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Use of Numerical Simulations for Improving Color Changes on a New Float Glass Furnace

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Outline

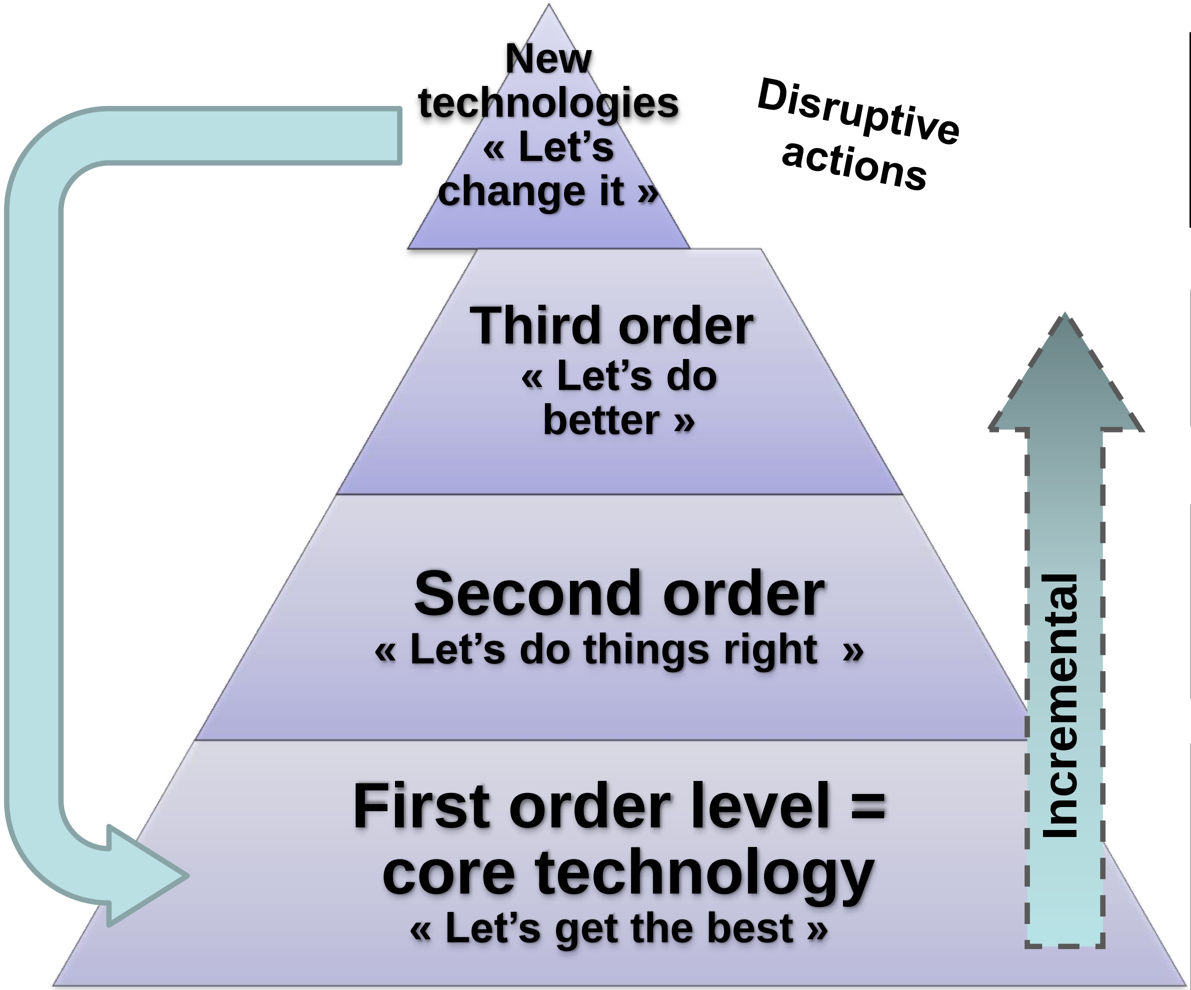
- **Economical context of flat glass sector in EU**
- New technology for flat glass furnace
- Color change numerical study
- Conclusions

Economical context

- Flat glass business in Europe is in over-capacity
- Low selling prices (from NW-EU to Russia) for commodities and specialties to some extends
- Adaptation of production capacities to match demand
- Huge pressure to reduce costs :
  - Raw materials
  - Manpower
  - Investments
  - Energy

