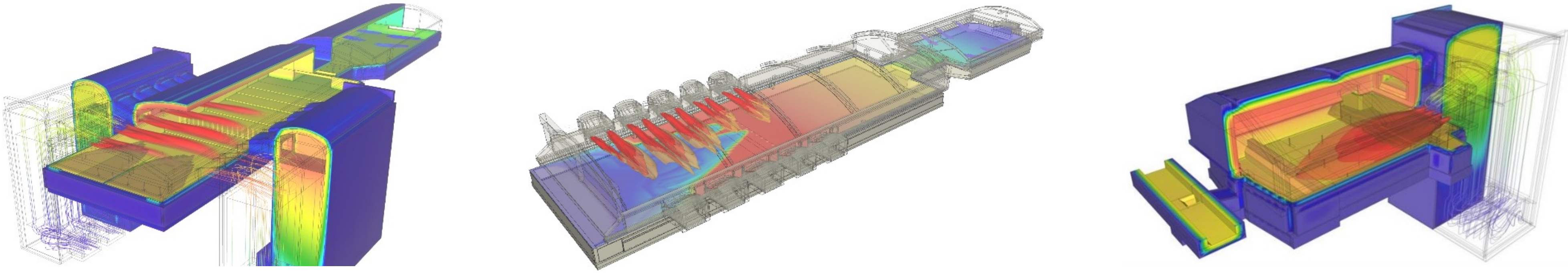
The usefulness of modelling for improving energy efficiency

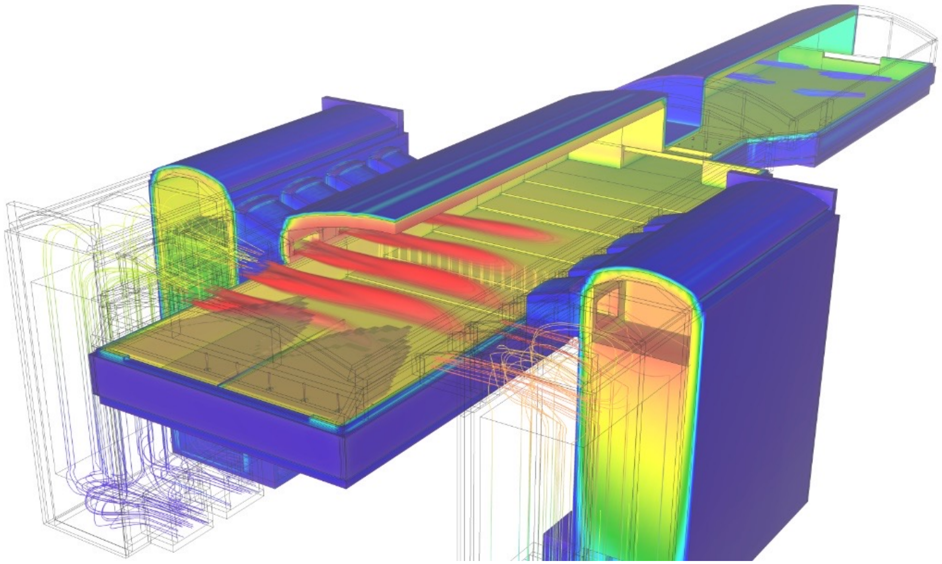


Glass for a sustainable future, Lloret de Mar

Miroslav Polák
(miroslav.polak@gsl.cz)

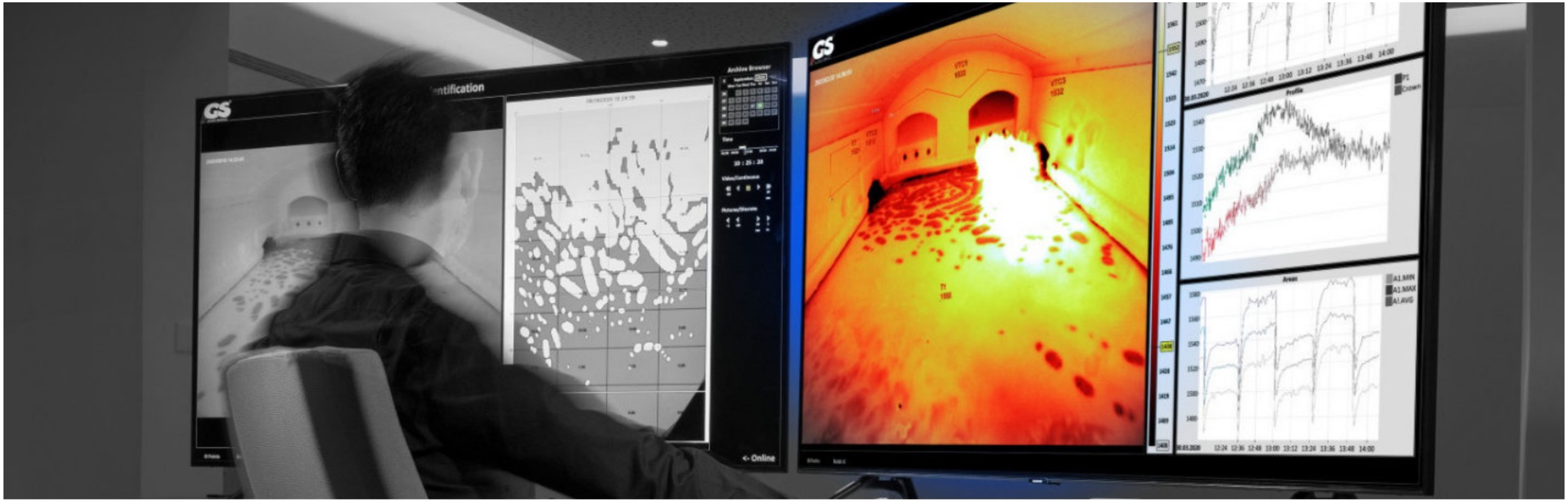
2. Contents

- About GS
- CFD, GFM (what is GFM, what it is good for)
- Typical modelling project workflow
- Examples (animations, design optimizations, concepts, cooperations)
- Conclusion



GLASS SERVICE

3. About Glass Service



ASSESSMENT

SIMULATIONS

3D advanced CFD simulation of the complete high temp. glass melting process for regenerator, melter, forehearth and forming.
more

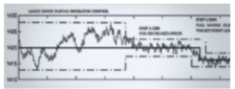
LAB SERVICES

Quick identification of glass defects and their origin to support quality improvements and operating parameter optimization.
more

AUDITS & DATA ANALYSES

Analyzing production, observing critical conditions and identifying optimization potential.
more

SMART PROCESS CONTROL



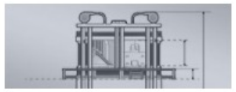
EXPERT SYSTEM *ES III™*

Full automatic process control resulting in stable operations, improved yield, reduced production costs and emissions.
more

CAMERAS & SENSORS

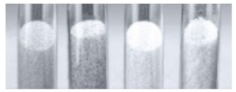
Smart AR sensors such as Camera systems in the Visible and NIR spectrum, simultaneously and on one chipset, compatible with Expert System.
more

PRODUCTS



ENGINEERING

Turn-key design and supply of specialized furnaces with high quality demands (for lenses, LCD or crystal).
more



RAW MATERIALS

Provide glass producers with Commodities, Specialties, Rare Earth Oxides and Polishing Compounds.
more

GLASS SERVICE, a.s.

