Electric Boosting and Melting Technology

Overview of developments and current work programs at FSL

March 2018
andy.reynolds@fivesgroup.com
Glass
Chemtec
Aluminium
Combustion
Automation
Filling | Sealing
Cutting Tools | Abrasives
Grinding | Ultra Precision
Cryogenics | Energy
Sugar | Bioenergy

Steel
Metal Cutting | Composites
Piping Solutions
Manufacturing
Maintenance
Intralogistics
Cement | Minerals
Induction
Fives, an international industrial engineering Group

Design, manufacture, installation and support of machines, process equipment and production lines for the world’s largest industrial players in aerospace, aluminium, automotive, cement and minerals, energy, glass, logistics and steel sectors

Understanding, pioneering spirit and commitment make Fives the enterprising partner by anticipating customer’s needs and providing them with the most relevant and forward-thinking solutions.
Electric Boosting & Melting Technology

Overview of developments & current work programs at FSL

1. Why we should all be thinking about using more electricity…
   – to offset gas usage?
   – to replace gas usage?

2. Electric Boosting (e-Boosting)
   – Maximizing efficiency
   – High boost input (super-boosting and ‘hybrid’ furnaces)
   – Electrical connections
   – Furnace life, corrosion

3. Electric Furnaces
   – The future of glass melting?
Electric Boosting & Melting Technology

Why we should all be thinking about using more electricity…

**Global Production of Fossil Fuel**

- **Conventional Oil**
- **Conventional Gas**
- **Other Oil**
- **Other Gas**

**EU legislation** to ensure climate/energy 3 targets:
- 20% reduction in greenhouse gases (from 1990 levels)
- 20% energy from renewables;
- 20% increase in efficiency
Electric Boosting & Melting Technology

Why we should all be thinking about using more electricity…

Global Production of Fossil Fuel

- EU legislation to ensure climate/energy 3 targets:
  - 27% reduction in greenhouse gases (from 1990 levels)
  - 27% energy from renewables
  - 27% increase in efficiency
Electric Boosting & Melting Technology

Why we should all be thinking about using more electricity…

**Global Production of Fossil Fuel**

- Conventional Oil
- Conventional Gas
- Other Oil
- Other Gas

EU low carbon roadmap:
- 80% reduction in greenhouse gases (from 1990 levels): Milestones to achieve this;
  - 40% by 2030;
  - 60% by 2040;
- All sectors to contribute
Electric Boosting & Melting Technology

Why we should all be thinking about using more electricity…

Planning a long-term investment? How long will your next tank last, what’s the payback term? Do you really want to base your future on fossil-fuels?
Electric Boosting & Melting Technology

Why we should all be thinking about using more electricity…

And what about CO2 emissions…

- **Clean-up incumbent technologies (improve APC, carbon capture)**
  - Has merits and will be followed, CO₂ capture is currently expensive

- **Reduce emissions (e.g. electric boosting/hybrids) and clean-up (!)**
  - Achieves shorter-term objectives but not the ultimate goal in itself

- **Move to ‘new’ technologies (induction melting, microwave, etc.)**
  - Small scale investigation of technologies – time/money need to develop

- **Scale-up all-electric melting (proven technology within current niche)**
  - Technology already applied, questions relate to scale only.
**Electric Boosting & Melting Technology**

Why we should all be thinking about using more electricity…

**Present situation**

- In most places, it is currently, still environmentally cleaner (on global emission basis) to burn fuel in the glass furnace than to use it to generate electricity for electric melting. And, Fossil-fuel combustion technology has achieved impressive energy performance levels.

**However…**

- Contribution of electric renewal energy is increasing rapidly; regions where above remains valid will diminish in the near future (within 10 years for W. Europe)
- F-Fuel combustion technologies rate of improvement (energy efficiency) has all but flatlined
- There is a (consumer driven) cultural sea change towards materials and technologies that are (or are perceived to be) environmentally friendly

**Conclusion:** Within one generation there will be a change in heat intensive process industries (including glass manufacture) from fossil-fuel to electric energy.
E-Boosting
Electric Boosting & Melting Technology

Electric Boosting (e-boosting)

- **Increase in output** without increase in footprint (reduced CAPEX on revamps)
- Improved **flexibility** (and turn-down) on/off capability
- Improved quality (improved refining); eliminate the need for **weir walls**, and/or **bubblers**
- **Reduced emissions**; reduced fuel usage reduced waste gas volume (and reduced crown temperatures)
- Improvement in overall **energy efficiencies** (improved combustion efficiency)

**Research and development work at FSL directed at:**

- Increasing efficiency (maximizing the benefit from each kW of electrical input)
- Reducing negatives (impact on refractory stress and corrosion)

→ One of the key tools used is **CFD modelling**
Electric Boosting & Melting Technology

Electric Boosting (e-boosting): Maximizing efficiency

Boosting under the batch layer will increase melt rate (increased convection) – and improve heat transfer into the batch layer (BEWARE connective forces pushing batch over the thermal barrier)
Electric Boosting & Melting Technology

Electric Boosting (e-boosting): Maximizing efficiency

Boosting heat energy can increase and homogenise temperature of glass (especially low transmission types) and help in de-gassing process. Intensity of boosting (in multizone) can define the position of hot-spot.
Glass Boosting in the hot spot will reinforce desirable convection currents (improve ‘thermal barrier’ between melting and refining zones) eliminate need for physical barrier

Electric Boosting & Melting Technology

Electric Boosting (e-boosting): Maximizing efficiency
Electric Boosting & Melting Technology

Electric Boosting (e-boosting): Maximizing efficiency

Boosting in refining zone – can help reduce stagnemt glass, and control throat temperature (BEWARE of creating short cut to throat)
Electric Boosting & Melting Technology

Electric Boosting (e-boosting): Maximizing efficiency

Analysis via CFD modelling allows us to…

1. Optimise **furnace geometry** and **electrode positioning/orientation**
2. Determine best **power distribution** (incl. variation for different output or production regimes)
3. Extending the model to look at burner configurations allows the interaction of the combustion system to be judged – **allowing optimum fuel-usage**
4. Depending on the model complexity, we can look at batch distribution/cover and its impact on the melting process to achieve best **furnace performance**.
Electric Boosting & Melting Technology

Electric Boosting (e-boosting): Maximizing efficiency
In complex systems we have extended our analysis to include the interaction of the combustion system:

1. This allows us to run simulations with different boost energy profiles at different combustion inputs.
2. Build a complete picture to allow optimising of operational conditions
Electric Boosting & Melting Technology

High boost input (super-boosting and hybrid furnaces)

- **Boosting**: FF combustion remains primary energy input supplemented by direct electrical input. Basic design and operation of furnace is unchanged and centred around ‘conventional’ melting processes.

- **Hybrid**: Melting processes still occur in the ‘horizontal sense’ (i.e. batch input to throat) however electricity becomes the primary energy input...

As electrical input increases total energy efficiency increases and emissions reduce
Electric Boosting & Melting Technology

High boost input (super-boosting and hybrid furnaces)
Electric Boosting & Melting Technology

High boost input (super-boosting and hybrid furnaces)

Multizone boosting allows the thermal profile of the furnace to be adapted according to output; and can eliminate the need for bubblers and weir walls.
Electric Boosting & Melting Technology

Electric Boosting (e-boosting): Maximizing efficiency

Electrodes make connection to melt; however, heating effect is not uniform (Joule effect in bulk of melt between electrodes is minor compared to in the close proximity to the electrode).
Electric Boosting & Melting Technology

Electric Boosting (e-boosting): Electrical Connections

Heating effect near electrodes creates localised hot spots; these in turn create convection and this is the primary mechanism of heat transfer through the melt.
If we wish to put a uniform thermal barrier across the tank the only way is to use bottom electrodes.
Interestingly, the method of connect has significant on the circuit resistance; and the resulting current impacts the heating effect – but not in regard to effects due to a different ‘current path’.

Electrical connections can be chosen to limit losses in external circuits as a primary factor.
Electric Boosting & Melting Technology

Electric Boosting (e-boosting): Electrical Connections

Key targets: uniform electrode currents within control zones and low current densities on electrodes.
Superposition of effects of shear and wall temperatures gives indication of corrosion rate; CFD analysis allows comparison of electrode position, immersion and power distributions to reduce affects of stress/temperature
Electric Boosting & Melting Technology

Electric Boosting (e-boosting): E-Glass fibre

E-Boost Installed Power kW (by FSL) 2005-2015
(installations still in operation)
Electric Furnaces
Electric Boosting & Melting Technology

Electric Furnaces – the future of glass melting

All-Electric Melting

- Technology applied successfully to many (most) type of glass
- Furnaces capacities limited by production requirements (not technology)
- Larger capacities for fibre and insulation products are common
- Large container furnaces have been implemented
Electric Boosting & Melting Technology

Electric Furnaces – the future of glass melting

All-Electric Melting

Glass quality - Refining

- Cold-top melting has one inherent ‘weakness’ in that it puts the batch layer directly above the throat.

- In convection furnaces whatever the convection/flow profile in the furnace some separation (RT) can be achieved with distance [aided by thermal or physical barriers]

- In a single chamber CT furnace some benefit is gained by depth but other methods have to be used to create the necessary ‘barrier’

- The higher the refining requirements the more this becomes an issue, and the ‘problem’ increases as capacity increases, and melt rate increases
Electric Boosting & Melting Technology

Electric Furnaces – the future of glass melting
Electric Boosting & Melting Technology

Electric Furnaces – the future of glass melting

All-Electric Melting

- Largest FSL Cold-top All-electric furnace installed:
- HQ Cosmetic glass (~90TPD)
- <850-900kWh/T
- 7-8 years life (full rebuild to full rebuild)
- High cooling air (integrated system)
Again, CFD Modelling can be used to assess different design options (e.g. True residence times for different furnace depths, electrode orientations, power settings, wall geometry)
Electric Boosting & Melting Technology

Electric Furnaces – the future of glass melting

All-Electric Melting – Upscaling for container production

Mitigating risks associated with large units

- Short-cuts to throat
- Redox control (colour uniformity)
- High cullet levels and metal contamination

Figure 5.10 – Residence Time Distribution (RTD) of the glass.
Electric Boosting & Melting Technology

Electric Furnaces – the future of glass melting

All-Electric Melting
Operation – Output and Flexibility

- Cold-top melting relies on maintaining a stable batch layer over the glass surface.
- Significant changes in the thickness of the batch layer impact furnace stability.
- CFD modelling and empirical trials has allowed improved understanding of optimum electrode orientation and immersion under the batch layer.
- With management of cullet furnace output flexibility has increased (~50% turndown)
- Determination of melt rate is a key factor when upscaling for container production
Electric Boosting & Melting Technology

Electric Furnaces – the future of glass melting

Figure 5.8 – Interior substructure refractory temperature distribution.

Figure 5.9 – Shear stress on the glass contact walls.
Electric Boosting & Melting Technology

Electric Furnaces – the future of glass melting
Electric Boosting & Melting Technology

Electric Furnaces – the future of glass melting

Scaling Up All-Electric Melting

- One solution is to use the modular approach… many merits…
Our thanks to

Celsian Glass & Solar
Andy Reynolds
Business Development Director
Fives Glass
andy.reynolds@fivesgroup.com
T +44 1235 517 226
M +44 7768 125 070

Fives Stein Limited
4CA Churchward,
Southmead Park, Didcot
OX11 7HB - UK