“All-Electric Melting”

The only future for glass industry will be “all-electric”

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Eurotherm is a leading global supplier of control, measurement and data recording solutions and services to industrial and process customers. The company’s international reputation as a provider of innovative solutions across a selection of vertical markets is supported by engineering services designed to realize greater benefits to customers’ plant-wide assets.
**CO₂ Targets against traditional Furnace Life Time**

The **2020** package is a set of binding legislation to ensure the EU meets its climate and energy targets for the year 2020. The package sets three key targets:
- **20%** cut in *greenhouse gas emissions* (from 1990 levels)
- **20%** of EU energy from *renewables*
- **20%** improvement in *energy efficiency*

The **2030** climate and energy framework sets three key targets for the year 2030:
- At least **40%** cuts in *greenhouse gas emissions* (from 1990 levels)
- At least **27%** share for *renewable energy*
- At least **27%** improvement in *energy efficiency*

**2050**: The European Commission is looking at cost-efficient ways to make the European economy more climate-friendly and less energy-consuming. Its *low-carbon economy* roadmap suggests that:
- By 2050, the EU should cut greenhouse gas emissions to **80%** below 1990 levels
- Milestones to achieve this are **40%** emissions cuts by **2030** and **60%** by **2040**
- **All sectors** need to contribute

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https://ec.europa.eu/clima/policies/strategies_en

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The “All-Electric” Transition seems to be Inescapable

> CO$_2$ emission reduction legislation
> NO$_x$ emission reduction legislation
> The risk of becoming a victim of unexpected political decisions
> Extreme long furnace life time against the rapidly changing energy market
> Increasing availability of renewable energy
> Increasing complexity of firing unstable fossil fuel compositions
> Focusing on our core business instead of dealing with all kind of energy questions and complex systems
> Increased complexity of traditions melting techniques
Perhaps more important…..The Customer…..?
Heineken:

“The aim of the project is to try to make the glass sector move. We want to help and inspire them to move in the direction of climate controlled glass production.”

“The worst case scenario would be if the glass suppliers cannot meet our targets so we would of course then have to look to other materials.
“the times they are a-changin”
A Tesla Model S has fewer than 150 moving parts, including the drive train, windows, controls, suspension and doors. A typical internal combustion engine car has about 10,000.
How complex can “glass melting” get?
# Required Electrical Melting Power

<table>
<thead>
<tr>
<th>Pull rate ton/day</th>
<th>Pull rate ton/hour</th>
<th>Gas Furnace (3.8GJ/ton = 1.06 MWh/ton)</th>
<th>Electric Furnace (2.7GJ/ton = 0.75 MWh/ton)</th>
<th>Installed Power Required</th>
<th>Installed Power Required</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>4.17</td>
<td>4.42 MW</td>
<td>3.13 MW</td>
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</tr>
<tr>
<td>200</td>
<td>8.33</td>
<td>8.83 MW</td>
<td>6.25 MW</td>
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<tr>
<td>300</td>
<td>12.50</td>
<td>13.25 MW</td>
<td>9.37 MW</td>
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<td>500</td>
<td>20.83</td>
<td>22.08 MW</td>
<td>15.62 MW</td>
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<tr>
<td>800</td>
<td>33.33</td>
<td>35.33 MW</td>
<td>25.00 MW</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1000</td>
<td>41.67</td>
<td>44.17 MW</td>
<td>31.26 MW</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>GJ/ton</th>
<th>kWh/ton</th>
<th>kWh/kg</th>
<th>kcal/ton</th>
<th>kcal/kg</th>
<th>MBTU/ton</th>
<th>BTU/kg</th>
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<tbody>
<tr>
<td>2.70</td>
<td>750.00</td>
<td>0.75</td>
<td>645315.49</td>
<td>645.32</td>
<td>2.56</td>
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<td>0.89</td>
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<td>3.70</td>
<td>1027.78</td>
<td>1.03</td>
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<td>884.32</td>
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<td>1123.33</td>
<td>4.46</td>
<td>4457.72</td>
</tr>
</tbody>
</table>
Energy Efficiency Improvements came to a Hold?
Fossil Fuel against Electric - Energy Efficiency

Furnace Size and Energy Efficiency

Electric Furnace Energy Efficiency %

Fuel-Fired Furnace Energy Efficiency %

Electric

Fuel-Fired

Pull Tonnes/Day

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Ohm’s law

\[ I = \frac{V}{R} \quad \text{or} \quad V = IR \quad \text{or} \quad R = \frac{V}{I}. \]