Departments of GS:

- R&D Melting
- Expert System III
- Simulation Software
- Engineering
- Raw Materials
- Lab Services
- Audits&Data

A.SENS d.o.o.

Advanced Sensors
AI NIR Camera

F.IC. (UK), Ltd.

Electric melting

→ F.IC. Germany GmbH

FlammaTec, spol. s r.o.

→ FlammaTec Germany GmbH

GS Offices:

USA, Netherlands, China, Japan

GS Agencies:

Brazil, Egypt, France, India, Indonesia, Malaysia, South Korea, Taiwan, Thailand, Turkey

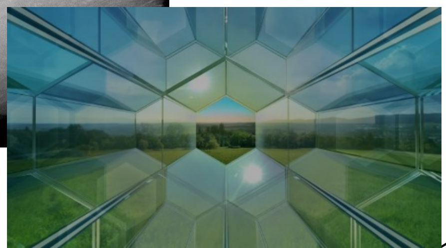

SEFPRO
BRIGHTER SOLUTIONS TOGETHER
GS
GLASS SERVICE
FLAMMATEC
Combustion Technologies
F.I.C.
Together
we shape a
carbon-neutral
glass industry,
for a brighter future

Glass products

- “traditional” glass products
  - Containers, windows, art, etc.
- but not only:
  - Composites (windmills, cars, etc.)
  - Bio - glass
  - Fiber glass
  - Etc., etc.







Glass production

- Very high energy consumption
- High pollutant production
  - CO_2 – combustion + batch decomposition
  - NO_x – high temperature flames
- High temperature process:
  - Limited maintenance during lifetime
  - Difficult measurements
  - Almost no possibility on inside inspection



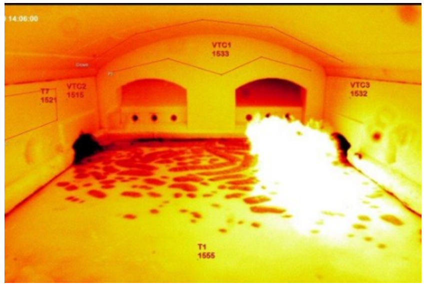
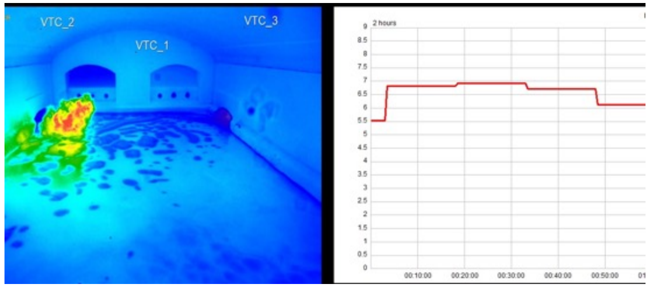


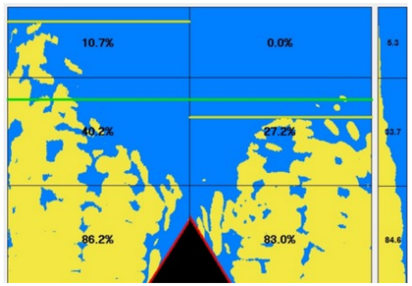
- Demand for:
  - High quality for low price

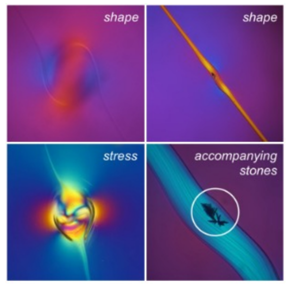
- Demand for:
  - Low energy consumption and low pollutants

High energy efficiency, recycling rate, alternative fuels, optimized furnace design…

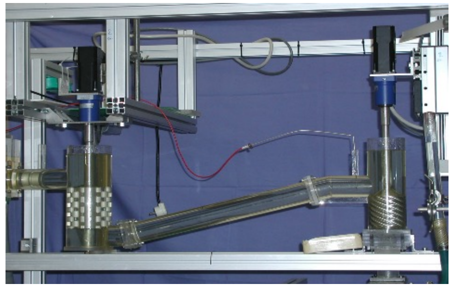
- **For keeping glass production under control:**
  - NIR camera
  - Control system (ES III) + batch monitoring system
  - Laboratory measurements (defect analysis, melting tests, corrosion tests, etc.)

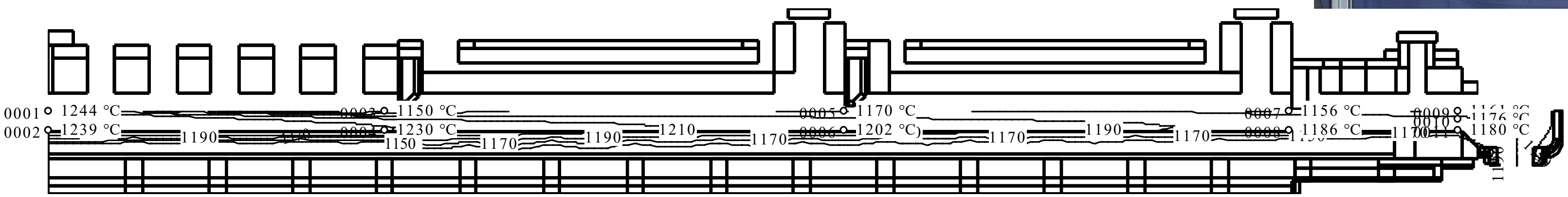







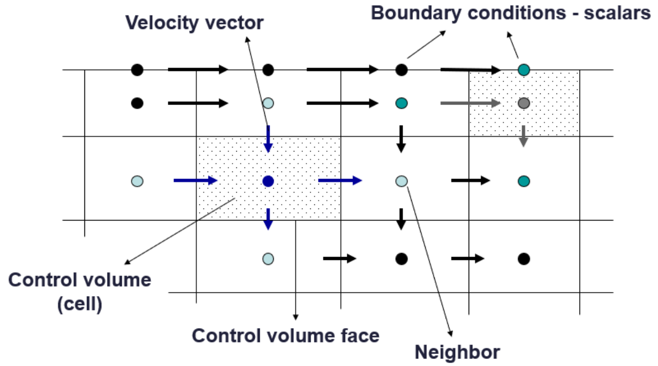
- **For (almost) anything else:**
  - Physical modeling (rarely used nowadays)
  - **Mathematical modelling – CFD - GS GFM**





