

TC11-Meeting, 19th September 2022

Düsseldorf



Crown Span

General Remarks

The crown of glass furnaces and glass furnace regenerators are a sensitive part of the furnace construction due to several reasons:

- Operation conditions & corrosion effects
- Crown width, corresponding load and insulation lay-out
- Lifetime expectations

In regenerative heated glass furnaces for soda-lime glass the melter crown is constructed out of silica bricks

Under oxy-fuel conditions the following materials are common:

- Silica & fused cast products for container glass furnaces
- Fused cast products for float furnaces
- Special glass: Silica, fused cast, spinel, mullite....

For regenerator crown three concepts are existing:

- Silica / Mullite / Magnesite whereas silica is mainly installed in float furnaces

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Silica for regenerative heated glass furnaces

Quite long experience in glass furnace construction

Max. span of standard Silica Stella GGS in float: 14.000mm (thickness 450mm)

Max. span of no-lime Silica Stella GNL almost 10.000mm (thickness 450mm)

Table 3.1. *Height of crown bricks as a function of span of crown*

<i>Brick height (mm)</i>	<i>Span of crown (mm)</i>
250	< 3000
300	3000–4900
375	4900–6700
450	6700–9750
500	> 9750

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From «Glass Furnaces Design Construction and Operation»
Wolfgang Trier
Society of Glass Technology Ed.1987

Scientific literature provide us some reference figures for the construction of a silica crown, and the relation between the span and the brick height.

These figures consider also the crown wear during operation.

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Stella GGS vs. Stella GNL

Stella GNL is lime-free and based on fused Silica, whereas Stella GGS is based on natural Quarzite and lime-bonding

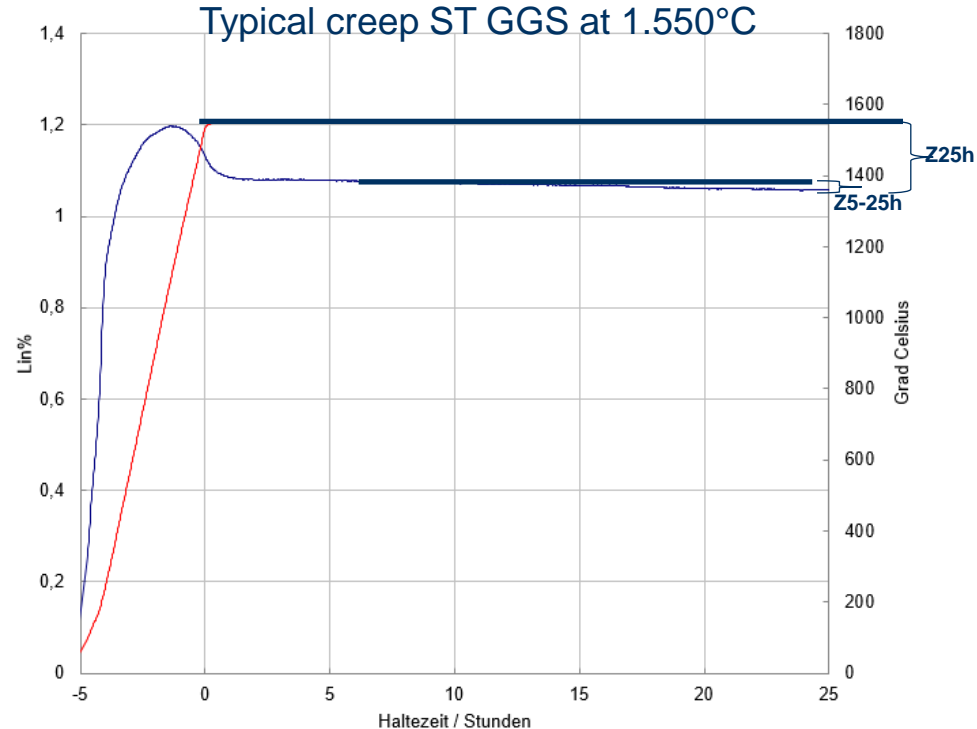
Experience with Stella GNL since 2005 (first installation)

Important creep-characteristics :