Joule’s law

\[ P = V \cdot I \quad \text{or} \quad P = I^2 \cdot R. \]
Electric Heating is Based on Joule’s Heating

V = 150V
I = 3333A
P = 500kW

\[ P = I^2R \]
\[ V = IR \]

\[ 500000 = 3333^2 \cdot 0.045 \Omega \]
Basic Power Control Concept

Long Distance - High Voltage & Low Current

\[ P_{\text{losses}} = I^2 \times R_{\text{busbar}} \]
Conclusions

Furnace boosting electrode systems:
• Require very high currents
• Run at relatively low voltages
• At a very low resistivity

The system controlling the high current of the electrodes needs be as close as possible to the electrodes
Cabling and connection resistances needs to extremely low
Transformer needs to be highly efficient
Induction needs to be avoided

The transformer, cabling, electrodes and the glass bath represent an induction-loop causing reactive power and inductive losses in the system.

In most cases parts of the furnace steelworks are inside this induction loop causing unwanted inductive losses.
Efficiency Losses From the Grid to the Melter

- Power Control & Management, Process Control, APC, Analytics
- High Voltage / Low Current
- Low Voltage / High Current

HV  ➔  HV  ➔  MV  ➔  MV  ➔  LV  ➔  LV

to make the System

➔ Energy & Cost Efficient, Flexible, Intelligent
**Flexibility**

> Real-time changing energy tariffs
> Avoiding Peak load penalties
> Grid Frequencies Control - DFFR
> Grid failure protection

https://qz.com/680661/germany-had-so-much-renewable-energy-on-sunday-that-it-had-to-pay-people-to-use-electricity/
Total Plant Power Demand Peak Shaving
Power Control Efficiency

SCR (thyristor) control:
> Is real time controllable
> Doesn’t have any moving parts
> Doesn’t show any wear
> Is very energy efficient

PLM or LTC features:
> Potentially reduced harmonics
> Improves Power Factor (cos φ)
Phase angle firing explained
Power factor in phase angle mode

Transformer

Incoming line

SCR

LOAD

≈ 1

Graph showing power factor values.
Conclusion

Phase angle firing is a simple and smooth way to control power demands with SCR’s.

But it has two major disadvantages:
• Poor power factor
• Harmonic distortion
PF improvement for Phase angle firing by Load Tap Changing

Triple Thyristor Application
Load Tap Changing gives us a more complete energy sine wave.

That is why Load Tap Changing Improves Power Factor.

And reduces harmonic distortion.
Full cycle firing

DUTY CYCLE

AVERAGE POWER DURING DUTY CYCLE
Peak power demand in a full cycle multiple load situation

- First load 80% duty cycle
- Second load 60% duty cycle
- Third load 40% duty cycle
- Forth load 20% duty cycle
Without Predictive Load Management
With Predictive Load Management

Total power

100 W

50 W

75 W
SCR control & Cathodic Protection Applicable

- Solid State Control
- No DC-components transferred by the transformer
- Controlled DC-feed for cathodic protection
- High Power Factor
- Minimum harmonic distortion
Power Management Features

- Lower an upper thresholds
- Configurable target lines
- HTML5 Application
  - Will work on any device/browser
- Configure viewing window
- Export data for further analysis
- View trends in full screen for detailed analysis
- Clear visual indication of thresholds
- Link your trends from other applications
- Change the viewing window while in “inspection” mode
- Enable “inspection” mode to pause the trend for analysis

Compare historical vs Real time information
Because of:

- The expected life of hybrid furnace is around 8 years…
- The Bigger part of the pull comes from electricity

The challenge is to improve performance and reliability of the booster system devices:

- Molybdenum rods (less wearing with higher current density)
- Electrode holders (more efficient waterway, strength, easy replacement)
- Trafo (high efficiency even if harmonics presence)
- SCR (2 taps – 3 taps arrangement)

…Combined with Smart design for failures fast fixing.
Conclusions

• All-electric melting systems will become the (near) future.
• Furnace boosting systems, including its power supply, need to be fully integrated into the overall furnace design as a result of close cooperation in between the different experts
• New electrode firing layouts need to be investigated, modeled and brought into practice
• The overall all-electric system needs to:
  • Be highly flexible
  • Be easy to control
  • Be easy to maintain
  • Be smart grid compatible
  • Be controlled and managed by MPC/APC using the freedom of control to tweak tariffs