

Crowns deformation during the furnace lifetime oxy firing

The logo for AGC, consisting of the letters 'AGC' in a bold, blue, sans-serif font. A small red square is positioned between the 'A' and 'G'.

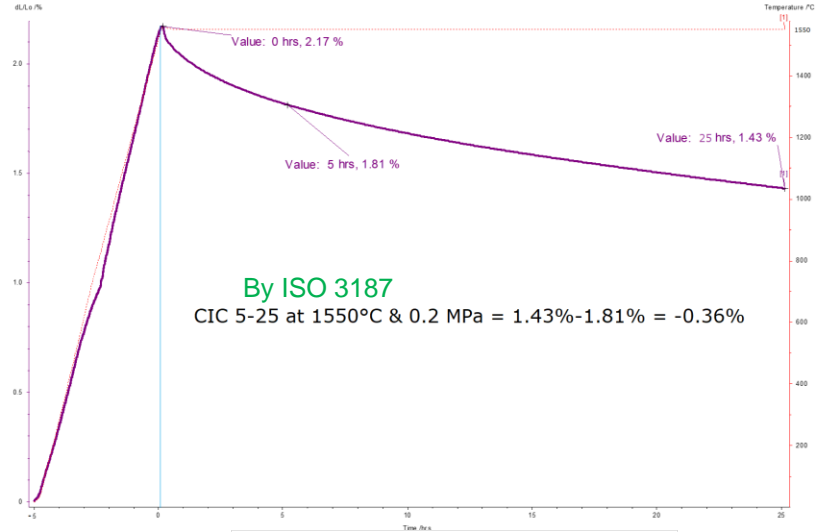
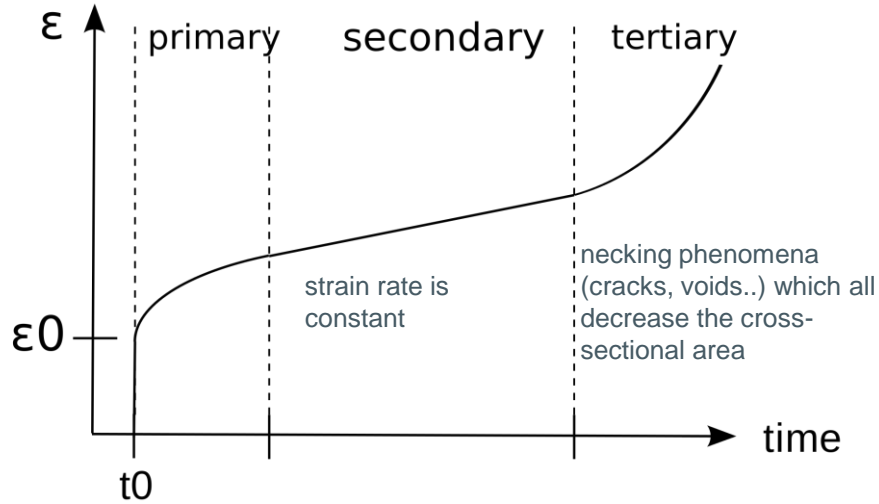
TC11 - 2022-09-19

JP Meynckens

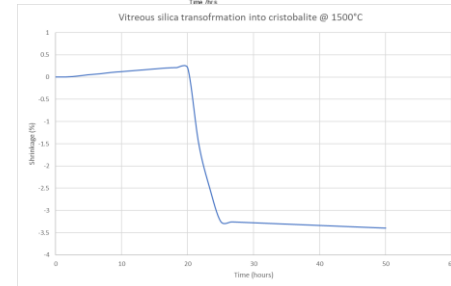
Your Dreams, Our Challenge

- The use of oxy-fuel combustion has led the glass industry to search for more corrosion-resistant refractories.
- Fused-cast $\alpha\beta$ alumina has been recommended as a candidate for the crown refractory application, specifically due to the excellent resistance to vapor corrosion by alkalis.
- The drawback of the $\alpha\beta$ alumina is the creep that has been observed and measured on large span crowns (i.e. > 10m).