Overview of actions for cost reduction

Classification in 4 main categories of actions



For stronger improvement steps but case by case profitability contexts

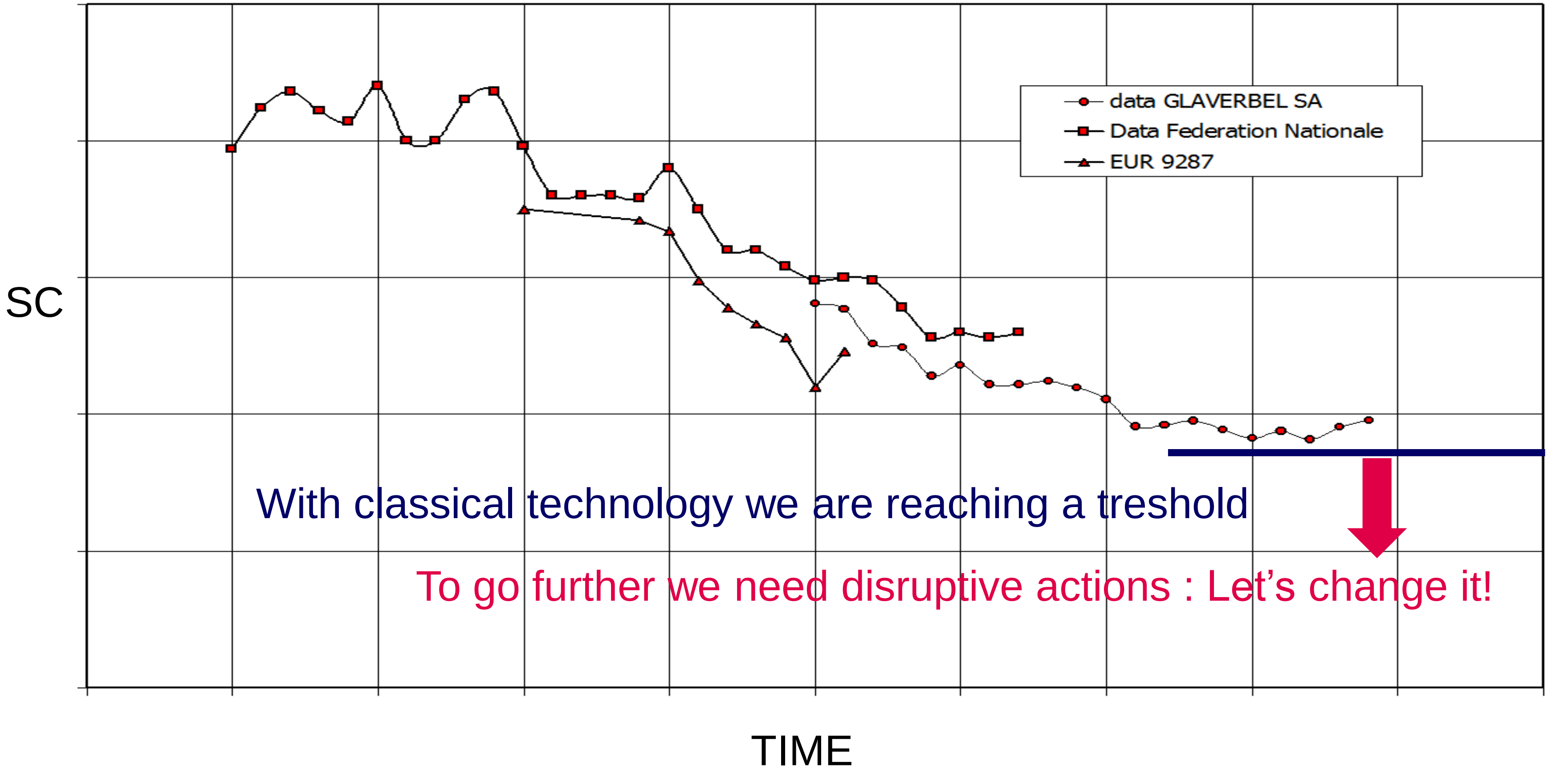
e.g. « Smart » furnace control

Accurate sensors installation and use to monitor and optimize operations

Furnace specifications, furnace design and standardization of operations

Energy use trend in flat glass sector

- Thanks to combined effect of specific actions we see over time big improvement of energy consumption to produce glass nevertheless….



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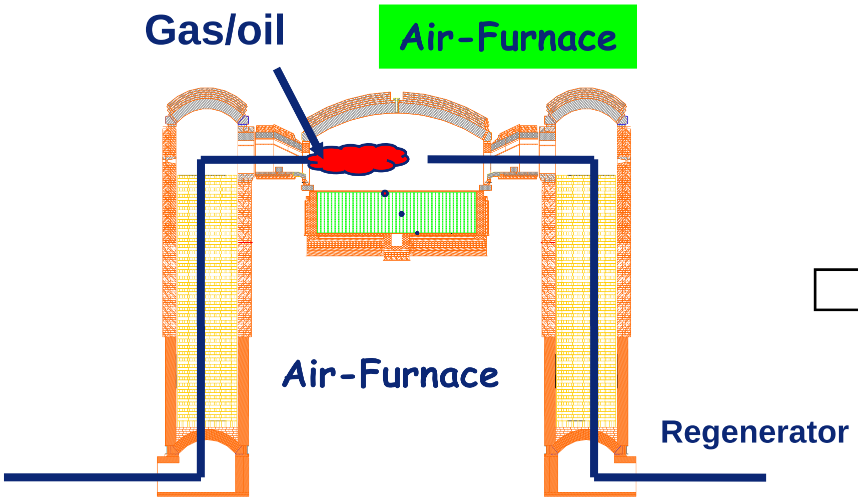
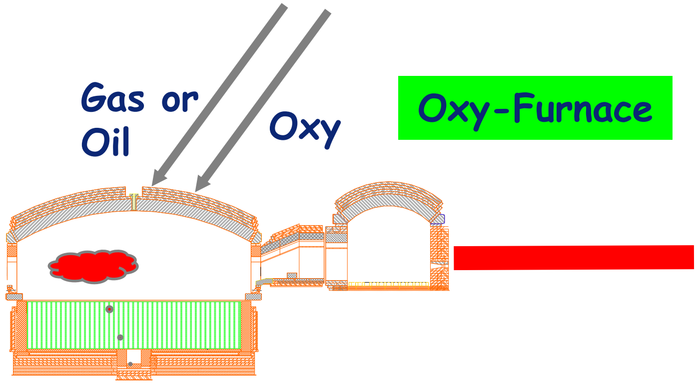
New technologies : Let's change it

- AGEU investigated **oxycombustion** for flat glass process as a breakthrough technology to
  - Decrease Nox
  - Decrease energy consumption
  - Decrease investment (no regenerators)
  - Increase stability of production (no reversal time) → Improve quality

- Nevertheless the only use of cold oxygen instead of air as oxidizer
  - Showed a negative profibality
  - Generated huge lost of energy in waste fumes