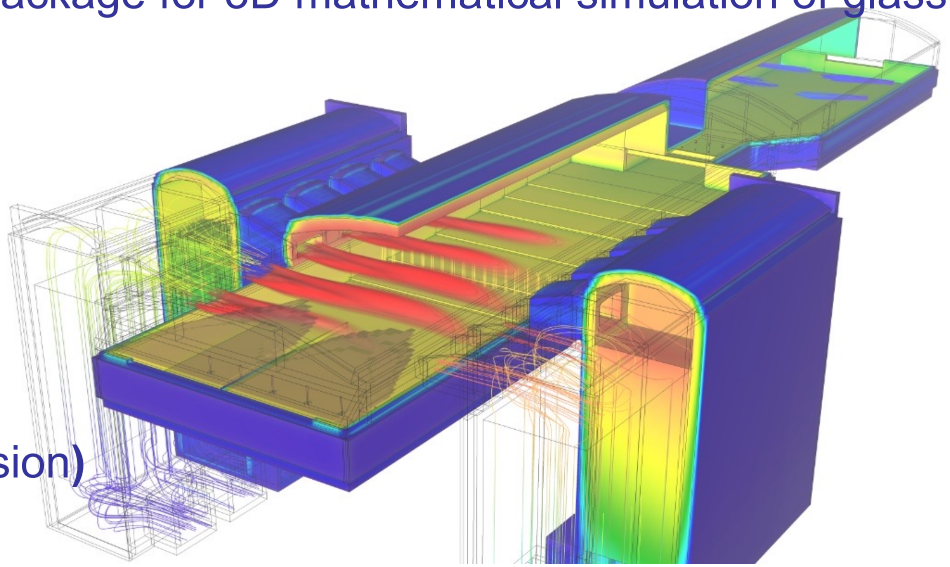
It is usually more cost effective compared to the “trial and error” tests (especially if there is no prior experience with desired change in the company)

- **CFD** = **C**omputational **F**luid **D**ynamics
- Wikipedia definition:
  - CFD is one of the branches of fluid mechanics that uses **numerical methods and algorithms** to **solve and analyze problems** that involve **fluid flows**.
  - **Computers** are used to **perform** the millions of **calculations** required to simulate processes.
- **Simulation**: CFD can predict **flows** of liquids and gases, **heat** and mass **transfer**, chemical **reactions**, etc.
- **Analysis**: CFD provides insight into simulated processes, which lead to possible **improvements in the simulated process**
  - 2D and 3D visualization including animations
  - Statistics and quantitative evaluation



- **Dramatic increase** in computational power and memory -> more detailed results in shorter time (cost reduction)

- **Glass Furnace Model (GFM)** is a software package for 3D mathematical simulation of glass melting furnaces
  - Melters
  - Refiners
  - Working ends
  - Distributors
  - Forehearths
  - Regenerators
  - Tin baths (**Tin Bath Module (TBM)** extension)

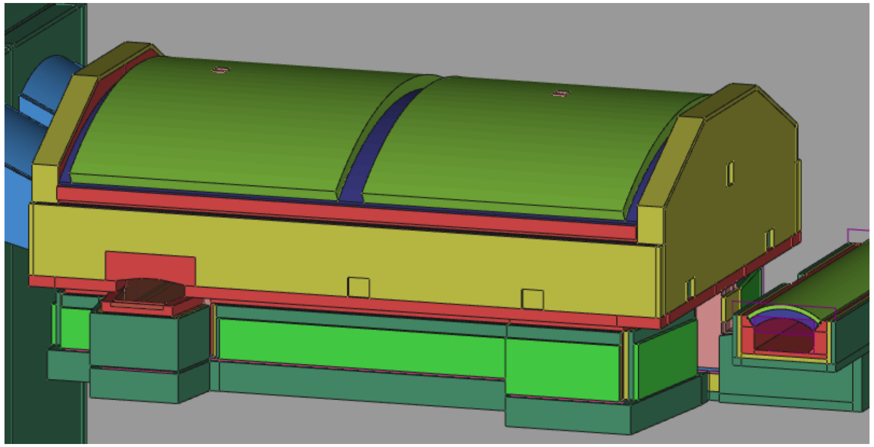


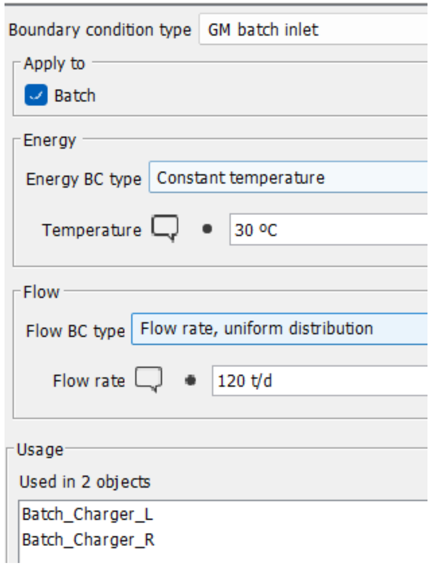
- What is furnace modeling good for:
  - Get insight into processes in glass furnace (for example, understand glass flow patterns)
  - Test ideas to optimize furnace efficiency, performance and/or lifetime
  - Test furnace operating strategies
  - Find good tradeoff between glass quality and energy consumption
  - Help operators understand their furnace

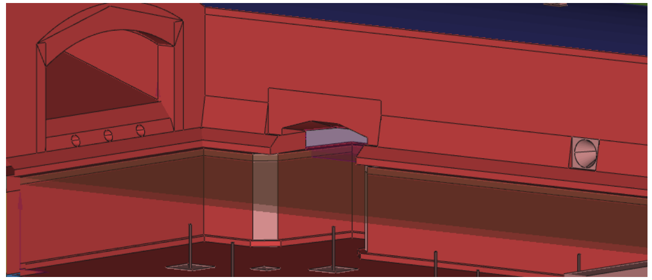
- Biggest advantage – you can see what happens if (any change is applied) with no risk of production interruption and / or furnace damage!

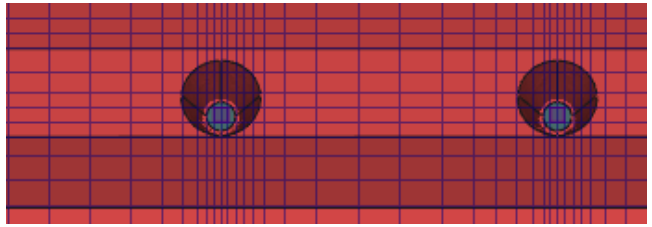
10. GFM – typical workflow (preprocessing + calculation)

- **Pre-processing** (geometry / design, boundary conditions, discretization / grid)