Absolute creep/shrinkage from maximum expansion till end of test after 25h: Z25h

Creep/shrinkage between 5th and 25th hour: Z5-25h

Z25 > Z5-25h



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Stella GGS vs. Stella GNL



Standard testing temperatures silica material from RHIM

Stella GGS: 1.550°C

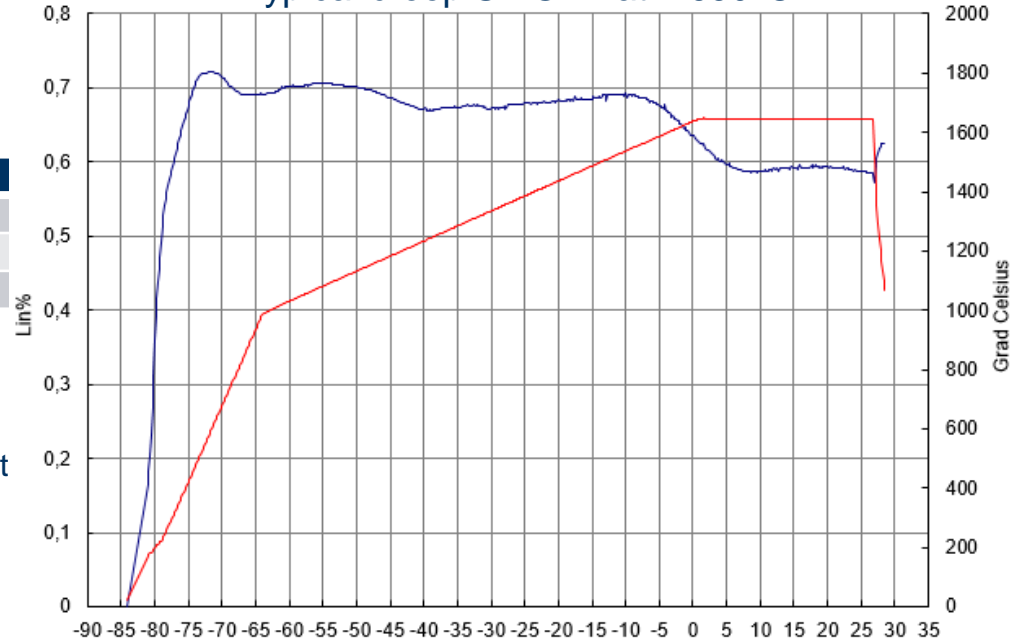
Stella GNL: 1.650°C (with slower heating-up rate)

Typical creep numbers:

	STELLA GNL	STELLA GGS
	1650°C, 0,2N/mm ²	1550°C, 0,2N/mm ²
Z5-25 [%]	~ -0,1	~ -0,1
Z25 [%]	~ -0,25	~ -0,25

Little information about GGS at 1.600°, but indication that creep-resistance is lower compared to 1.550°C

Typical creep ST GNL at 1.650°C

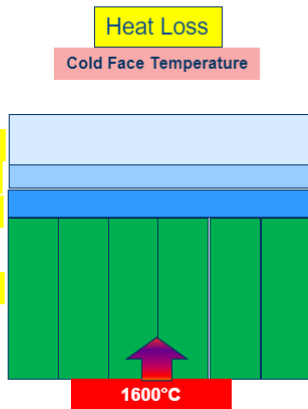
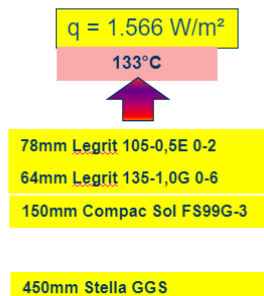


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Insulation of silica crowns

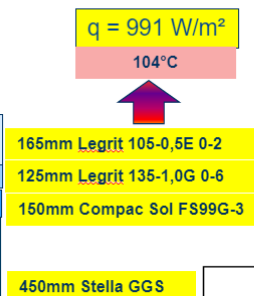
#1 Monolithic: Equal Heat Loss

Heat Loss is set as the benchmark



#2 Monolithic: Reduced Heat Loss

Heat Loss is set to < 1.000 W/m²



Concept	Layer Description	Heat Loss W/m ²	Cold Face Temp °C	Energy Savings MWh/year (*)
Monolithic #1 Equal Heat Loss	See above	1.566	133	BM
Monolithic #2 Reduced Heat Loss		991	104	504
Market Benchmark	64mm Silica 160-1,1 3x64mm Silica 150-0,5 30mm Silica Mix	1.566	133	BM
RHI Magnesita Brick Concept	64mm Legral 55/07 3x64mm Legral 50/04 30mm Stellit GH 0-1	1314	121	221