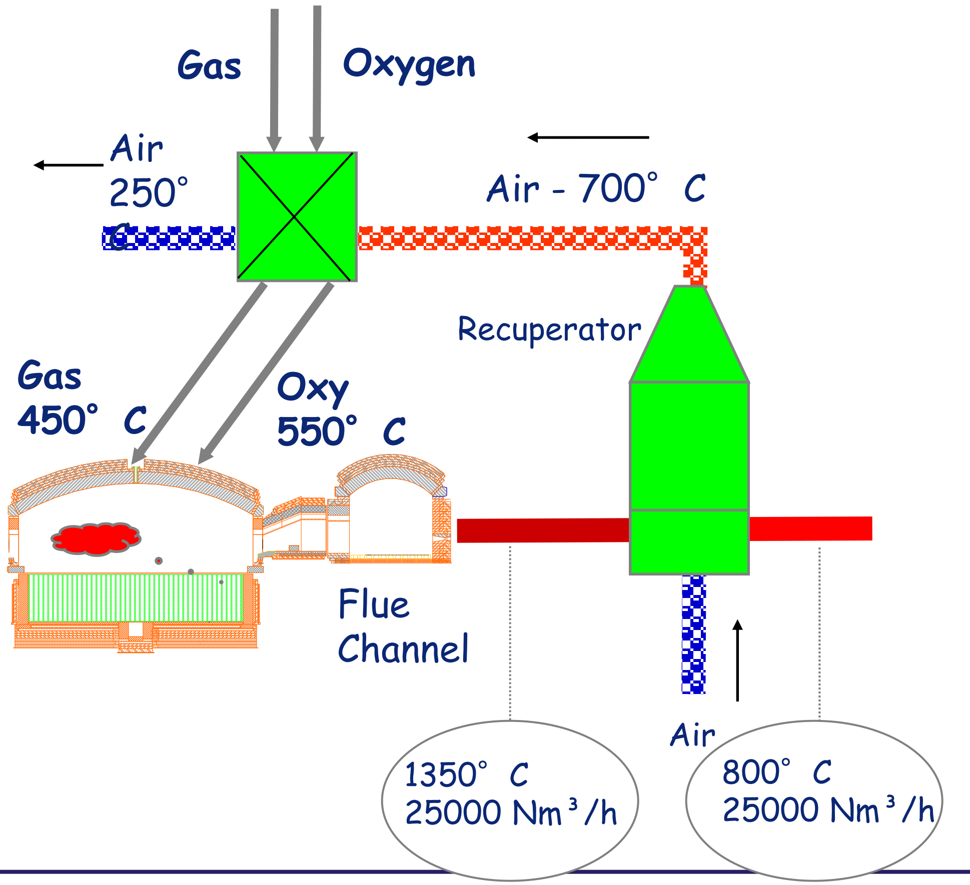
Why not to recover it
To preheat Oxygen/ Fuel ?





New technologies : Let's change it

- Energy of waste fumes is used to preheat air
- Preheated air is used to heat oxygen to 550°C and gas to 450°C



* Technology developed with AIR LIQUIDE

New technologies : Let's change it

- **Hot oxygen combustion technology has to be validated on a real furnace for flat glass production**
- Two-step project
  - **1st step*** : furnace started in 2008 - France

  Hybrid fuel : natural gas and heavy oil as combustible

  Architectural clear glass

* Project founded by EC Program Life+ : LIFE07 ENV/F/000179

New technologies : Let's change it

- **Hot oxygen combustion technology has to be validated on a real furnace for flat glass production**
- Two-step project
  - **2nd step***: furnace started April 2014 – Czech Republic

  100 % natural gas as combustible

  Automotive colored glass

  New challenges are, for each color produced, from lighter to darker one

  - Manage the foam
  - Optimize furnace operation (crown temperature, burners, fire curve, …)
  - Reach good glass quality with higher level of requirement for automotive
  - Reach energy and environmental theoretical expectation

    NOX: - 79.2% ; SOX: - 34.5% ; Energy : - 19.7% vs Air/Gas furnace

* Project founded by EC Program Life+ : LIFE11 ENV/CZ/000488 HOxyGas

Outline

Automotive colored glass

- Context
  - The new Czech furnace produces several glass colors for automotive, requiring frequent color changes
  - During each color change, glass cannot be sold because out of specifications (color, quality)

- In addition to challenges directly related to Hotox technology, one key challenge for this new furnace was to **manage color changes** on a new type of furnace