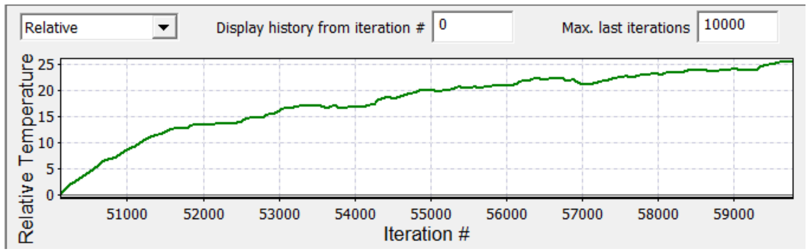


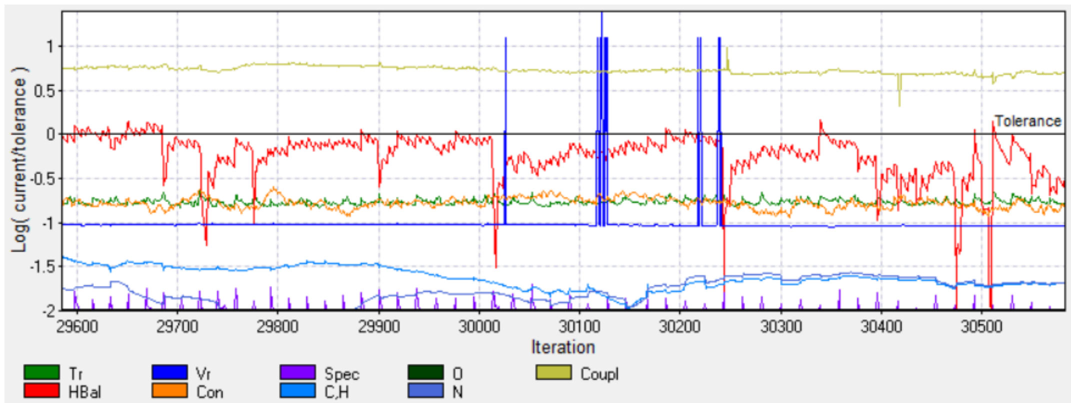




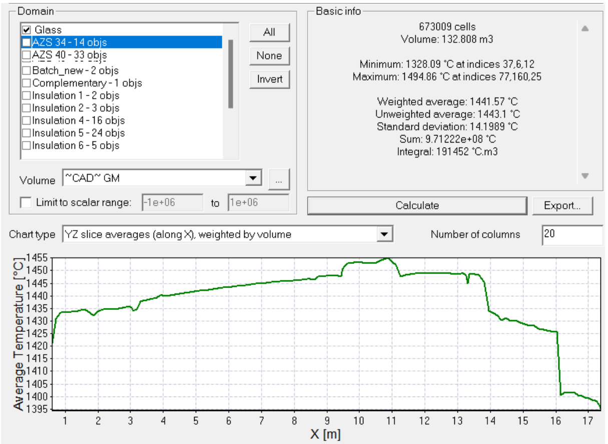
- **Simulation calculation** (convergence)

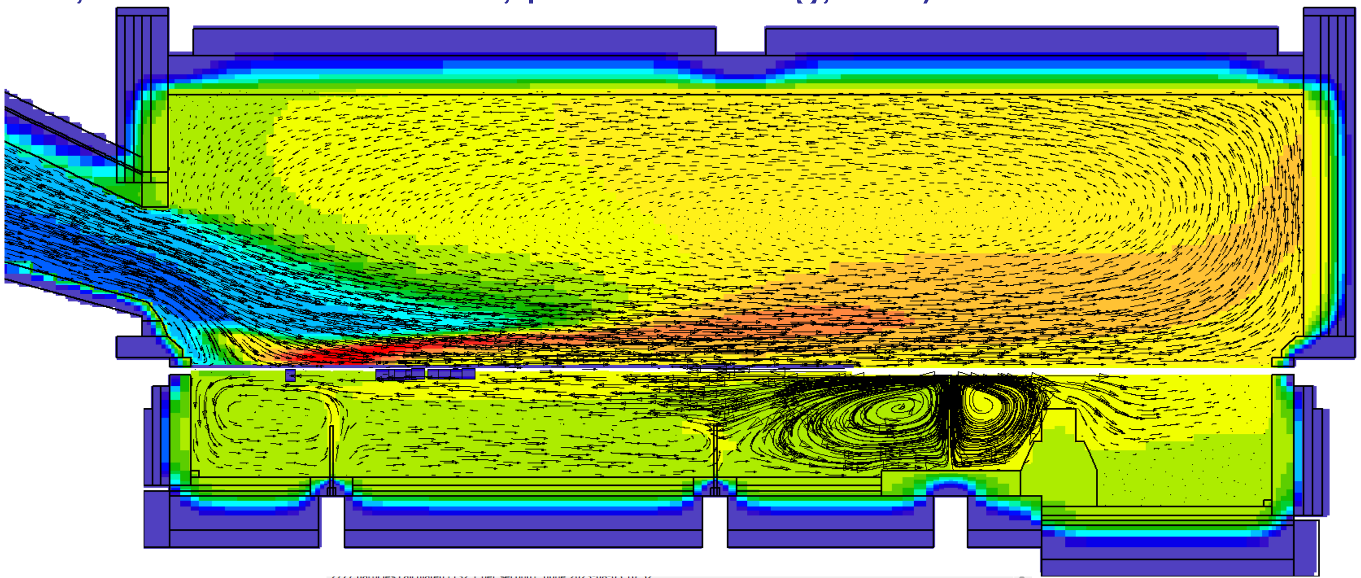
Step	Time	Elements	Mass	A_batch	A_total	Q_glass
15660000	21:45:00	799(-104)	250.597	1.94839	8.04879	0.550029
15672000	21:46:00	816(-79)	252.527	1.98961	8.09001	0.531919
15684000	21:47:00	814(-94)	251.005	1.9835	8.0839	0.545072