Creep – laboratory measurement



- Avoid phases transformation during creep test, for example vitreous silica → cristobalite
- Ensure primary state is completed during the furnace operation & avoid tertiary unstable state
- Confirm if lab measurement conditions (short term) is in line with the furnace operation by using strain gauges.



Example: $\alpha\beta$ Al₂O₃ – “zero” creep curve

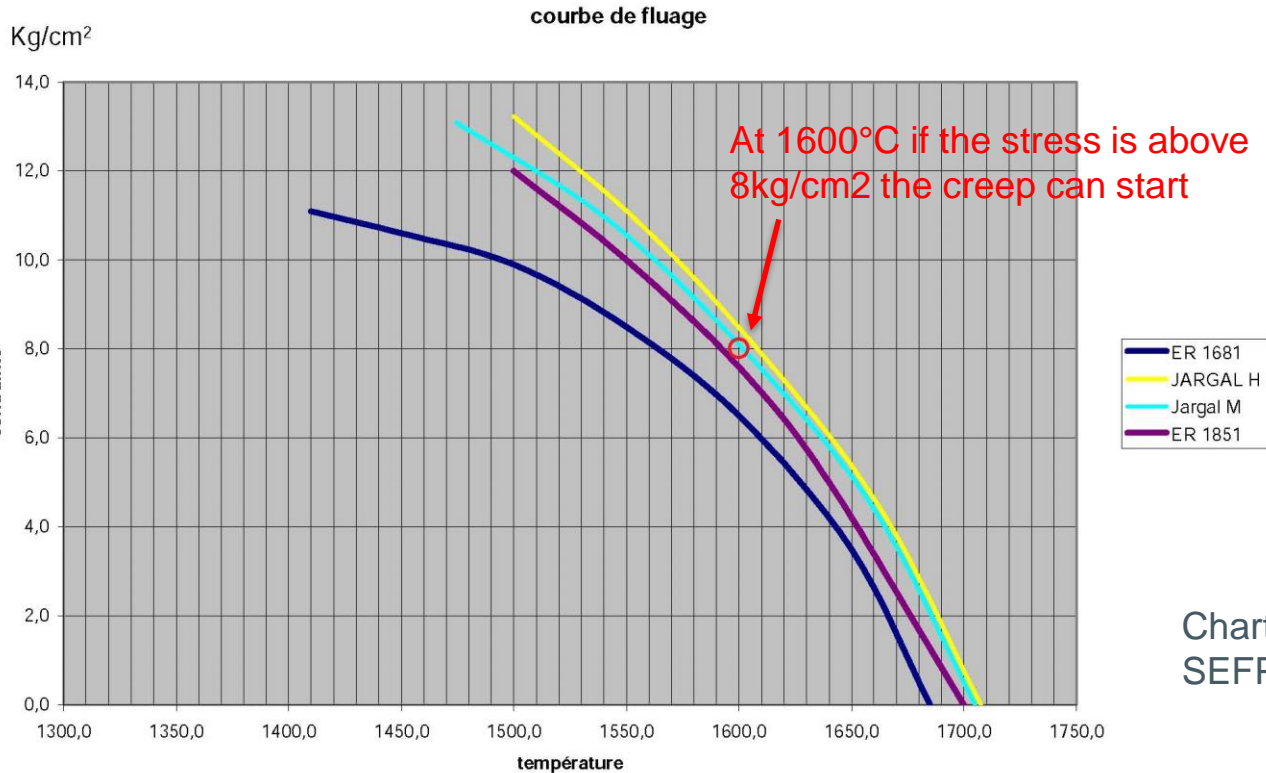

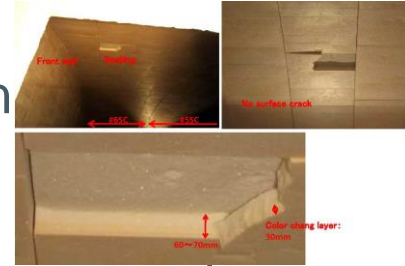


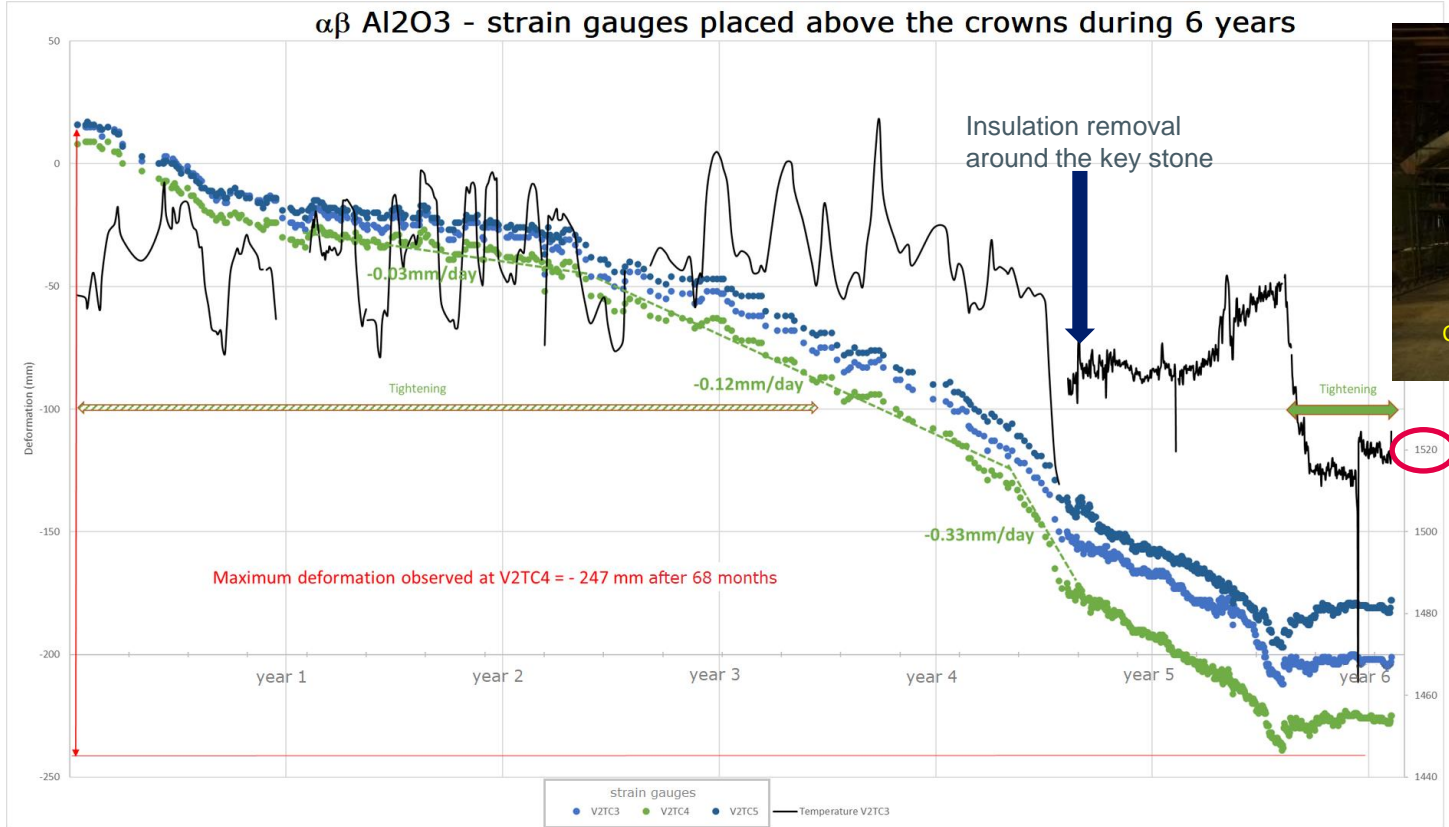
Chart provided courtesy of
SEFPRO – CREE