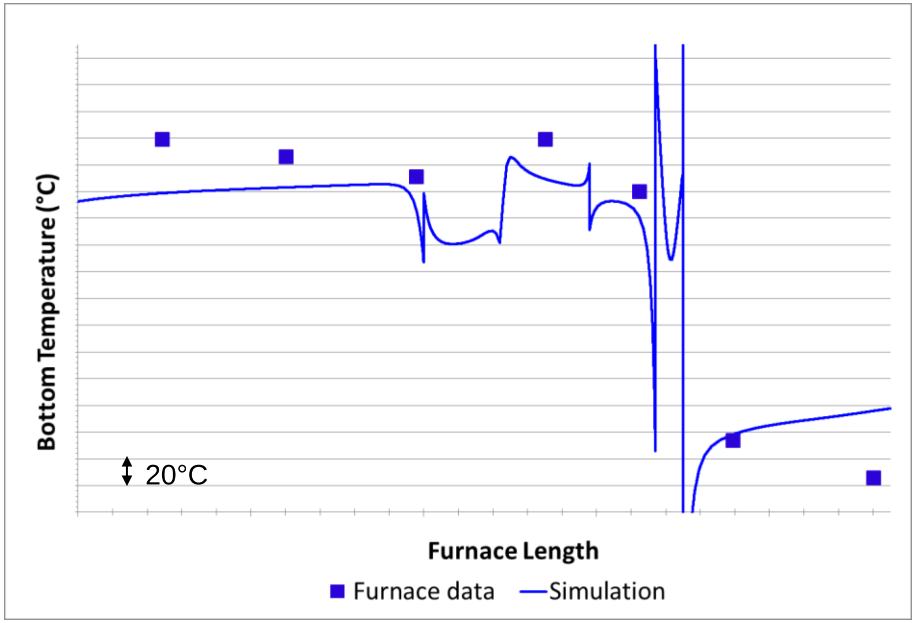
Color change study

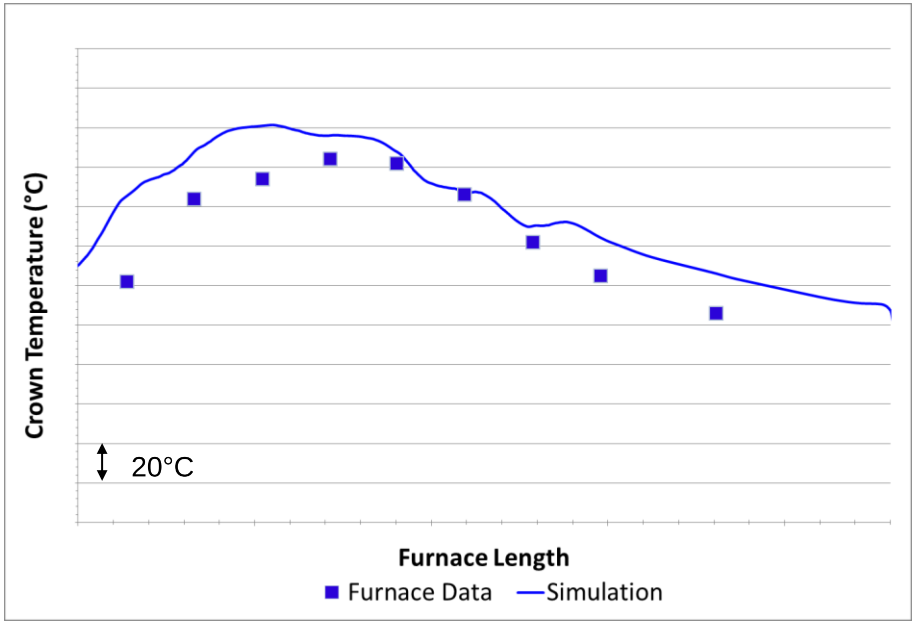
- Why numerical simulation of color changes?
  - To improve our understanding of colorant mixing in the new furnace
  - To prepare each new color change on the furnace
  - To provide information for colorant adjustments during production

- Methodology
  - Validate a 3D coupled model (glass-combustion sapces) in **steady state conditions** as initial state
  - Perform **transient simulation** of a color change with the 3D model
  - Set-up a **simplified model** based on perfect mixer models

Color change – Starting condition

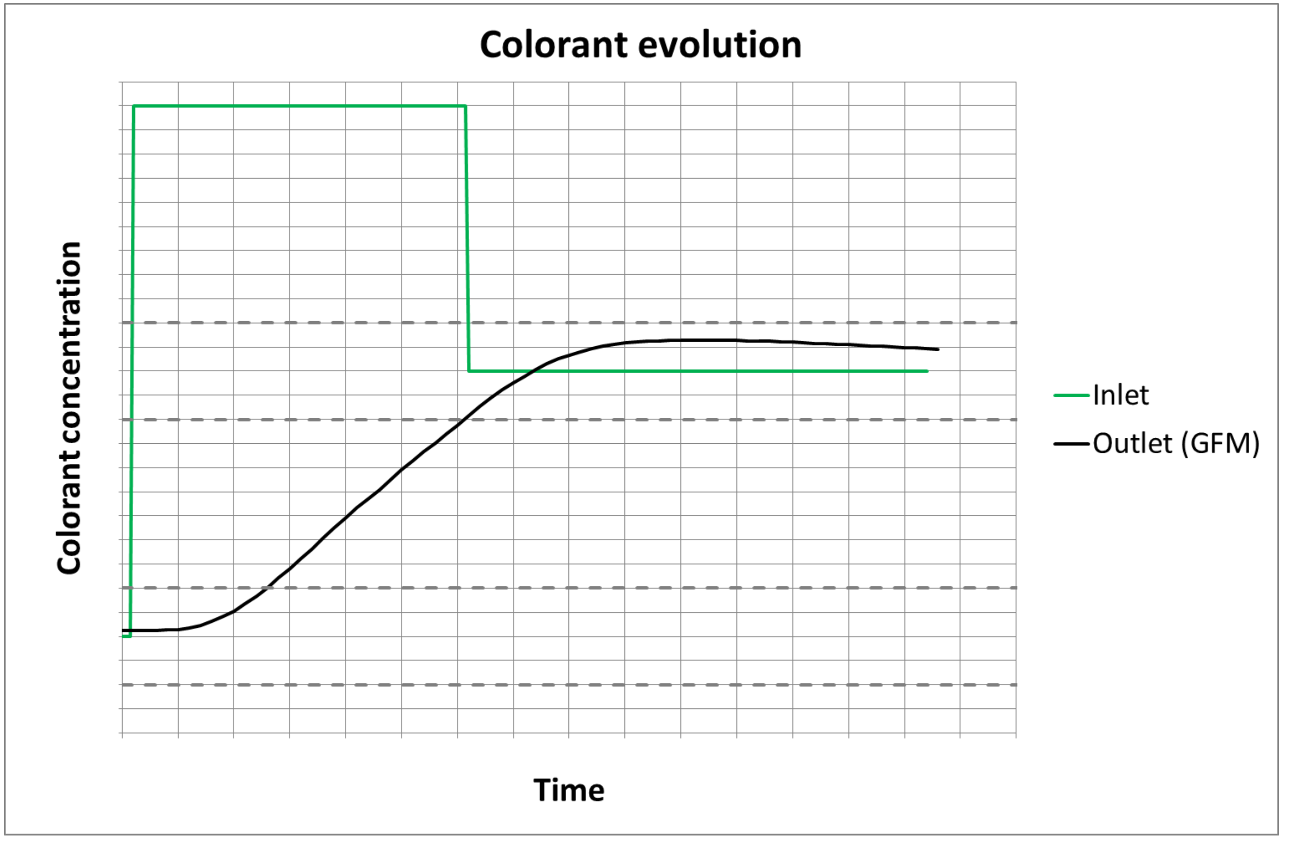
- Steady-state numerical model validation
  - GFM model including glass and combustion domains
  - Validation at furnace start based on bottom and crown thermocouple measurements