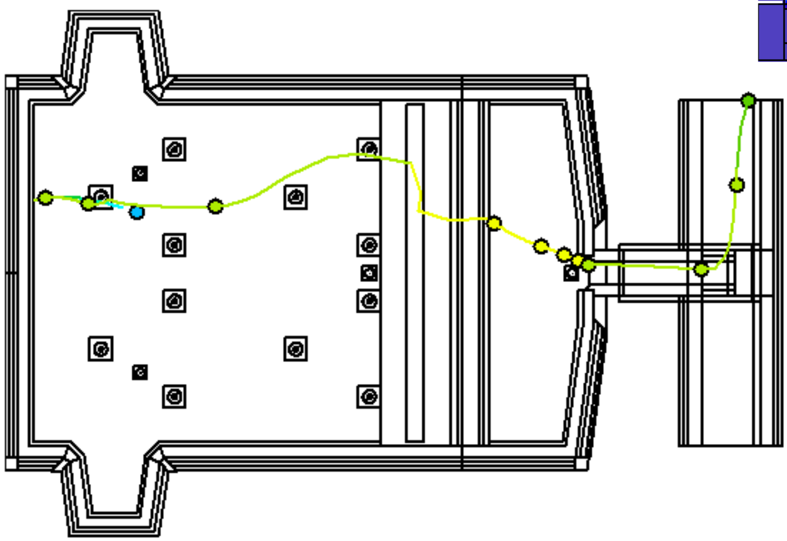


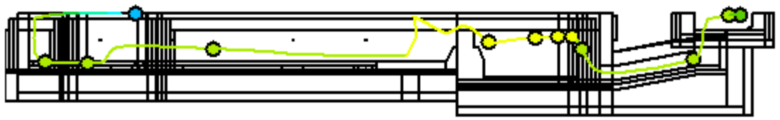


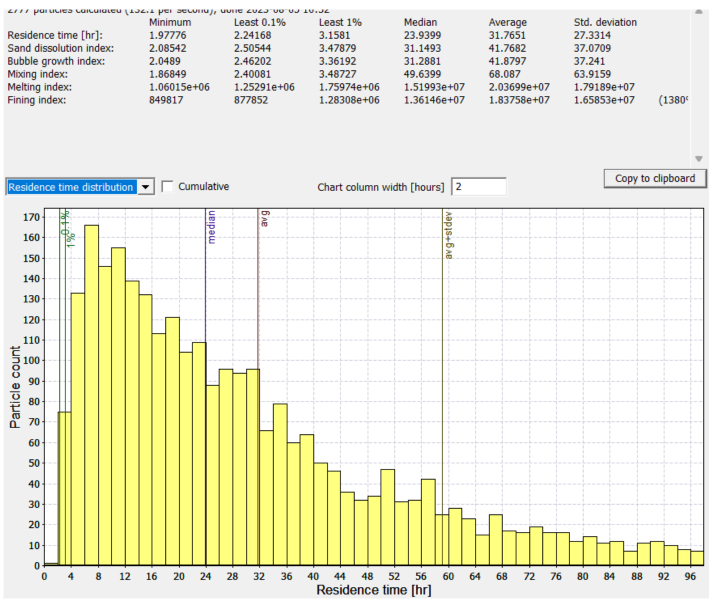
- **Post-processing** (visualization, evaluation of results, particle tracing, etc.)







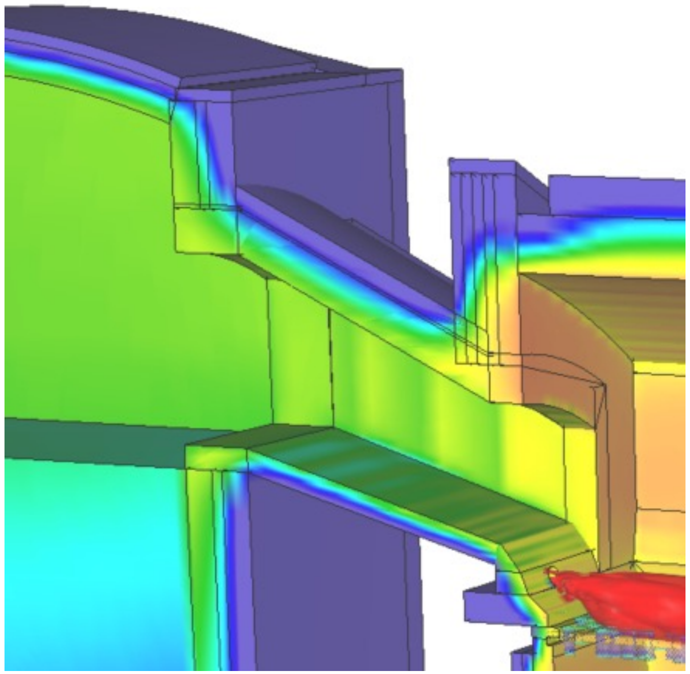




*GS GFM sample model

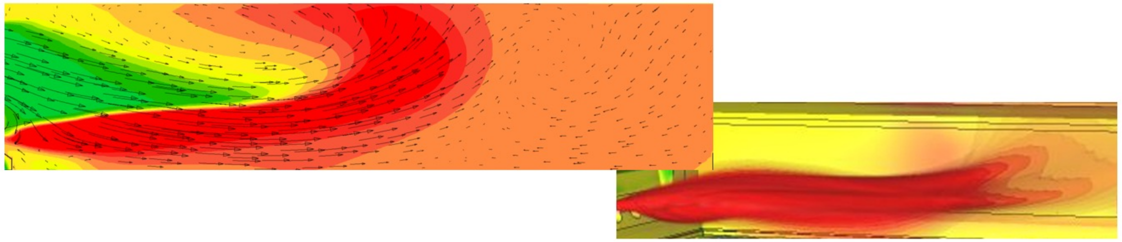
Problem to solve - insufficient burning

- **Customer reports fuel residues entering regenerator.**
- **Modelling case: different port – neck design -> enhanced mixing of fuel with combustion air**

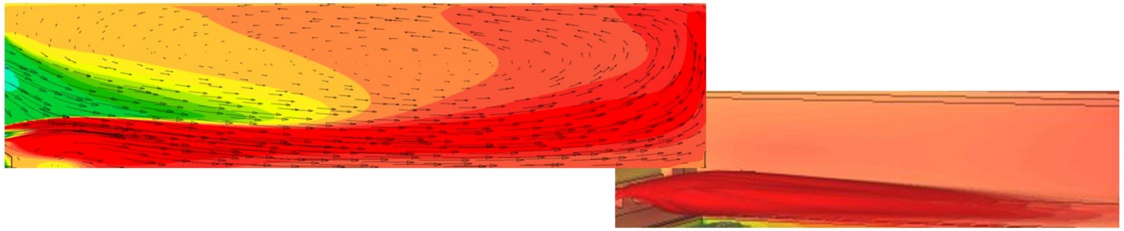


*GS GFM sample model

Original port–neck design



Optimized port–neck design



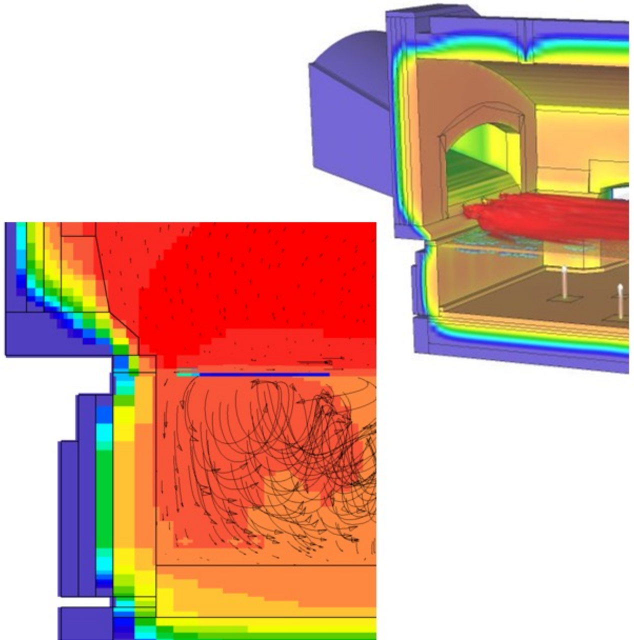
	Original design	Optimized design
Combustion efficiency [%]	97.4	99.6
Fuel residua entering regenerator [m	0.15	0.03
Max. glass temperature [°C]	1597	1616
Max. crown temperature [°C]	1609	1638

Direct cost savings, CO_2 reduction possible…

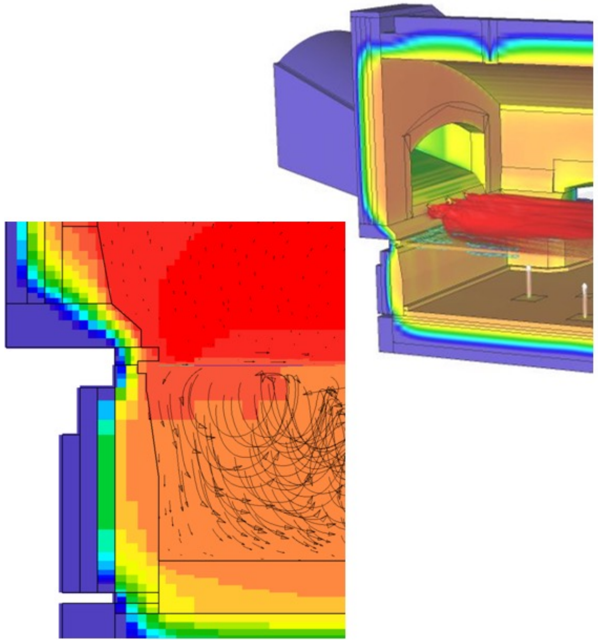
Problem to solve – glass tank wall corrosion

- Customer is interested in change of heat losses and difference in quality indexes.
- Modelling case: estimated (or measured, if 3D scan is available) corrosion profile is applied, and the results are compared.