*Energy savings are calculated for 100m² crown with 1.600°C internal temperature

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Thoughts to crown design

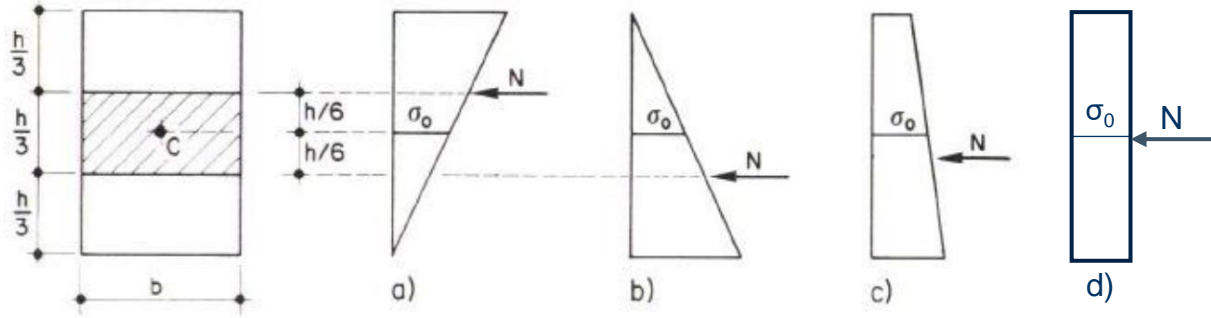
Romans and middle age architects have built arches up to 30 meter span

«Devil» Bridge – Lanzo Torinese- Turin- Italy



Crown Span

Thoughts to crown design



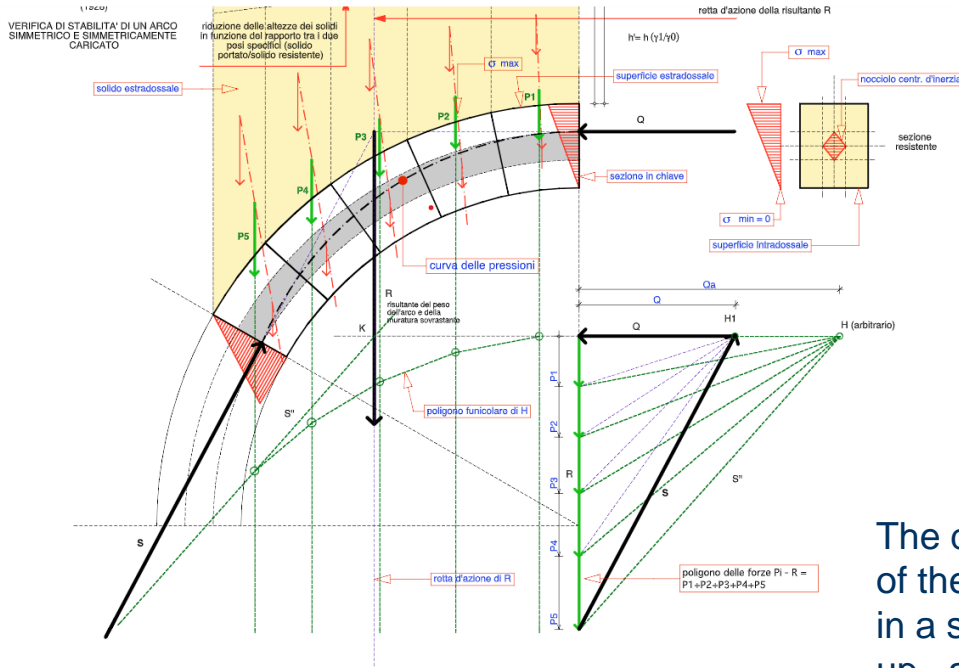
From the engineering point of view it is possible to realize a stable crown with a span larger than 14.000 mm.

It is important to understand which parameters influence the arch stability. On top, safety margins must be considered.

Physics applied to Constructions can provide several inputs

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Thoughts to crown design



The arch stability depends on:

Pressure distribution – only compression stresses on each section of every wedge



- Height of the wedges
- Weight and therefore Material of the arch
- Cold and Hot mechanical properties of the material used for the crown.

An accurate design permits to overcome the dimension limit of the existing installations

The design must involve the structural calculations of the steelwork that must be able to resist and consent in a suitable way the forces that develop during the heat up , and contribute to the crown stability during the operation.