Color change – Transient simulation

- Colorant average concentration at furnace exit



Color change – Transient simulation

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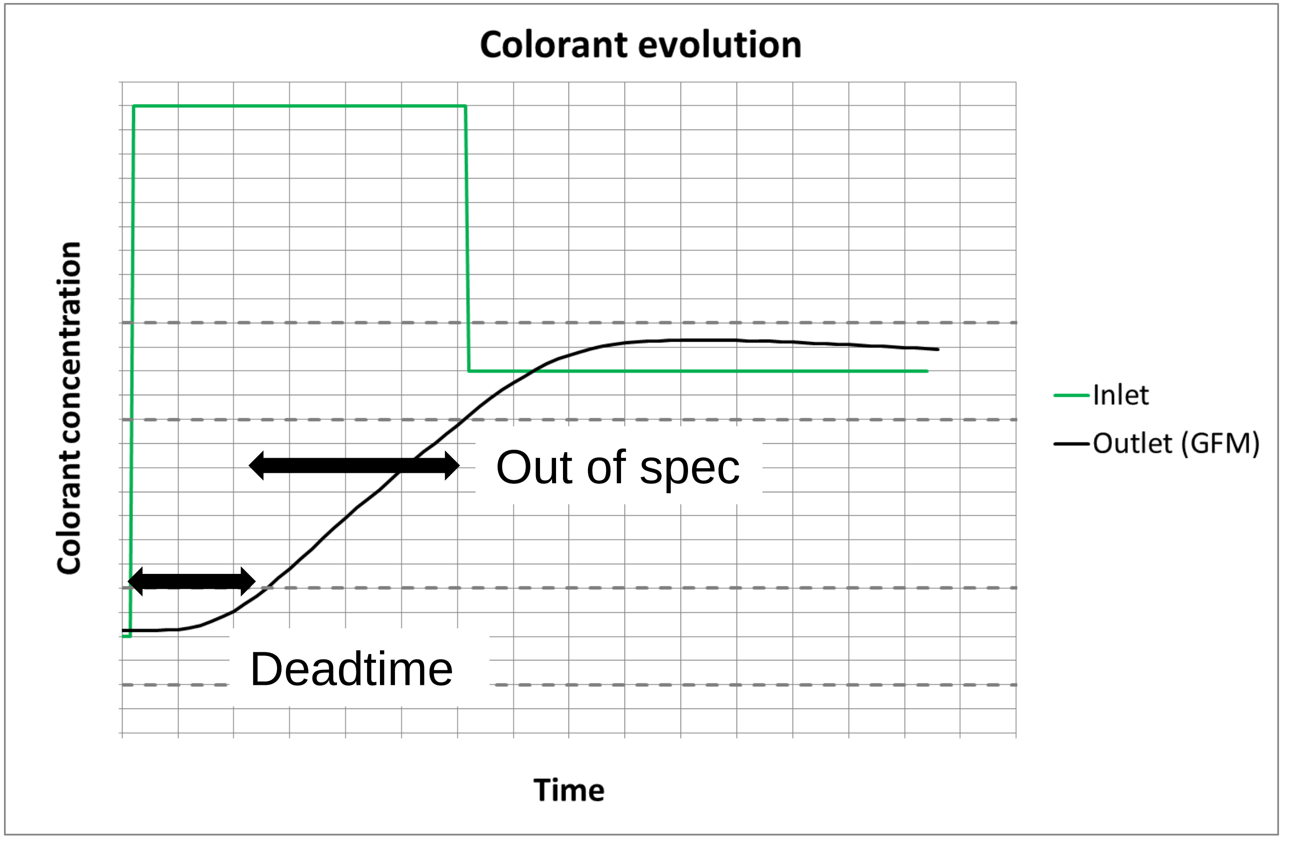
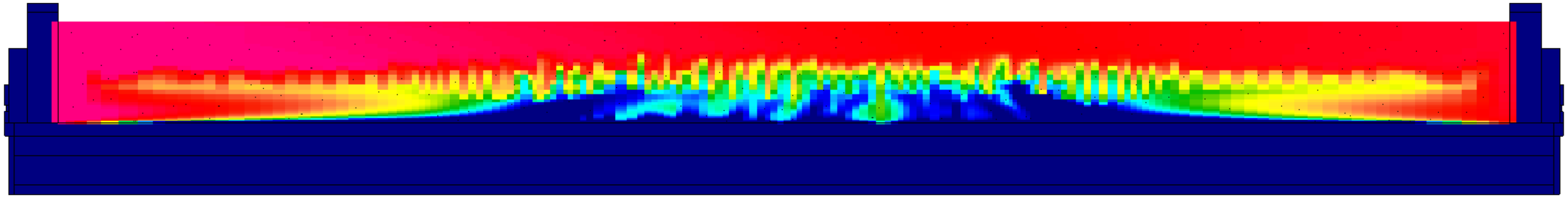


Color change – Transient simulation

- GFM model can also be used to analyze and get better understanding of colorant distribution inside the furnace