Original design – new furnace



Target design – furnace with simulated corrosion



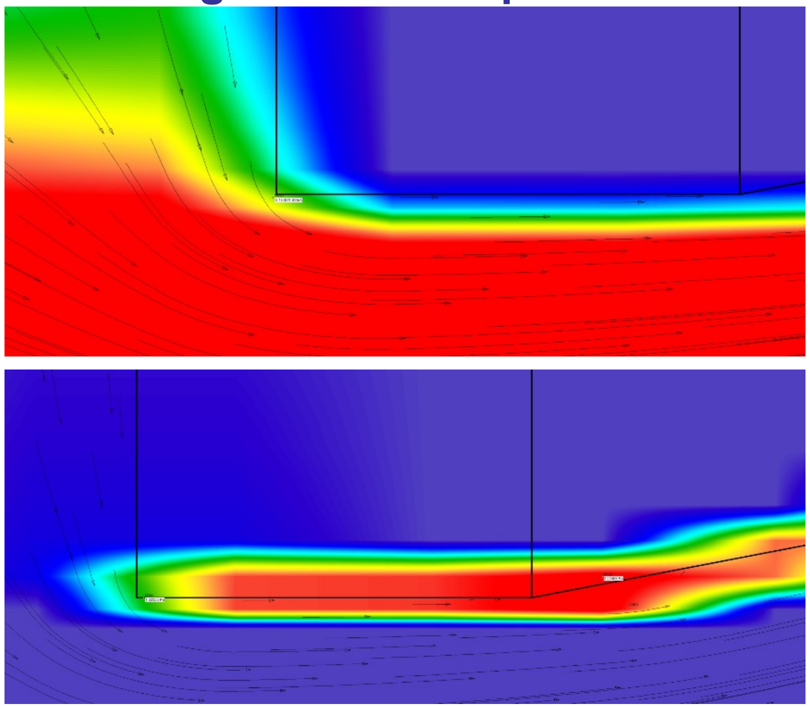
	Original	Corroded
Minimal residence time [h]	2.1	2.2
Bubble growth index	2.1	1.9
Average glass temperature [°C]	1439	1436
Avg. throat glass temperature [°C]	1427	1424

*GS GFM sample model

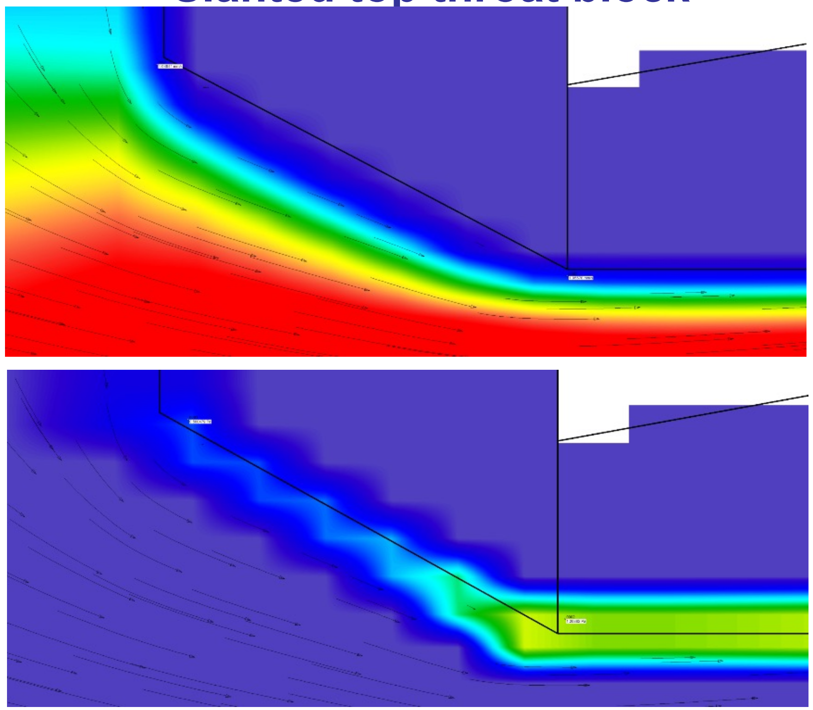
Problem to solve – throat shape

- Customer is interested in velocity magnitude and shear stress in the vicinity of the original / slanted throat top block.
- Modelling case: Show the differences in the glass flow in the surrounding of top throat block corner. The lower the velocity, the lower corrosion rate.

Original throat top block



Slanted top throat block

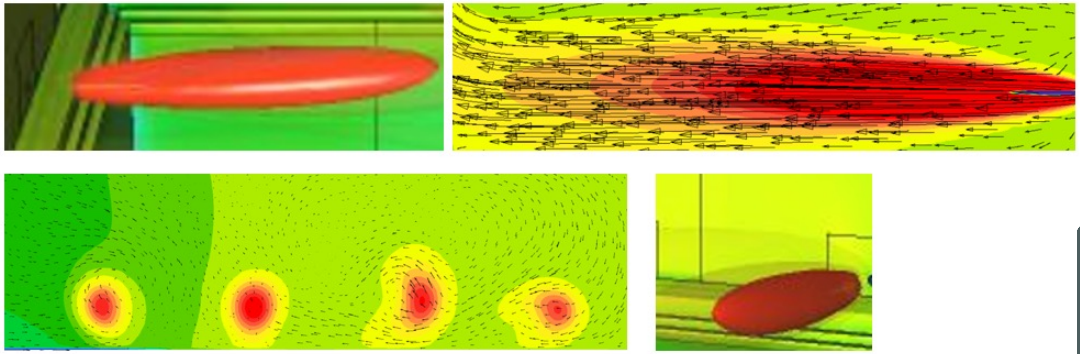


	Original	Slanted
Velocity magnitude [mm/s]	**3.2**	**1.06**
Shear stress 1 [Pa]	1.8	0.5
Shear stress 2 [Pa]	2.2	1.2

