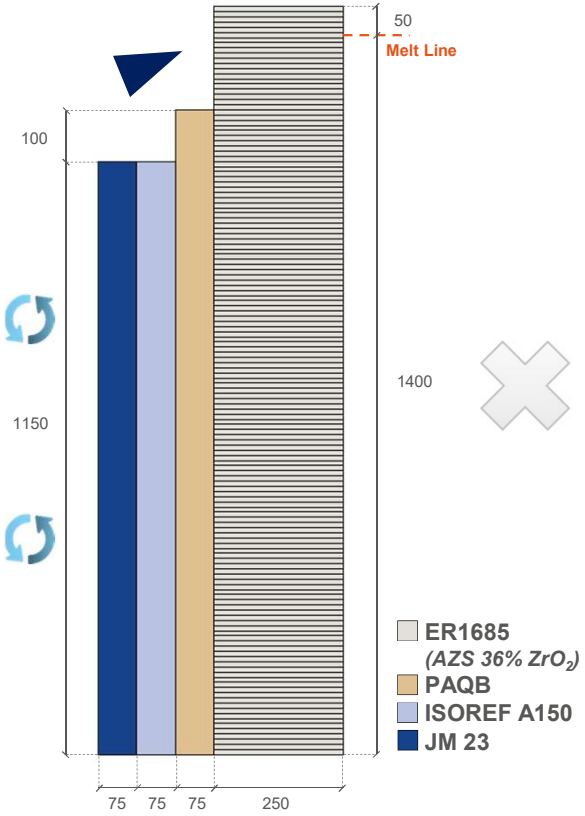
- **Current development of air cooling efficiency using CFD**
- **Several corrosion laws**
  - Different refractory materials
  - In Different glass types
- **Validated with industrial data**
  - 3D Scans, Hook measurements
  - Flat, Container, Tableware
  - Sodalime, Borosilicate glass…
  - Float, End-fired, Cold Top Furnaces…



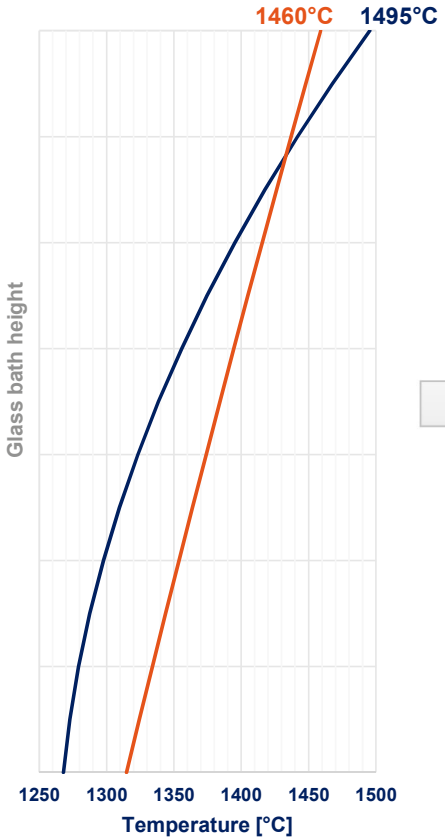
SOLDIER BLOCK CORROSION - *CASE STUDY, EFFECT OF HIGH BOOSTING*

BLOCK ASSEMBLY

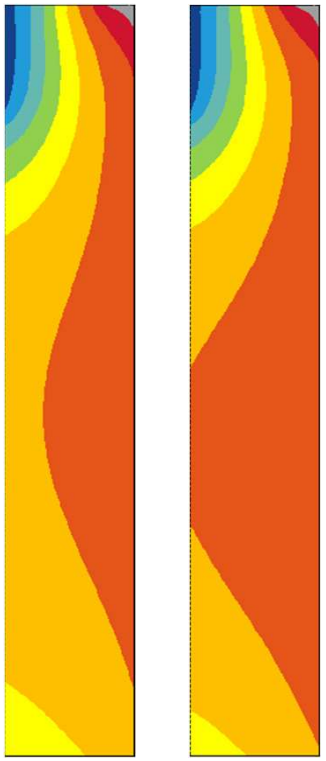
GEOMETRY



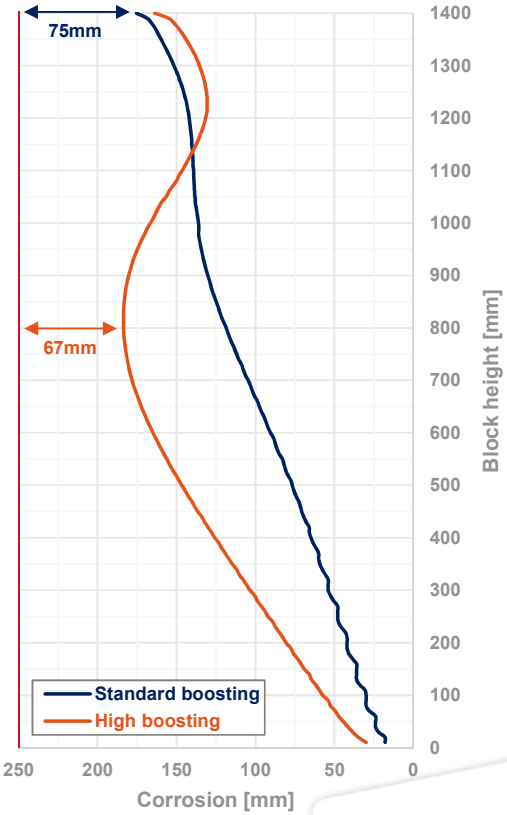
GLASS TEMPERATURE



CORROSION AFTER 5 YEARS



CORROSION PROFILE



5 YEARS TO REACH CRITICAL REMAINING THICKNESS AT MELT LINE → INSTALLATION OF PATCHING TILE

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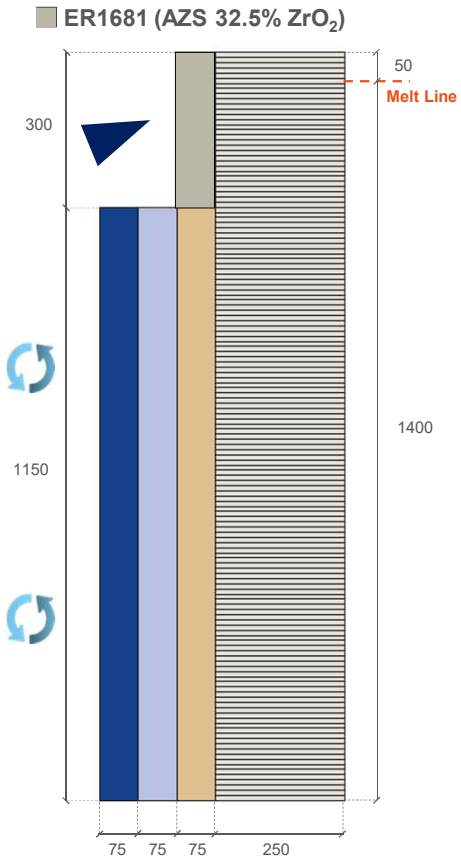
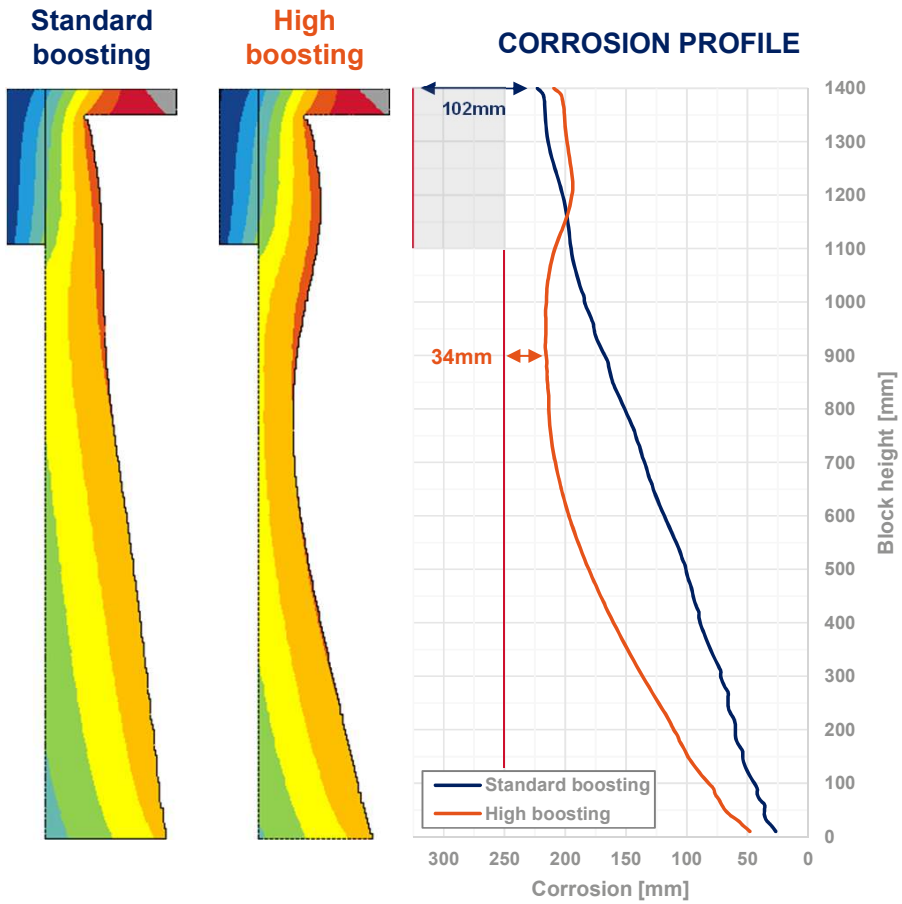
It's a matter of trust.

SOLDIER BLOCK CORROSION - *CASE STUDY, EFFECT OF HIGH BOOSTING*

BLOCK ASSEMBLY



CORROSION AFTER 10 YEARS



- Design viable for **10 years** operations **with standard boosting**
- With high electrical boosting, **critical corrosion point is shifted** below patching tile
- Design/patching strategy **adjustments are needed** to operate with high boosting

HOW TO MAINTAIN / IMPROVE LIFETIME OF THE SOLDIER BLOCK ASSEMBLY WITH HIGH BOOSTING?

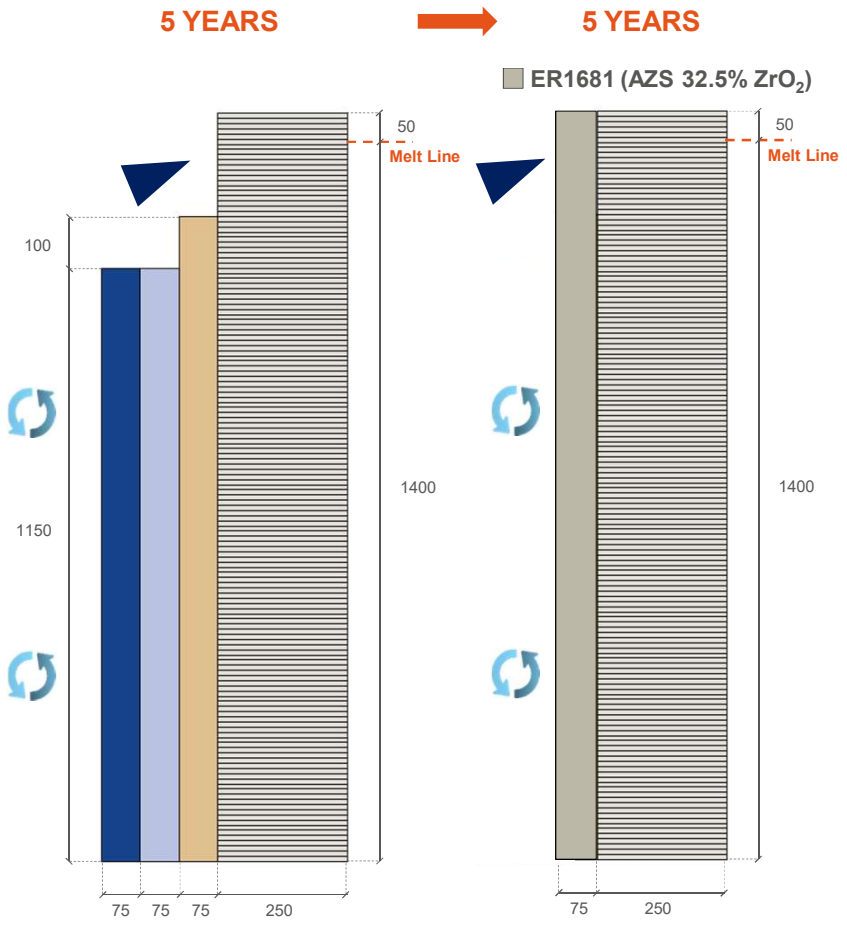
STUDY OF 2 ALTERNATIVE DESIGNS:

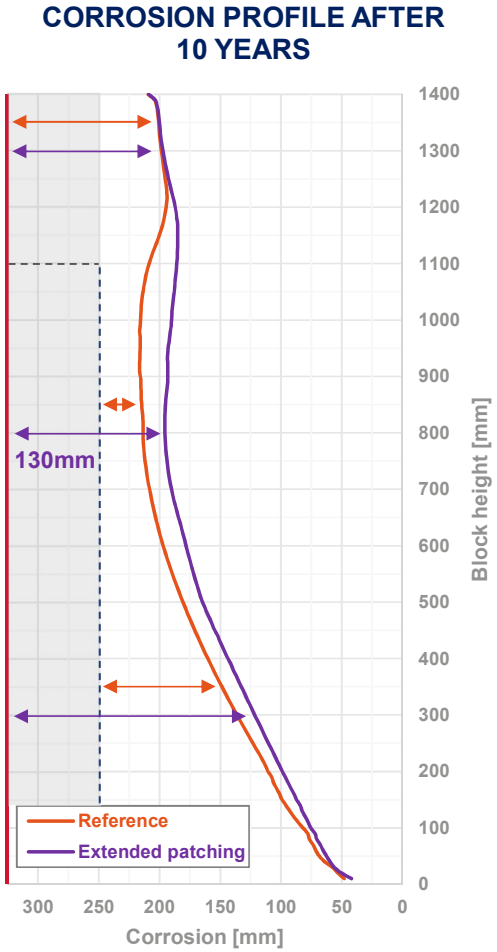
Corrosion management by patching

Corrosion management through initial design

IMPROVE SOLDIER BLOCK'S LIFETIME WITH HIGH BOOSTING

EXTENDED PATCHING – *ER 1685 block / 250mm thick / Insulation removed after overcoating*





COMPARISON WITH INITIAL DESIGN

- **Extended overcoating** allows to run for **10 years with high electrical boosting**
- **Reduced corrosion** in the bottom part of the block due to **insulation removal**
- **Safe refractory thickness** on entire block height

TOTAL HEAT LOSSES OVER CAMPAIGN

Top patching only *Critical Corrosion*	Extended patching
705 MWh/m²	855 MWh/m²

+21%

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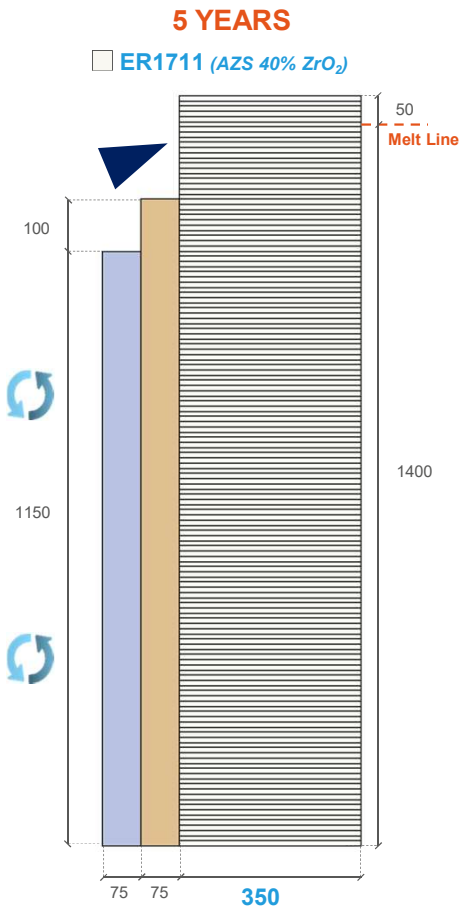
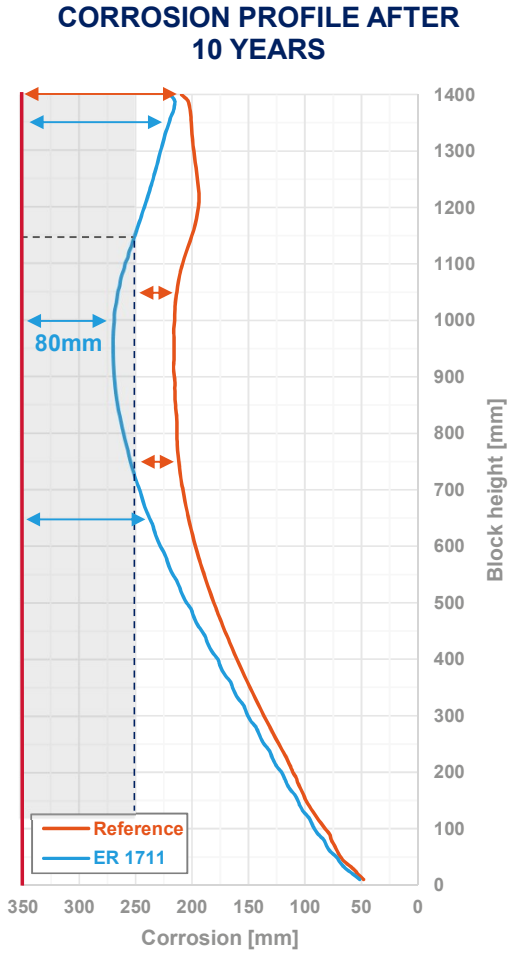
IMPROVE SOLDIER BLOCK'S LIFETIME WITH HIGH BOOSTING

IMPROVED INITIAL DESIGN – *ER 1711 block / 350mm thick / Reduced insulation*





COMPARISON WITH INITIAL DESIGN

- **No patching** needed leading to **lower maintenance costs**
- **Safe refractory thickness** on entire block height after 10 years
- Significantly **lower thermal losses**

TOTAL HEAT LOSSES OVER CAMPAIGN

Top patching only *Critical Corrosion*	Extended patching
705 MWh/m²	855 MWh/m²

Thicker ER 1711 Block
292 MWh/m²

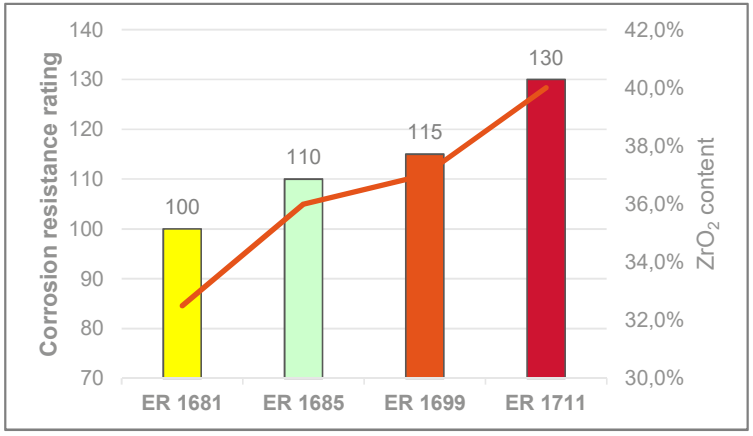
-66%

For 100m²
>5M€ in Energy Savings

IMPROVE SOLDIER BLOCK'S LIFETIME WITH HIGH BOOSTING ALTERNATIVE NEW FC AZS (ER 1699 RS) COMPARE TO ER 1685 RR

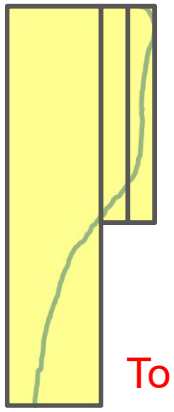
A higher ZrO_2 content and lower glassy phase compare to ER 1685 RR

Chemical composition	ER 1699 RS	ER 1685 RR
Al_2O_3	47,8%	48,1%
ZrO_2	37,0%	36,0%
SiO_2	13,5%	14,0%
Na_2O	1,2%	1,4%
Crystallographic analysis		
Corundum	44,0%	43,5%
Zirconia	36,5%	35,5%
Vitreous Phase	19,5%	21,0%



Improved filling
+
Improved chemistry
=
Higher corrosion resistance vs ER 1685 RR

- A substitute to regular cast (ER 1685 RR) in area with risk of leakage below patching area (flint & clear glass)



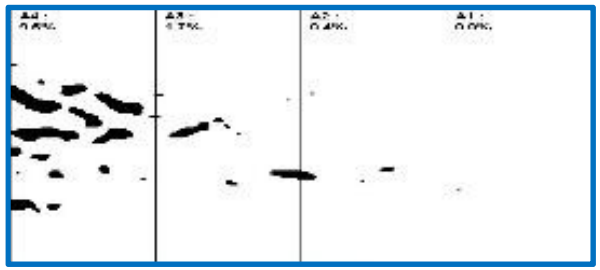
To prevent bottom block corrosion

REFRACTORY SOLUTION FOR ELECTRICAL GLASS FURNACE SOLDIER BLOCK

BLOCK FILING STRATEGY

- Coloured glass
- Lower temperature area
- Sidewall is not the weak point

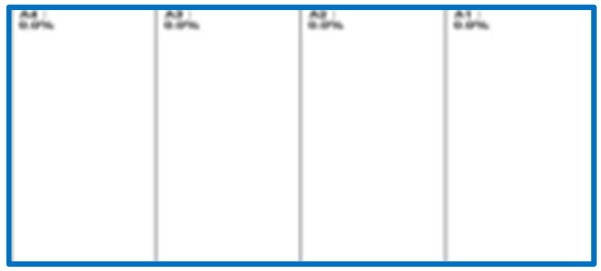
RR sidewall
“Standard”
ER 1685



- Clear Glass
- Hybrid melting
- Variable Boosting
- RR weak points

RS sidewall
“Special”
ER 1699 5S

RT sidewall
“Security”
ER 1711 RT



- High wear area
- Extra white glass
- Long campaign
- Electric furnace
- High boosting area

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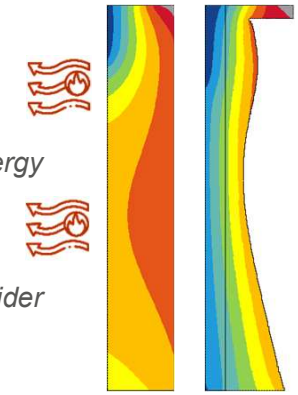
CONCLUSION

EFFECT OF HIGH E-BOOSTING ON CORROSION

- **Modification of corrosion profile**
  - *Glass temperature profile*
  - *Glass shear velocity*
- **Melt line might not be the critical corrosion point**
  - *Critical corrosion point lower in the block (below usual patching area)*
  - *Importance of filling quality / shrinkage cavity size & position*
- **Design / maintenance of sidewalls need to be adjusted**

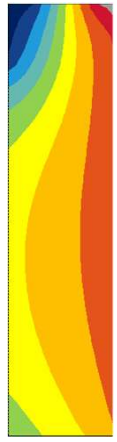
MAINTENANCE STRATEGY MODIFICATION

- **Extended patching**
  - *Critical corrosion point secured*
- **Insulation removal**
  - ***Higher thermal losses*** → *Energy consumption increase*
- **Sidewall block filling**
  - *Numerical simulation does not consider* ***shrinkage cavity effect***



SIDEWALL DESIGN OPTIMIZATION

- **ER 1711 RT block**
  - ***Higher corrosion resistance***
  - ***Void free product***
- **ER 1699 RS block**
  - ***Improved corrosion resistance***
  - ***Close to Void free product***
- **350mm thickness**
  - ***No patching needed***
  - *Entire campaign with reduced insulation*
  - *Significant* ***reduction of thermal losses*** *and energy consumption*



Electrical boosting increase leads to **significant environment modifications** for sidewall refractories

Numerical simulation can help:

- Assess the **effect on sidewalls' corrosion**
&
- Choose the **right Refractory block to secure life time and limit energy consumption**

THANK YOU FOR YOUR ATTENTION

Any questions?