- Example of colorant concentration during one color change



Old glass along the bottom center of the furnace

Color change – Transient simulation

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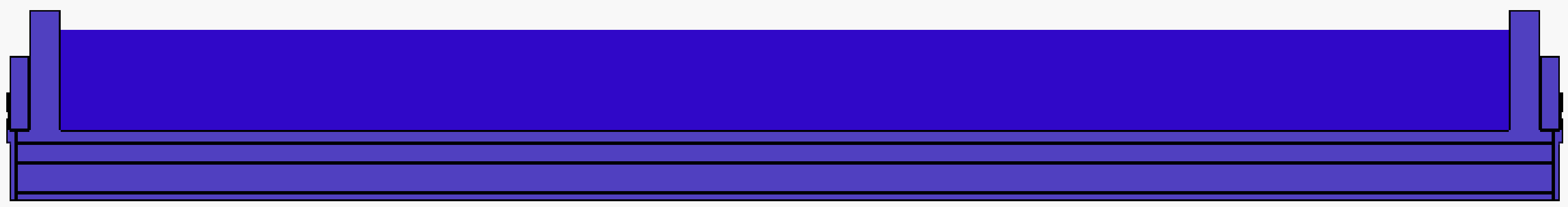
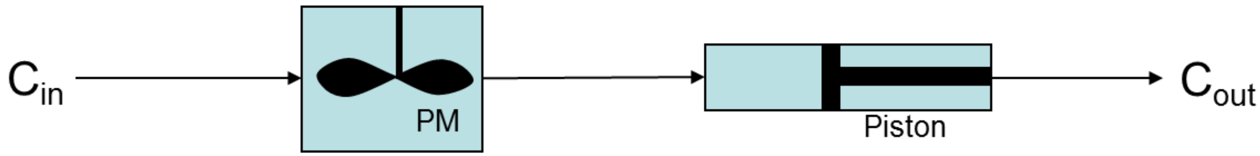


Old glass along the bottom center of the furnace

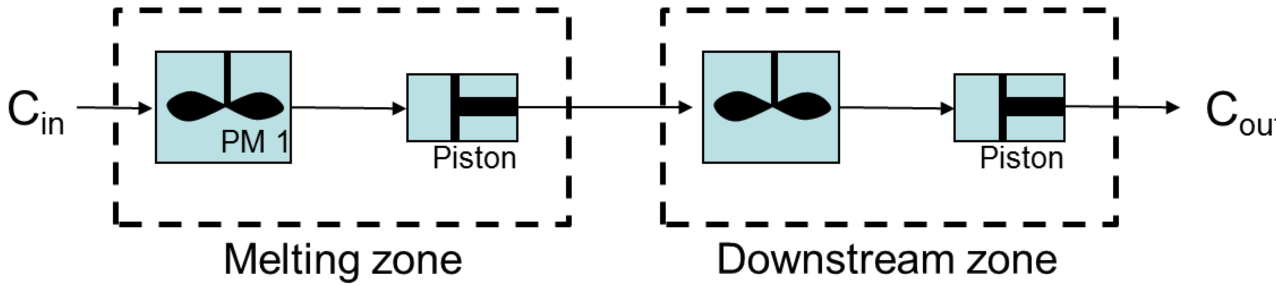
Color change – Simplified model

- 1-mixer model (2 parameters)



Time constant $\tau = \frac{Melter\ Capacity}{Pull} - t_d$ Deadtime t_d

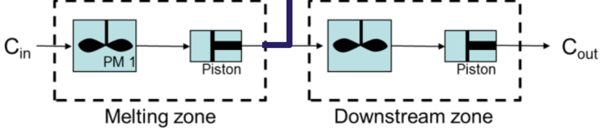
- 2-mixer model (4 parameters)

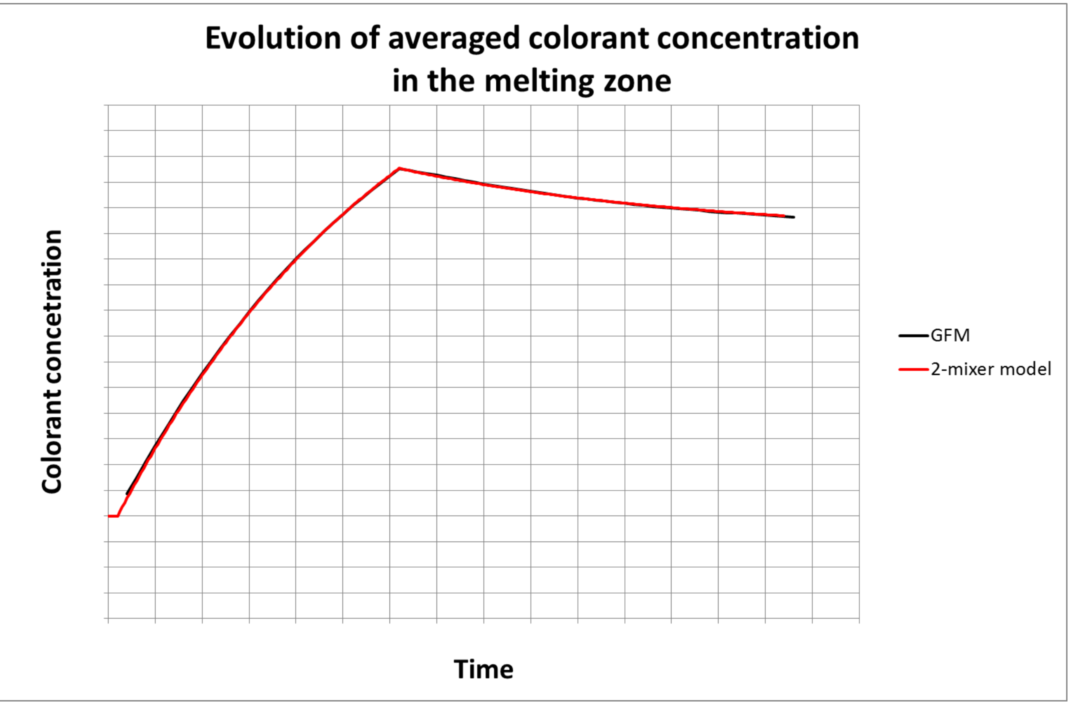


- Deadtimes can be adjusted by comparison with results of GFM model

Color change – Simplified model

- Comparison between GFM model and 2-mixer simplified model in the melting zone

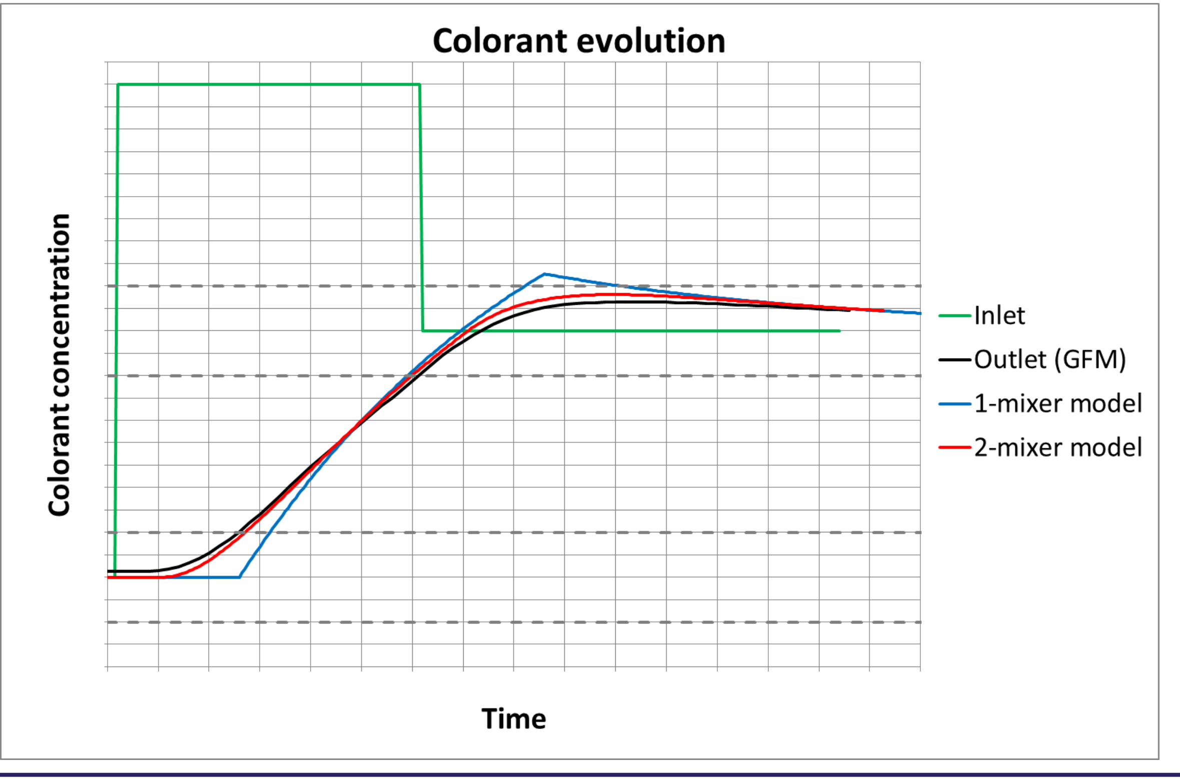




Melting zone deadtime has been determined in order to fit GFM results
Melting zone is very close to a perfect mixer

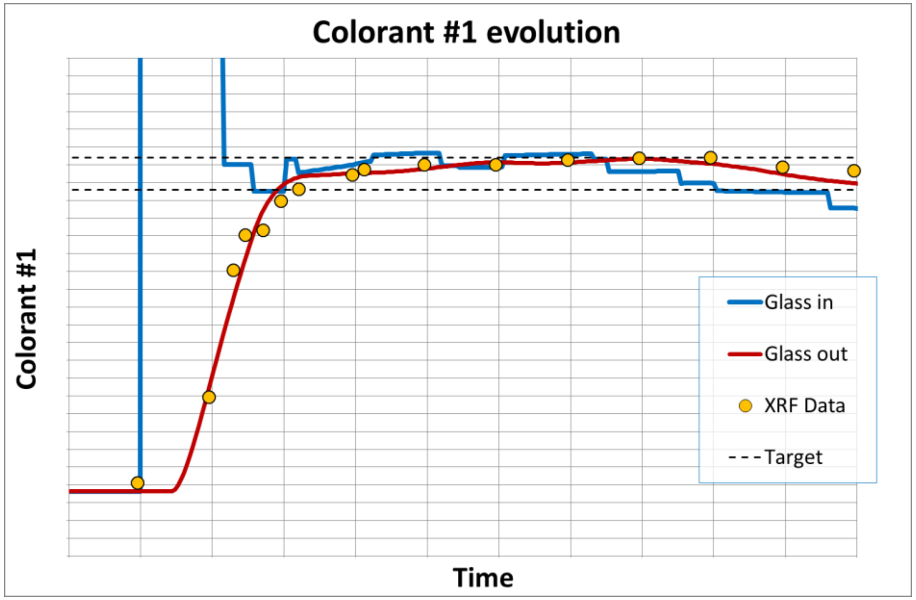
Color change – Simplified model

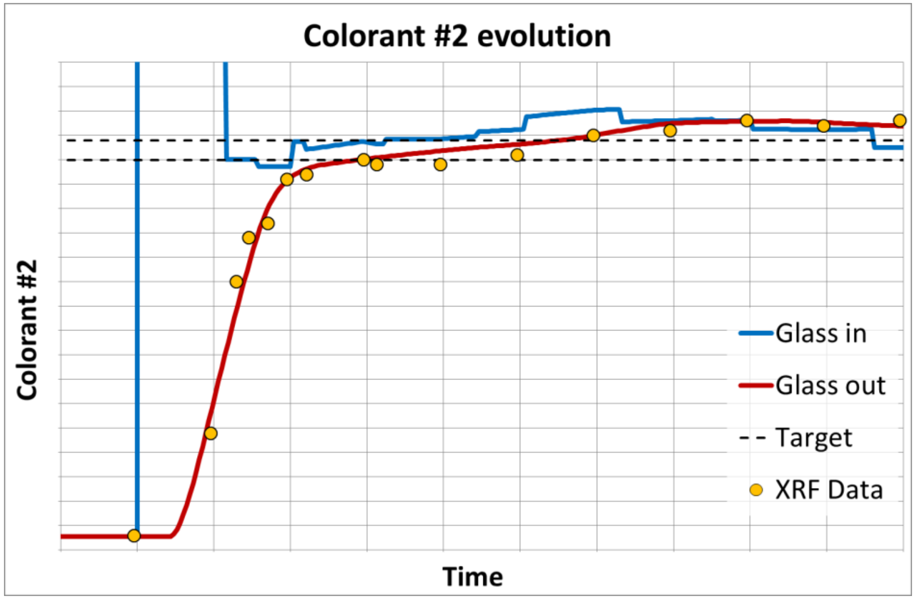
- Comparison between GFM model and simplified model
  - Very good fit between GFM and 2-mixer model
  - 1-mixer model is able to reproduce asymptotic behavior



Color change – Practical examples

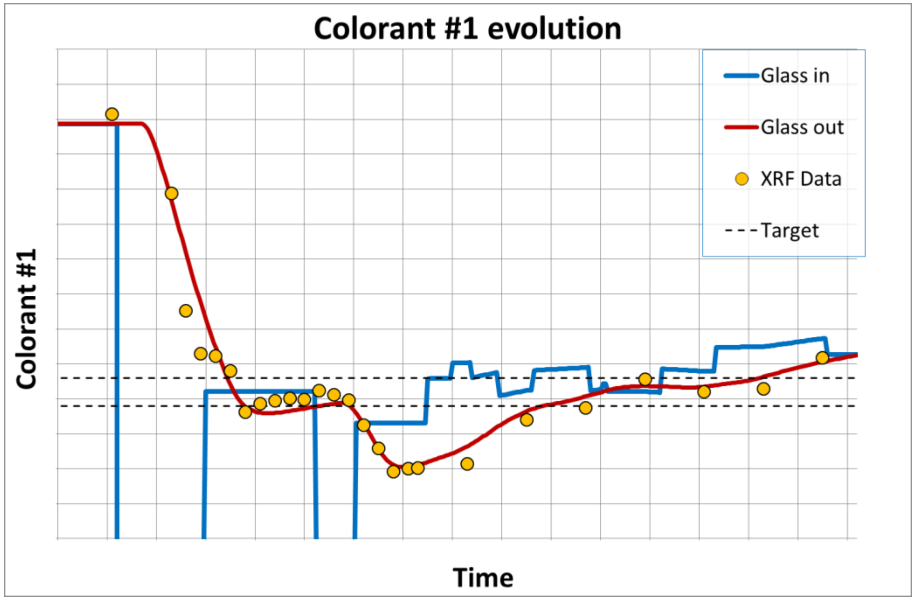
- Tool validation: Example 1
  - Very good fit between the 2-mixer simplified model and experimental data when increasing colorants
  - The simplified model can be used to help for adjusting colorants during and after color change

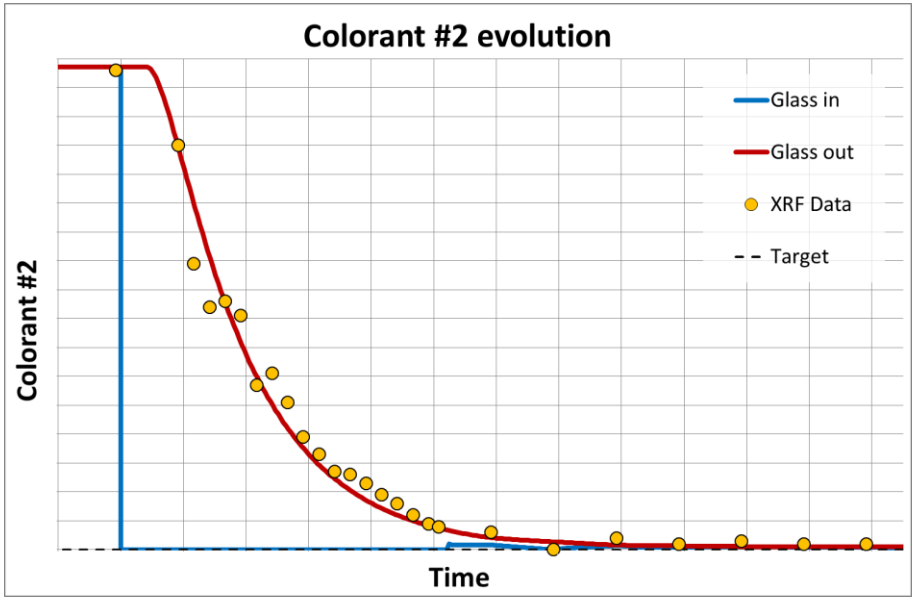




Color change – Practical examples

- Tool validation: Example 2
  - Very good fit between the 2-mixer simplified model and experimental data when decreasing colorants
  - The simplified model can be used to help for adjusting colorants during and after color change





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Conclusions

- In April 2014, the second furnace in AGEU using Hotox technology has been started with new challenges to face
- One of these challenges was to manage color changes on a new type of furnace
- Transient simulations of color changes have been used in order to improve our understanding of colorant mixing in the furnace and to fit a simplified color change model
- This simplified model has been validated, and is successfully used in order to
  - Prepare the settings of each color change
  - Adjust colorants during production

Thank you very much for your attention

LIFE11 ENV/CZ/000488

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For any question, please contact

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