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Thoughts to crown design



Our ideas for future developments

1° STEP

FEM modeling of a wide span crown up to 20 m in cold conditions (or the maximum span that makes sense according to the limits coming from the furnace combustion and operation) ;

The study aims to investigate on the crown stability and which actions is possible to take to improve it.

2° STEP

FEM modeling of the same crown in hot condition, considering the wedge height reduction at the end of the campaign .
The study will be extended considering the mechanical properties of the material in hot conditions; material characteristics like composition due to batch oxides infiltration, cristalline distribution, etc, will involve maximum 50-60 mm of the bricks for Stella GNL, without affecting the central core where the forces are acting.

The study aims to verify if the crown maintains its stability and which actions is possible to take to prevent destabilisations.

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MgO for regenerator crowns

In the past there were quite a lot of problems regarding the stability of MgO regenerator crowns; this was due to the sensitivity of MgO products regarding creep in case of insufficient quality control (those problems fostered by the way the development of the mullite concept for the regenerator casing)

Focus of RHIM is creep testing at 1.550°C and 1.600°C !

For EF furnaces there is a limit of 200 m² which has not been overcome yet, due to the possibility to control properly the combustion. For such furnace, and considering a ratio 1:1 for the regenerators section design, the span is approx. 6.800 mm. This can be considered the maximum achievable for limits connected to EF furnaces.

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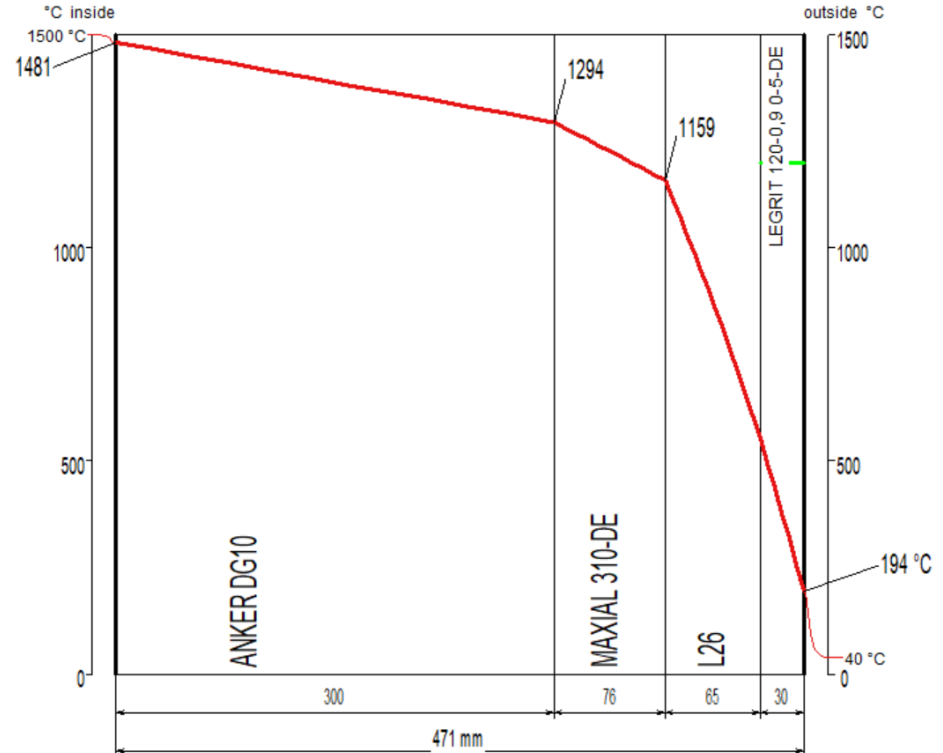
MgO for regenerator crowns

TYPICAL INSULATION CONCEPTS

Design #1

magnesite wedge h= 300 mm
1x 76 mm 42% Al₂O₃
1x65 mm ASTM 26
1x30 mm Legrit 120-0.9