- Creep test measured in the laboratories could be less severe as it does not combine the material transformation due to the furnace atmosphere
 - Allotropic transformation β Al₂O₃ \rightarrow α Al₂O₃ observed in the crowns 
- Creep test measured in the laboratories could be more severe as it does not take into account the temperature gradient (hot & “cold” face).
- Maximum theoretical stress in the material is calculated based on a perfect crown shape and a perfect contact surface in between the wedges. Any deviation leads to stress concentration.
- Due to the stress concentration, the average calculated stress in the Al₂O₃ electrocast (i.e. 0.4 to 0.5 MPa for 12 m large span & 60°) could reach the limit of 0.8 MPa where the creep can start.



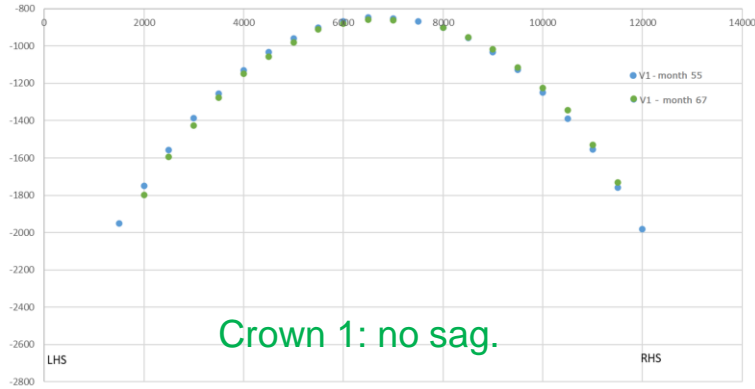
$\alpha\beta$ Al₂O₃ – crown deformation measurements

$\alpha\beta$ Al₂O₃ - strain gauges placed above the crowns during 6 years



$\alpha\beta$ Al₂O₃ – crown shapes measurements by laser

transversal measurements (crown n°1) during one year



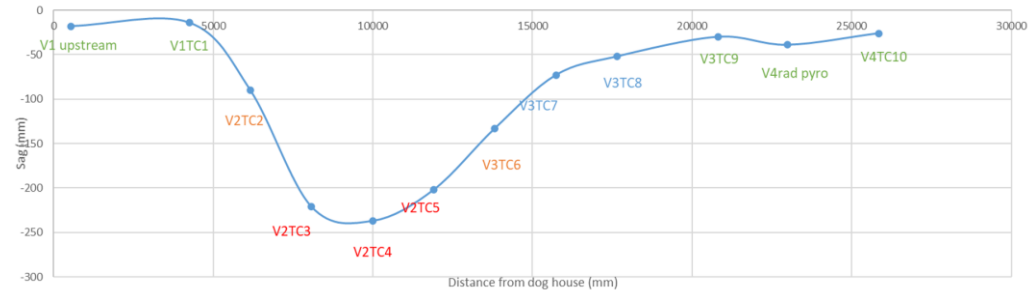
No sag observed in crown # 1

-> Counter measure to stop the creep at crown 2:
reduce T at crown #2 to the level of crown#1, combined
with tightening in order to avoid the creep.

transversal measurements (crown n°2) during two years



Crown shape along the key stone (month 69)

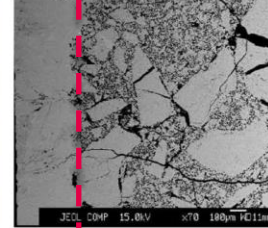


Development of lime free Silica

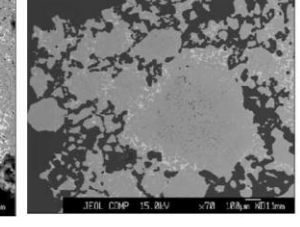
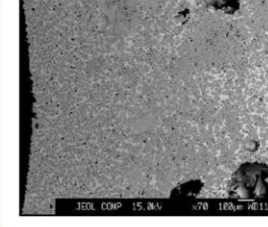
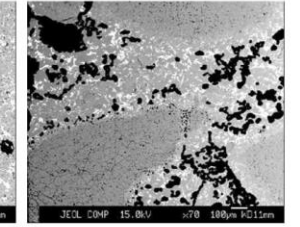
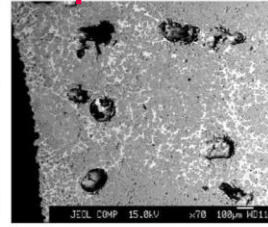
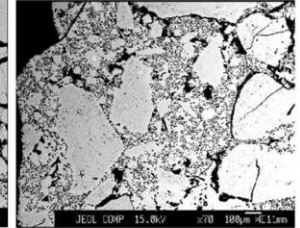
Quality	Standard		Lime free		
	AVERAGE	STDEV	AVERAGE	STDEV	
Chemical Analyse					
Al ₂ O ₃ %	0.41	0.04	0.09	0.00	
SiO ₂ %	96.71	0.27	98.76	0.36	
Fe ₂ O ₃ %	0.20	0.02	0.05	0.02	
CaO %	2.58	0.29	0.05	0.01	
K ₂ O %	0.04	0.03	0.04	0.01	
Na ₂ O %	0.05	0.00	0.87	0.24	
TOTAL %	100.0		99.89		
RX :	residual quartz	0.18	0.17	0.50	
	others	+/-50/50 cris/tridym	+/-30% vitreous 70%cris/tridym		
DENSITY	gr/cm ³	1.85	0.03	1.81	0.06
POROSITY	%	19.94	0.99	20.17	3.21
PERMEAB,	nanoperm	8.41	4.68	2.14	2.37
CCS	Mpa	39	6.94	31.50	
RUL (2kg/cm²)	°C - T0.5	1677	9	>1700°C	



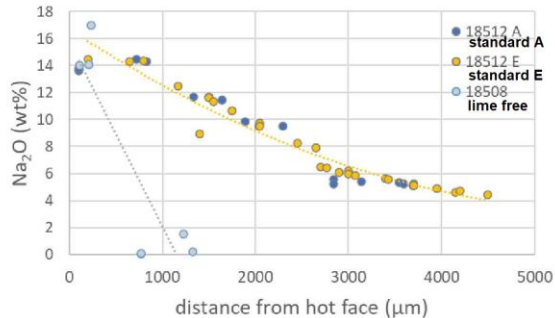
Contact with Na-vapor



Opposite side



Vapour test:
Na₂CO₃ @ 1550°C
(ASTM C987)



- The use of oxy-fuel combustion has led the glass industry to search for more corrosion-resistant refractories comparing to the usual silica bricks. Electrocast refractories have been often used for that purpose.
- In order to avoid the AZS glassy phase drawbacks and to maintain a reasonable creep resistance, the $\alpha\beta$ alumina electrocast has been selected for the melter crown in the large melters. The drawback of the $\alpha\beta$ alumina is the creep that has been observed and measured on large span crowns (i.e. > 10m).
- In order to increase the corrosion resistance of usual silica bricks, a new generation of silica material without lime is being developed and return of experience of furnaces of more than 10 years start to be disclosed.
- For soda lime glass, creep resistance of $\alpha\beta$ alumina (FC) should be compared with the new generation of lime free silica (after devitrification) at temperatures ranges of 1550°C – 1575°C. For large span furnaces, long term creep tests at 0.4 MPa should be studied in order to select the most appropriate material.