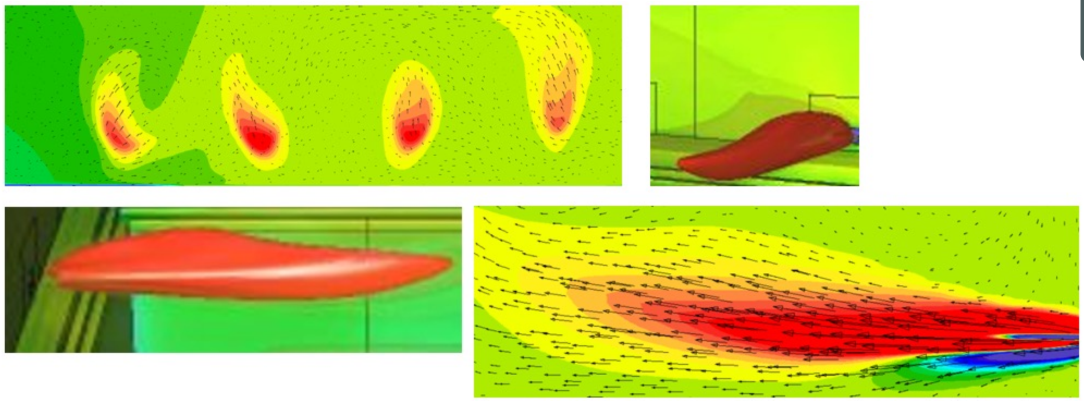
Problem to solve – which burner type is more suitable for a specific production?

- Customer is interested in heat transfer to glass, overheating of opposite wall, etc.
- Modelling case: low and high momentum burners were simulated in the same furnace design.

High momentum oxy-fuel burner



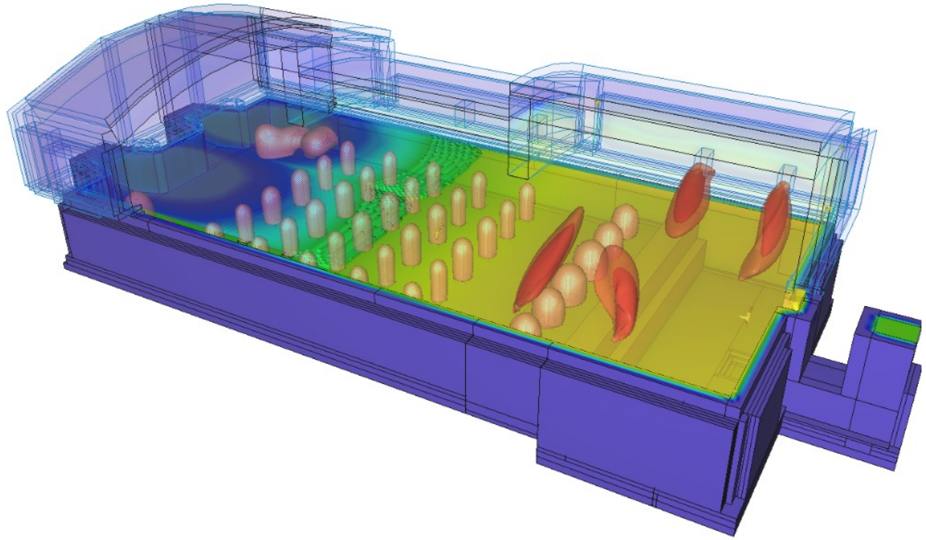
Low momentum oxy-fuel burner



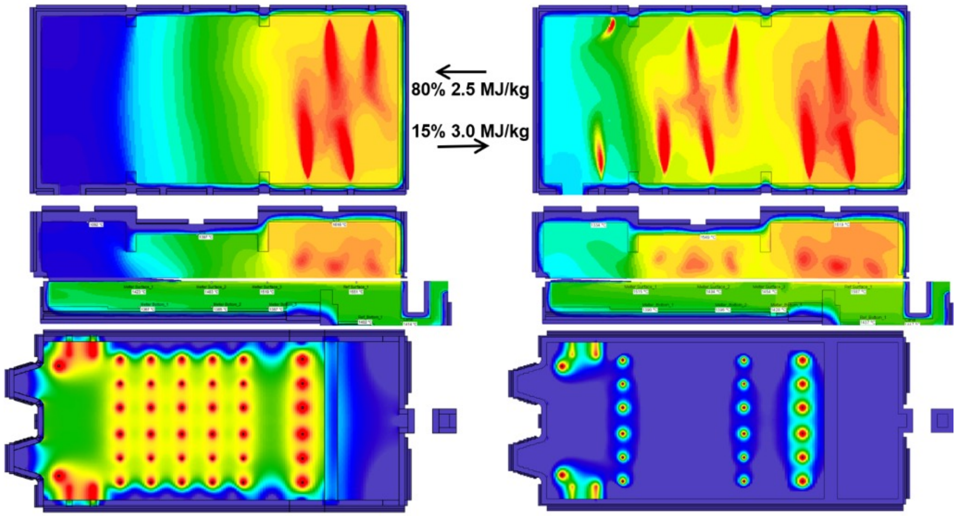
	High momentum	Low momentum
Opposite wall temperature [°C]	1421	1407
Energy to glass and batch [kW]	1144	1125
Min. residence time [hr]	2.6	2.8
Glass temperature in throat [°C]	1050	1044

16. Example – super boosting / hybrid furnaces

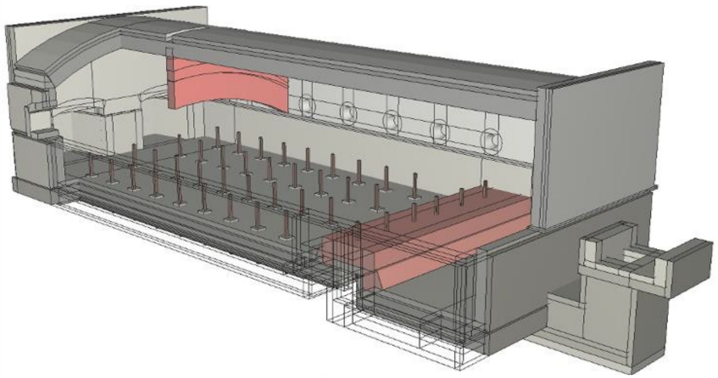
GS H²EM Concept furnace design (2017)

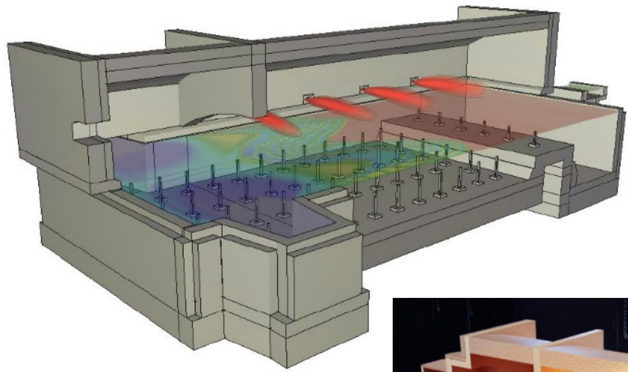


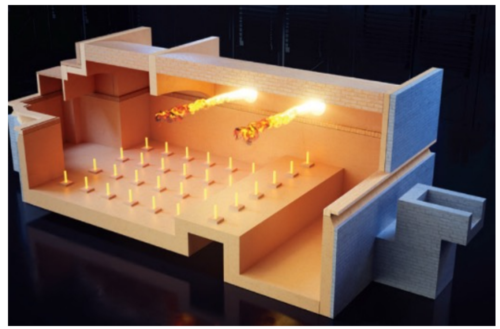
- More details for 350 TPD H²EM concept working in 80% electric mode (left) and 15% electric mode (right)