Total heat dispersion 2.864 W/m²



Crown Span

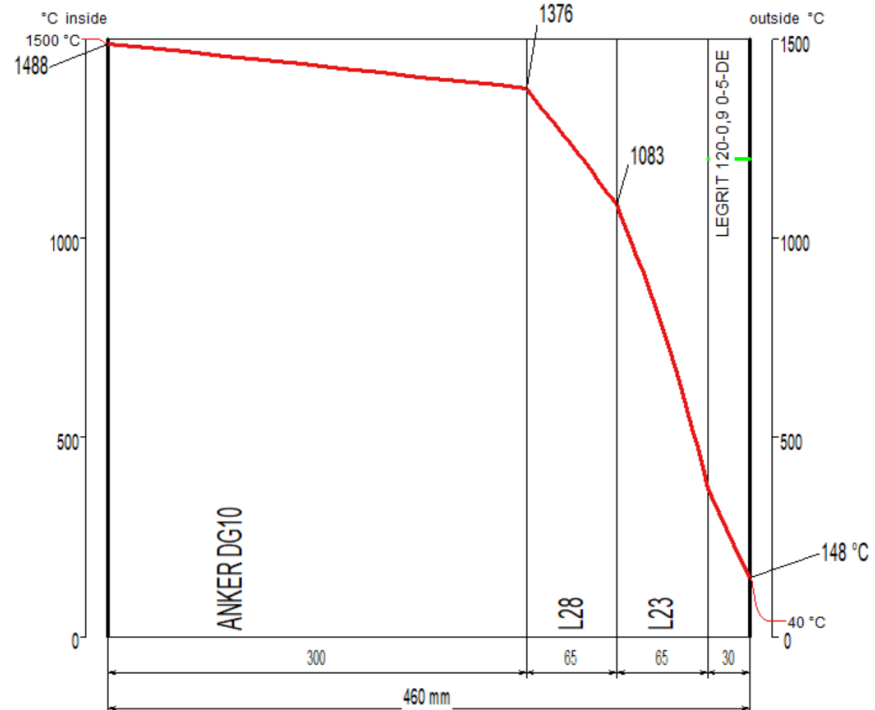
MgO for regenerator crowns

TYPICAL INSULATION CONCEPTS

Design #2

magnesite wedge h= 300 mm
1x 65 mm ASTM 28
1x65 mm ASTM 23
1x30 mm Legrit 120-0.9

Total heat dispersion 1.726 W/m²



Crown Span

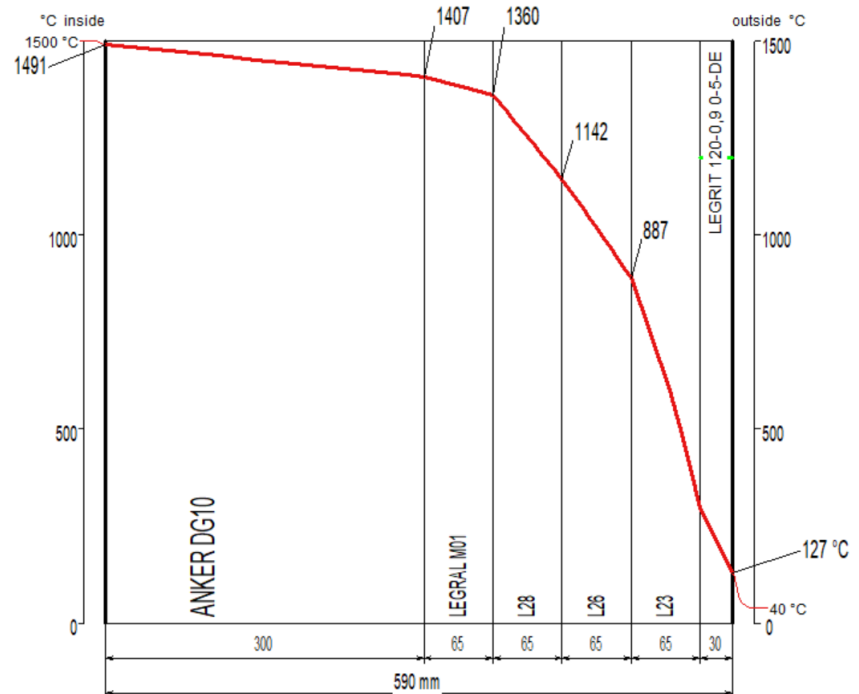
MgO for regenerator crowns

TYPICAL INSULATION CONCEPTS

Design #3

- magnesite wedge h= 300 mm
- 1x 65 mm Legral M01
- 1x 65 mm ASTM 28
- 1x65 mm ASTM 26
- 1x65 mm ASTM 23
- 1x30 mm Legrit 120-0.9

Total heat dispersion 1.293 W/m²



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MgO for regenerator crowns

Typical creep curves of typ 'Anker DG10' at 1.600°C:

