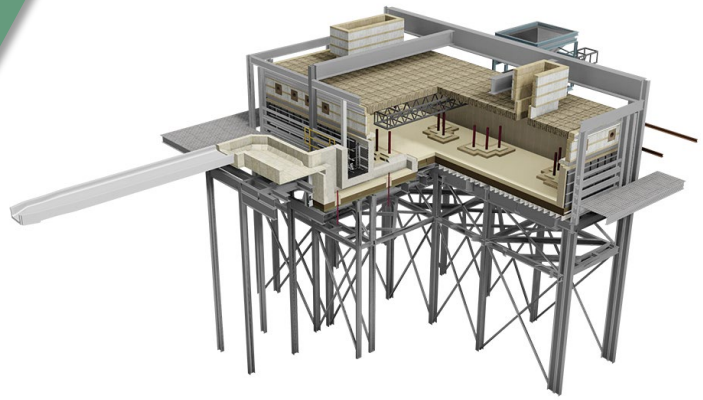
Modeling Collaboration & Insights



Jonathan Blevins

October 07, 2025

U.S. DEPARTMENT OF ENERGY

GMIC GLASS MANUFACTURING INDUSTRY COUNCIL

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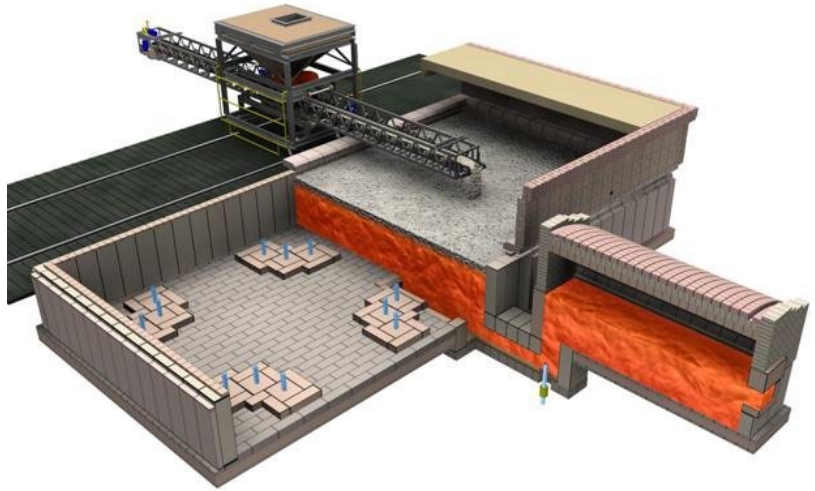
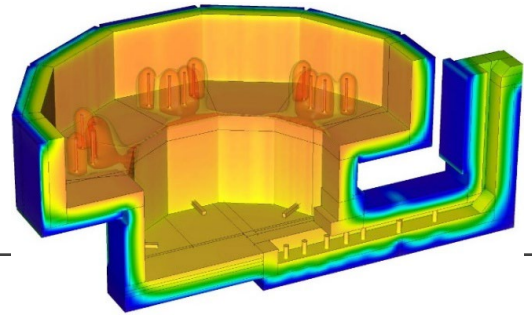
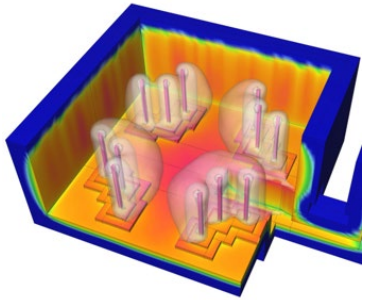
All Electric Melting

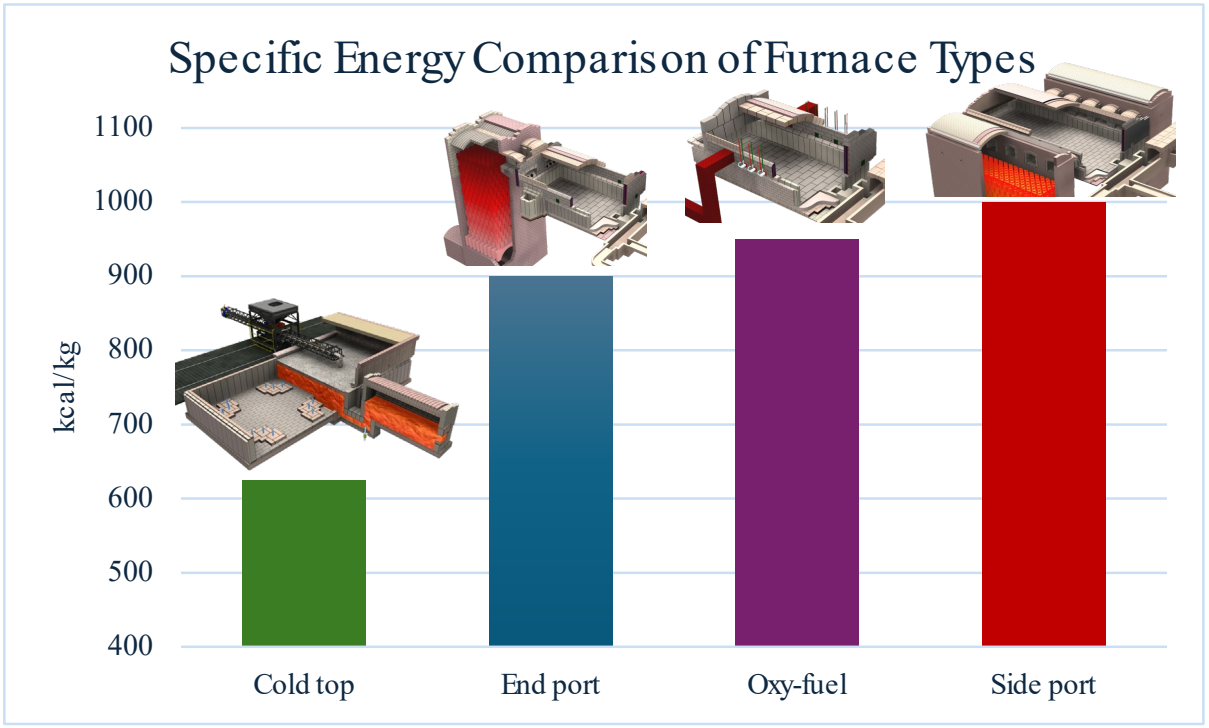


Benefits of Cold Top Melting

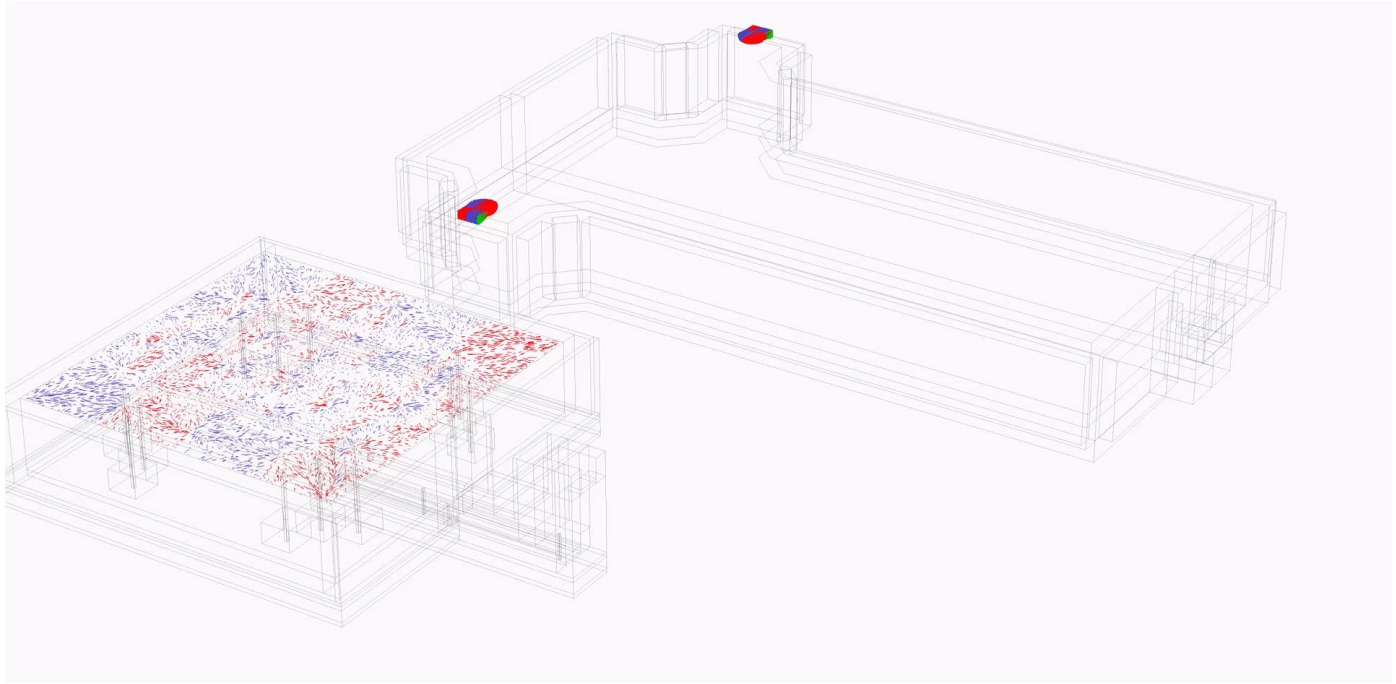


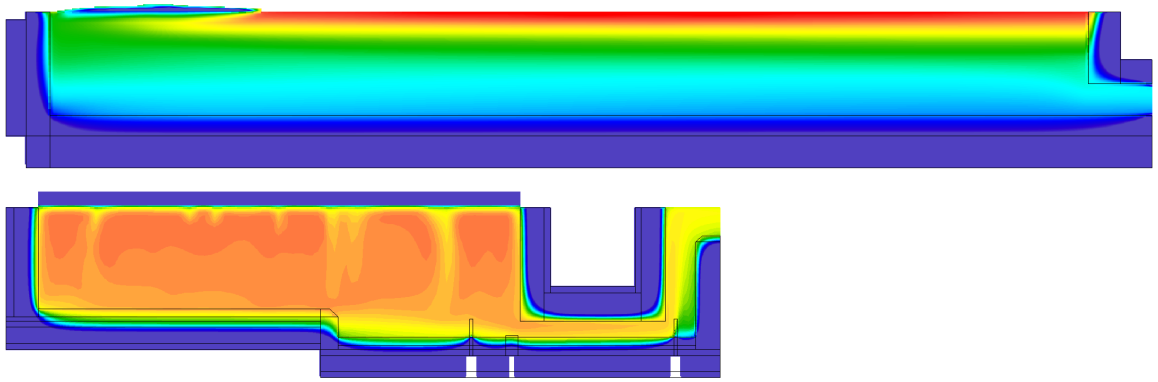
- Specific energy of cold tops ~600 – 800kcal/kg
- Why is it more efficient?
  - Joule heating is ~95% efficient
    - Combustion heating is ~45% efficient
  - Batch forms a significant thermal barrier minimizing heat losses
- Reduced emissions
- Simple design and operation





Melting – Electric vs. Combustion





Electric

- High glass velocity
- Consistent temperature ~1400 °C
- 1-direction heat transfer to batch

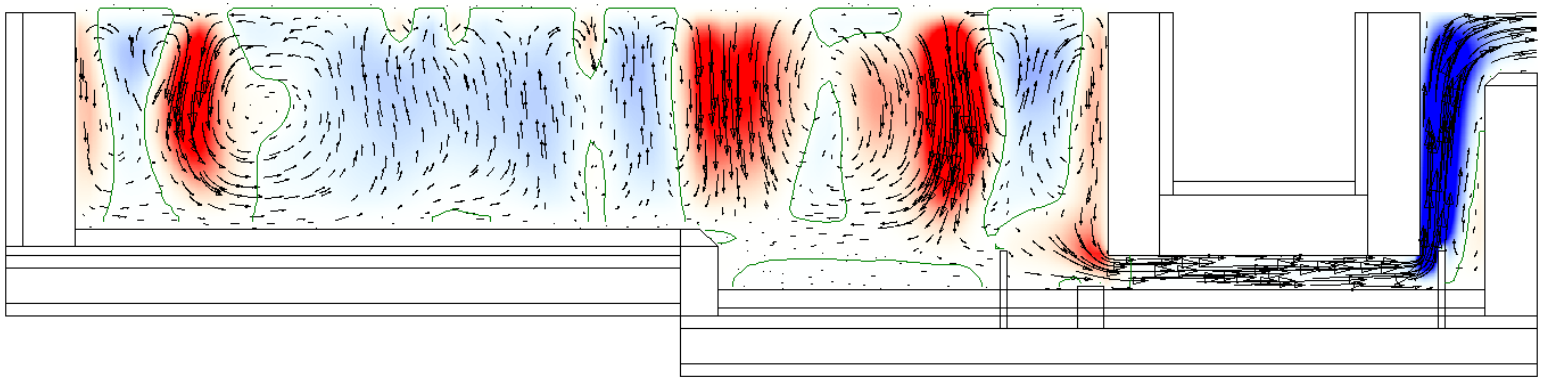
Combustion

- Lower glass velocity
- Variable temperature (1200-1500 °C)
- 2-direction heat transfer to batch

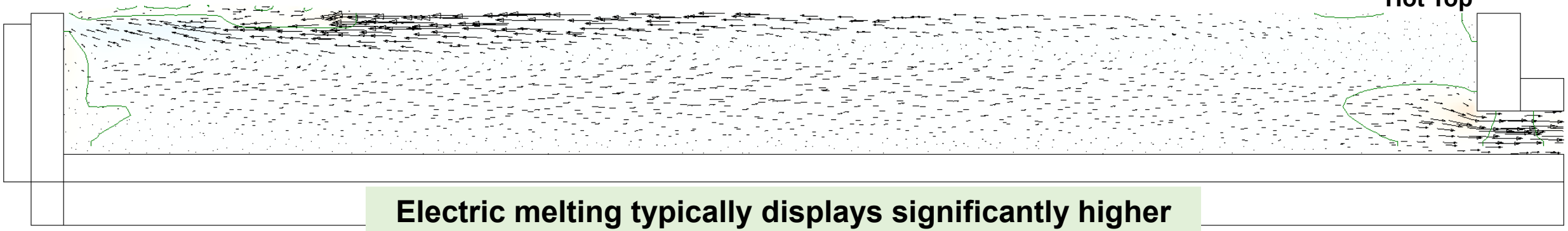
Melting – Electric vs. Combustion: Vertical Velocities

Furnace Centerline

Cold Top



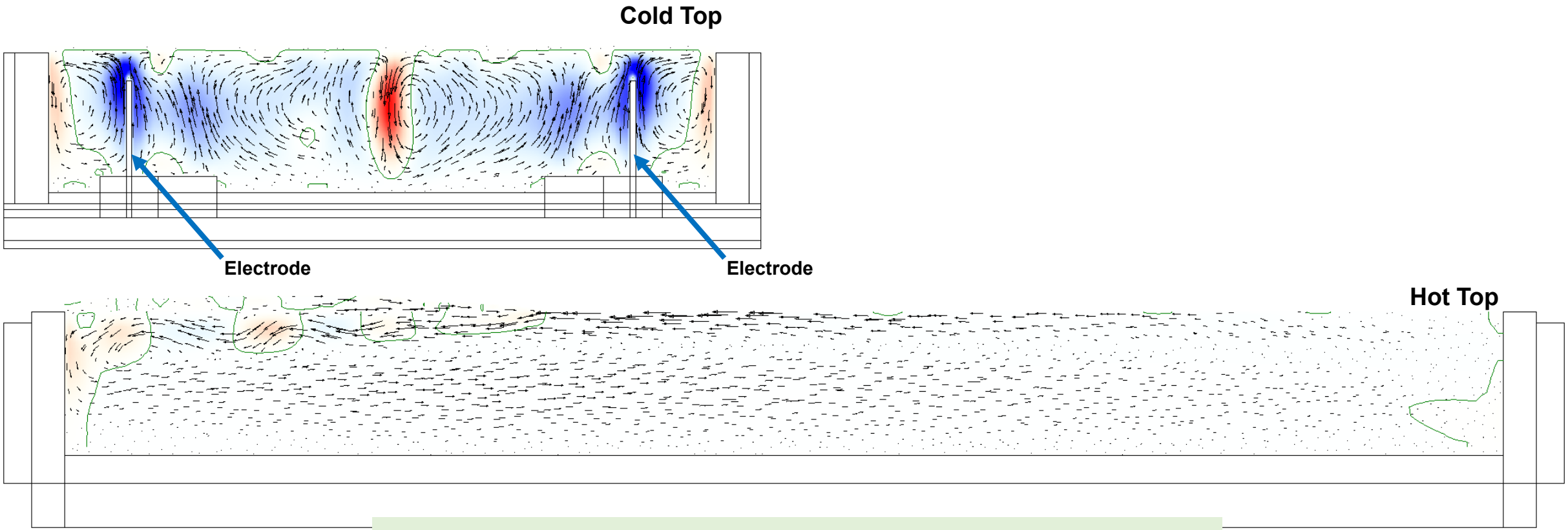
Hot Top



Electric melting typically displays significantly higher velocities than hot top furnaces

Melting – Electric vs. Combustion: Vertical Velocities

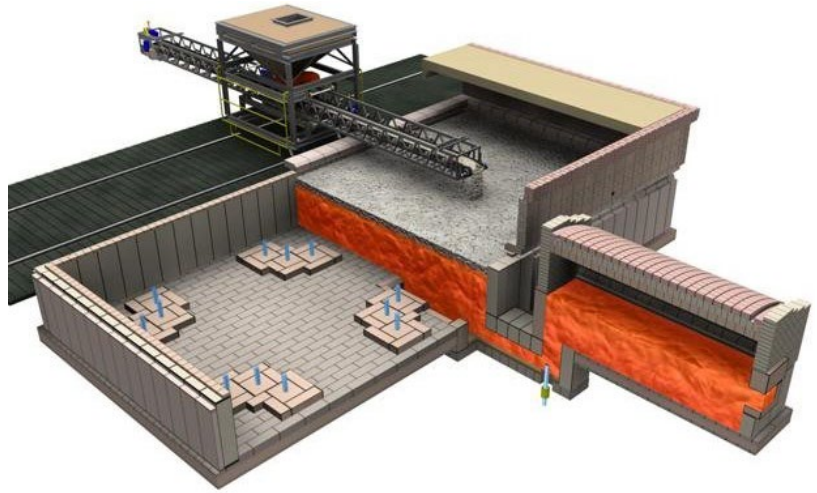
Off – Centerline



Electric melting is complex and varies spatially much more than hot top furnaces

Tradeoffs of Cold Top Melting

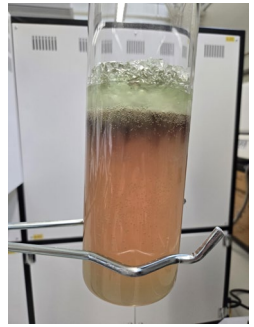
- Limited melt rate turndown
  - ~50% of design pull is minimum
- Shorter campaign life
- Difficulty in melting reduced glasses
  - Foaming and “volcanoes”
- Glass quality typically not suitable for higher quality products

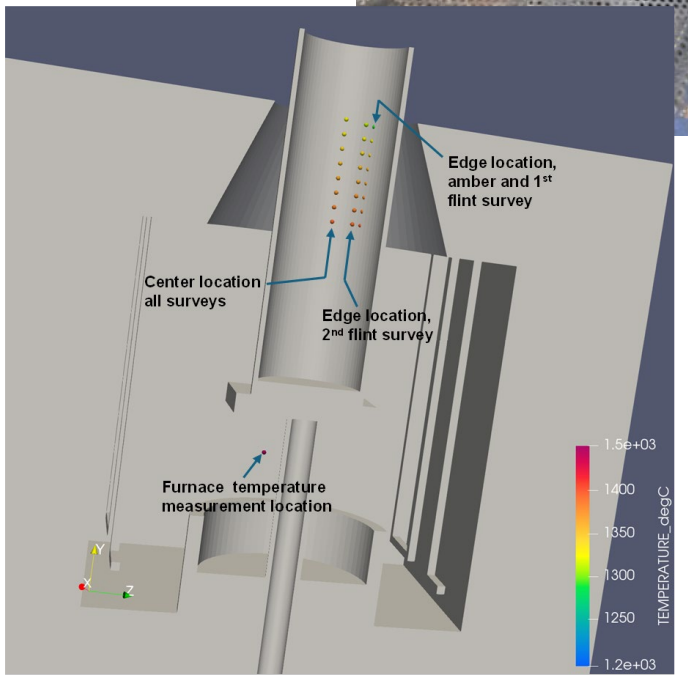


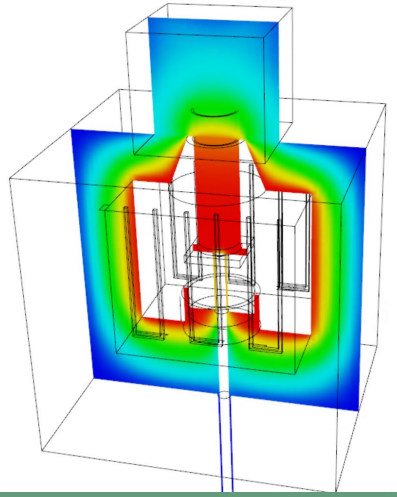
HTMOS Cold Top Rig CFD Modeling

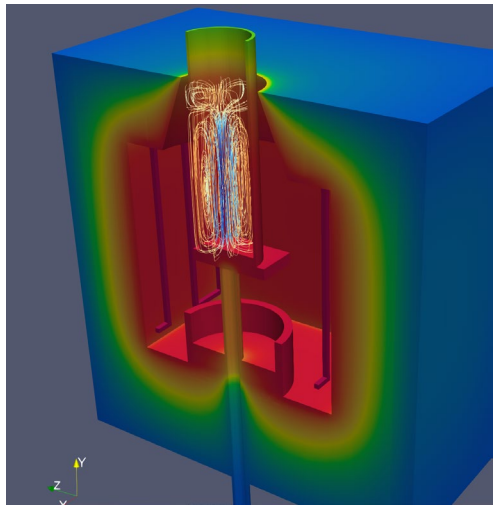
HTMOS Cold Top Rig CFD Modeling

- Purposes of cold top rig modeling
  - Have a digital version of the rig
  - Gain further insight into melt phenomenon
  - Enhance the productivity of the project by seeing ahead of time what may be worth pursuing
  - Improving modeling techniques to account for new findings





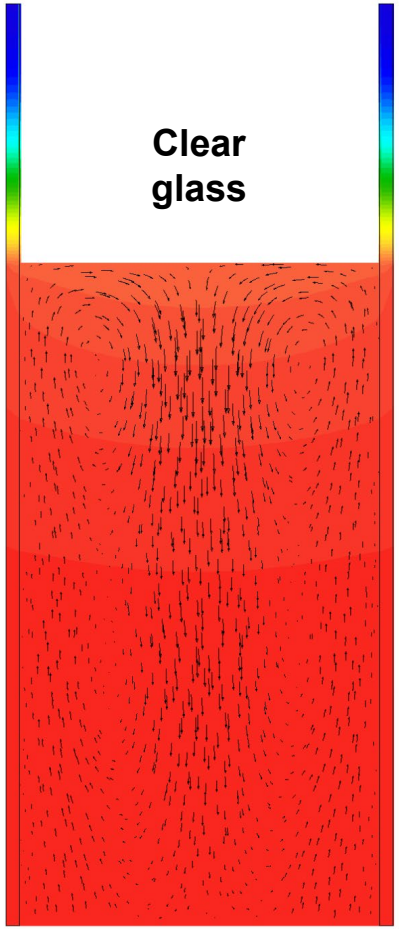


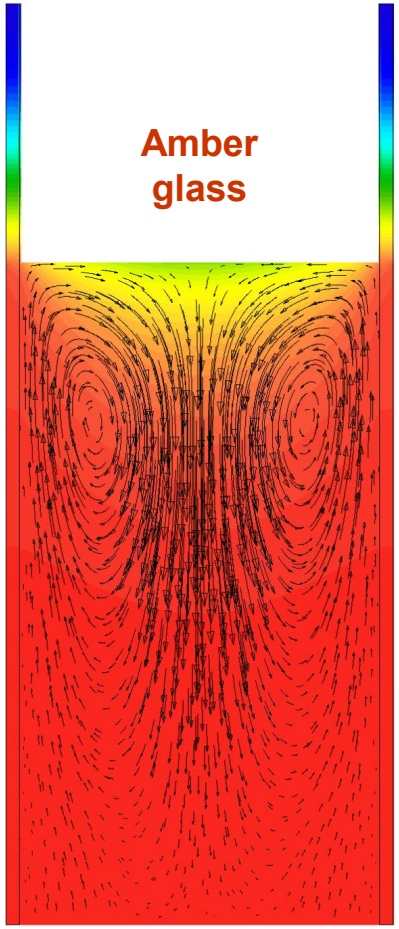


3 Modeling Tools Available

- GTM-X
- GS
- ANSYS

Cold Top Rig CFD Modeling



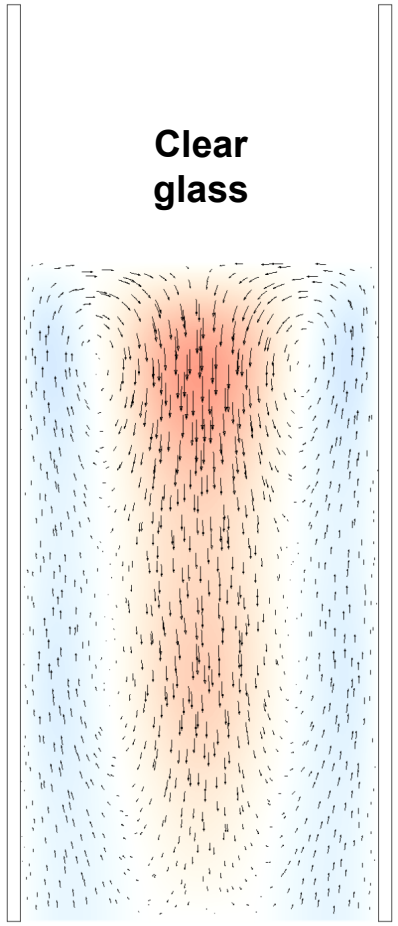


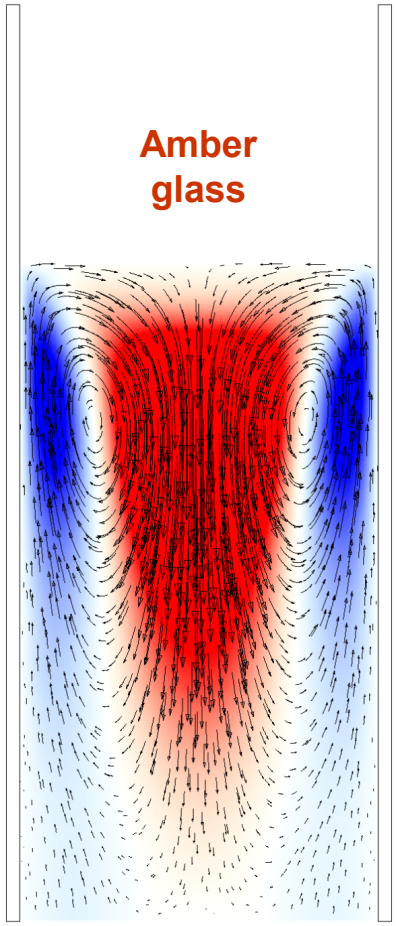
Heat is introduced through the walls leading to rising flow at the outside and sinking colder flows in the center

The top is exposed to ambient room conditions

The difference in glass thermodynamic properties of amber glass leads to stronger temperature gradients and flows

Cold Top Rig CFD Modeling





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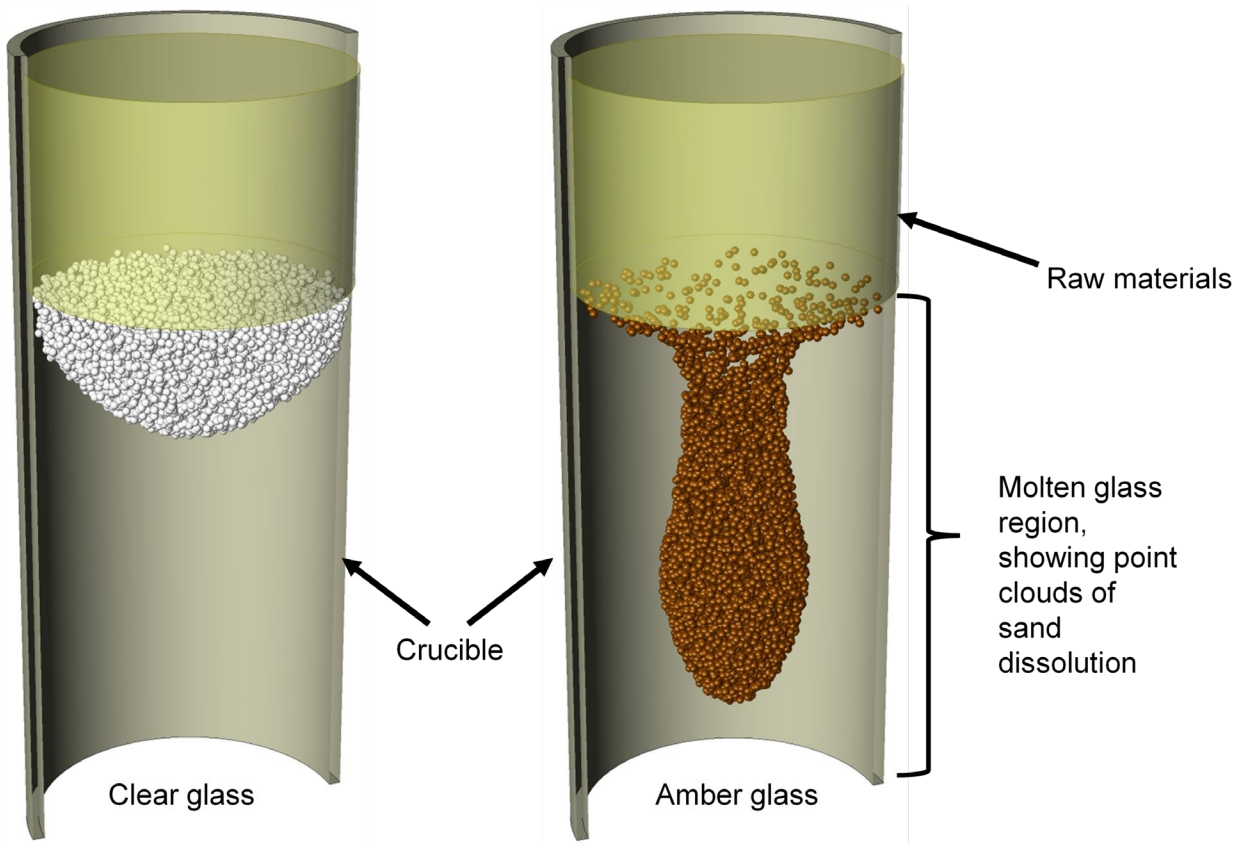
Cold Top Rig CFD Modeling

- Trends in furnace power between clear and amber are well reflected in the modeling
  - Furnace control temperature is constant for all testing – 1450C
  - Clear requires more power than amber

CFD Comparisons to Rig Tests

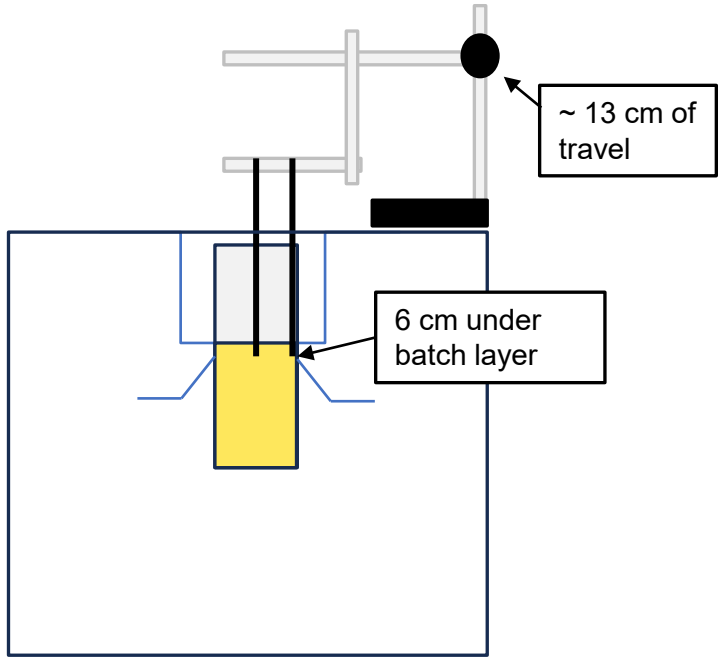
Parameter	Units		
Glass color		Clear	Amber
Rig Power	W	5064	4780
Rig Temperature	degC	1450	1450
CFD model power	W	5064	4475
CFD model temperature	degC	1450.6	1450.2
Power difference	%	0	-6.38
Temperature difference	%	0.0	0.0



The differences in glass properties between clear and amber lead to different raw materials melting behavior

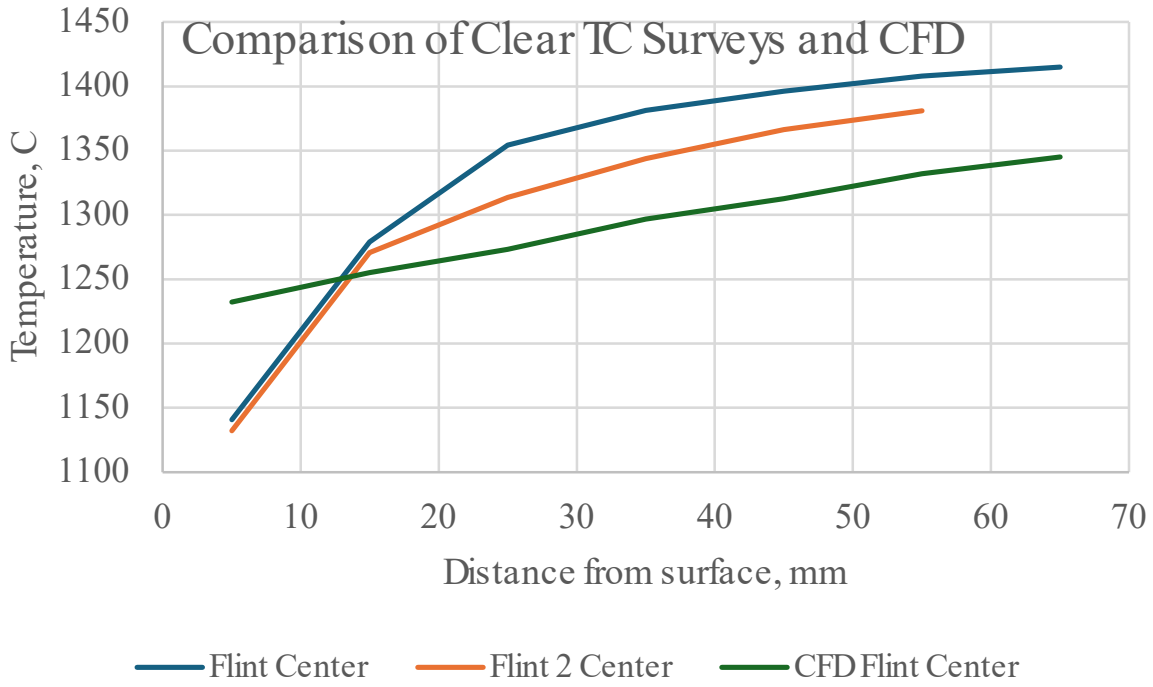
Cold Top CFD Model Validation

- Two R-type thermocouples can measure center and edge temps
- Differences between center and edge temperatures can be captured
- Temperatures can be measured several inches into the glass
- Can be used to measure change in temperature in batch layer or just below melt zone



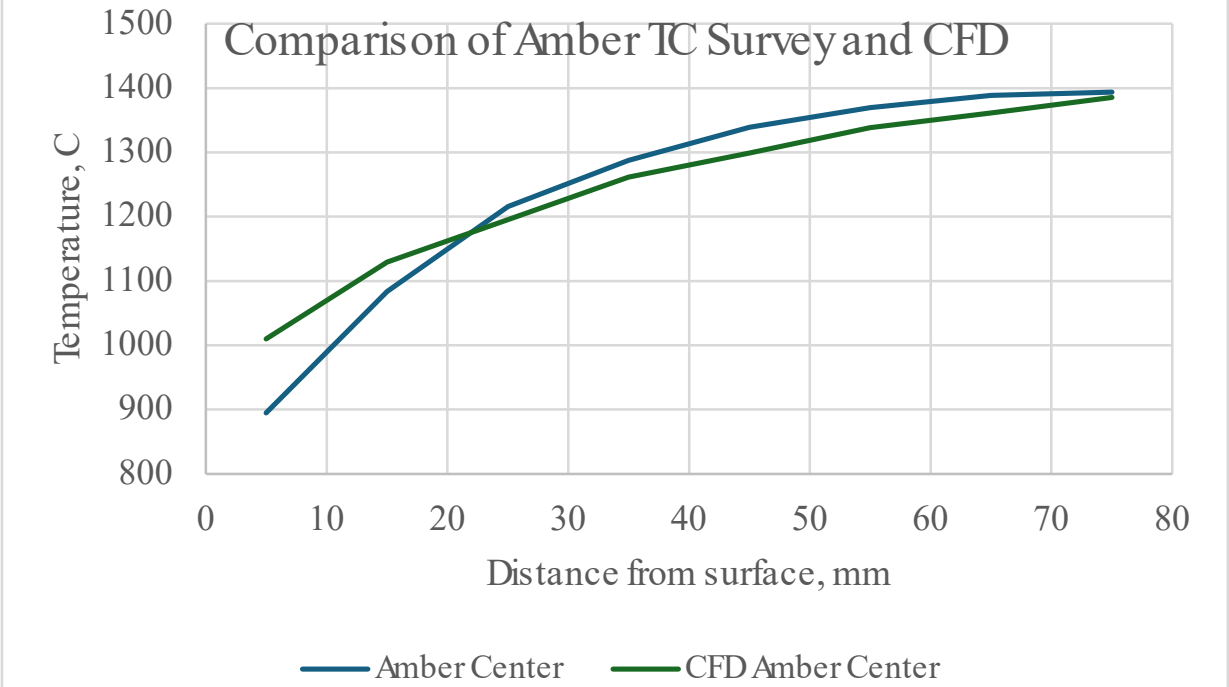
Thermocouple Survey & CFD Comparisons

Clear



- Temperatures near surface are not as strong of a match as preferred
- Slope of curve below the surface is a good match
- Comprehensive investigation was done on material properties and boundary conditions, which did not significantly reduce glass temperatures near the surface
- Therefore, surface temperatures are believed to be due to phenomenon not presently accounted for in the modeling, such as a micro-foam layer, for example

Amber

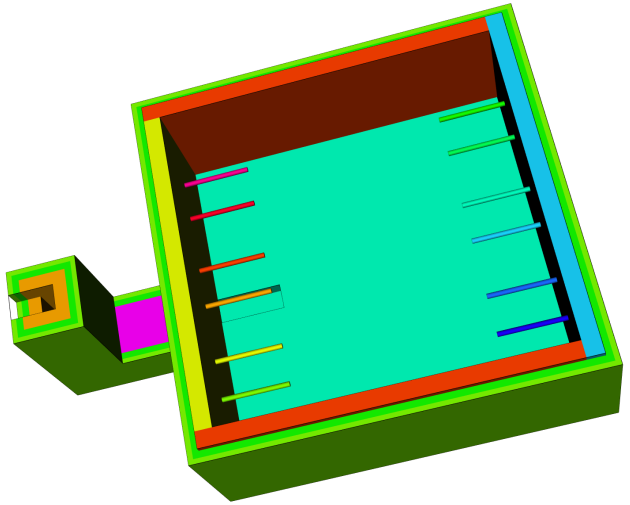


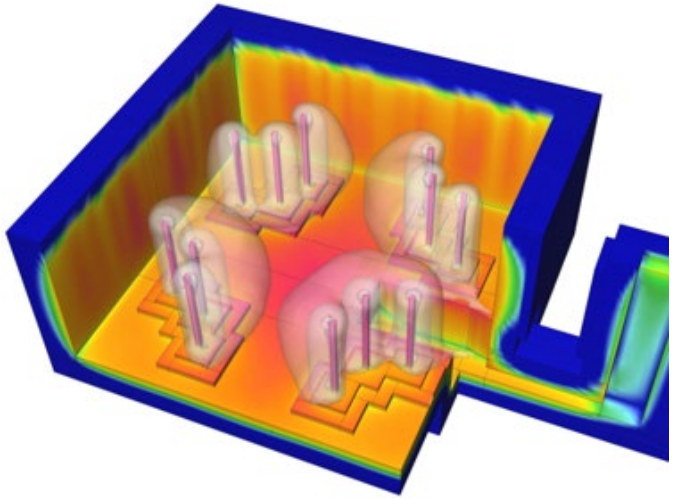
- A good overall match achieved on amber
- Largest discrepancy near the surface
- A surface phenomenon also appears to exist with amber though somewhat less pronounced

Industrial Scale Cold Top Study

Scope of Study

- Addresses multiple project objectives targeting improvements to flow fields and furnace life
- Electrode positioning
- Electrode immersion
- Electrode size
- Electrode layout pattern
  - Scott-T and 3-phase arrangements
  - Bottom boost layouts
  - Sidewall boost layouts
- Clear vs amber
- **Study is currently underway**



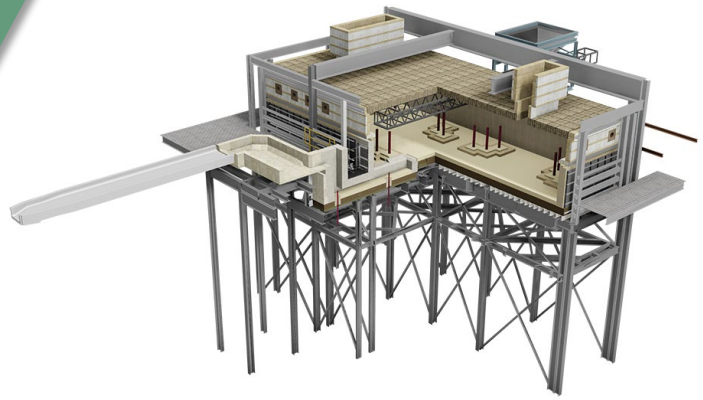


Wrap Up

Wrap Up

- Broadening the implementation of all-electric melting is necessary
- Cold top melting is significantly different than hot top melting
- Cold top rig experiments are on going, accompanied by CFD modeling to predict and capture findings
- An industrial scale cold-top modeling study is underway to assess boost design impacts on convective flows, temperature patterns, and campaign life

Thank you!



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