SORG's CLEAN-Melter ® (2023)

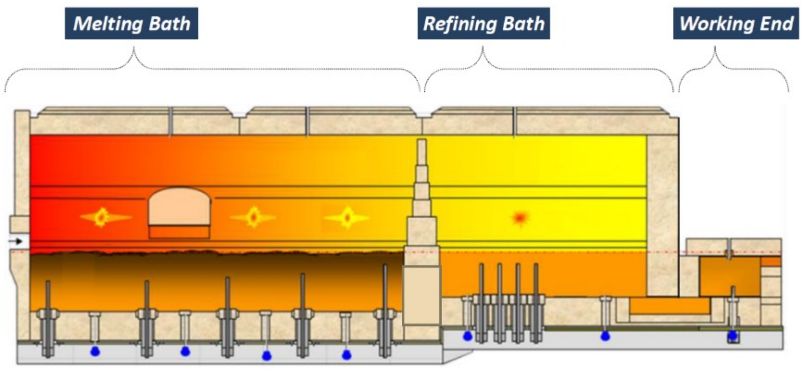






Nikolaus SORG GmbH & Co. KG - Dirk Schnurpfeil (F&E)
Zwieseler Fachschulkolloquium - 08./09.05.2023

Base Case : Our Furnace in 2018

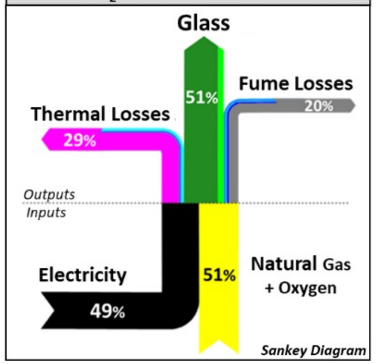


- 6 Oxy-Gas Burners
- 5 Rows of Electrodes
- Separating Crosswall

- 2 Oxy-Gas Burners
- 2 Rows of Electrodes
- Max Temp : 1550°C

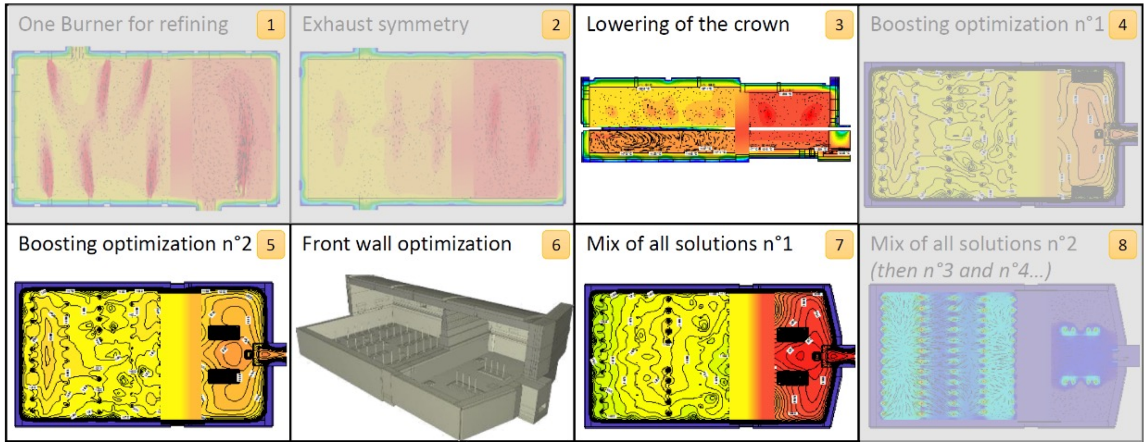
Almost no CO_2 from batch

Max Pull (Borosilicate)	≈ 160 t/d
Average Cullet	≈ 25 %
Natural Gas (Fossil)	620 kWh/t (LHV)
Electricity	600 kWh/t
CO_2 Emission	186 kg CO2e/t

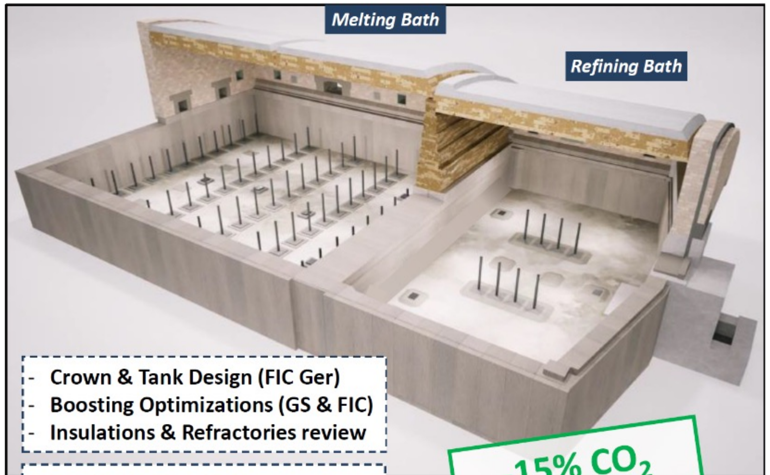


Base case

From 2018 to 2022 : Partnerships for a new design



The Result : Our Furnace in 2023

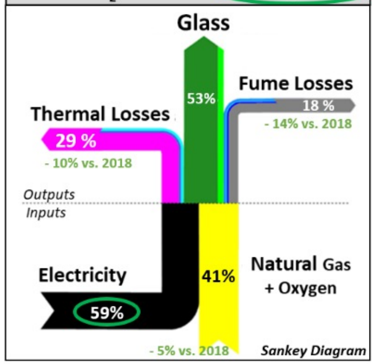


- Crown & Tank Design (FIC Ger)
- Boosting Optimizations (GS & FIC)
- Insulations & Refractories review

- Near IR Camera (GS)
- Tank Blocs Monitoring (SEFPRO)
- ESIII (GS)

-15% CO_2 versus 2018

Max Pull (Borosilicate)	≈ 160 t/d
Average Cullet	≈ 25 %
Natural Gas (Fossil)	475 kWh/t (LHV)
Electricity	687 kWh/t
CO_2 Emission	157 kg CO2e/t



Result

- Current global situation (environmental / economical) pushes (not only) glass producers to dramatically change production processes, mainly in:
  - Energy consumption decrease
  - Pollutants production decrease (CO_2, NO_x, etc.)
- Glass production – as a high temperature process → high energy demand, high pollutant production (e.g., CO_2 from batch decomposition, NO_x from flames, etc.)

Big pressure for production transformation

- Any change in the furnace is very difficult and expensive

Great opportunity for mathematical modeling!

- At Glass Service we are ready to help the customers in many ways, one of them being the GFM modeling studies.

Thank you for your attention!