All-electric Melting Technology
(and application to Container Glass)
All-electric Melting Technology

All-electric Melting (Alternative Technologies)

INDIRECT USE OF ELECTRICITY

e.g. $2\text{H}_2\text{O} \rightarrow 2\text{H}_2 + \text{O}_2$

DIRECT ELECTRIC HEATING

Resistive, Induction, Radiative, Microwave

$2\text{H}_2 + \text{O}_2 \rightarrow 2\text{H}_2\text{O}$
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Cold-top Vertical Melter (CTVM)

75TPD furnace for neutral borosilicate
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Applications

All-electric CTVM melting is already successfully applied to many (most) type of glass and at various capacities.

- Bottles (high volume/low $)
- Container
- Tableware
- Crystalline/Crystal
- Perfumery and Cosmetics
- Drawn fibre (E, ECR, Silica)
- Coloured glasses (float/rolled)
- Opal Glass
- HV Insulators
- Cover Glass
- Tubing (Neutral Borosilicate)
- Spun fibre (C Glass)
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Applications

- All-electric (resistive) melting generally implies cold-top vertical melting (CTVM)
- CTVM formats have been applied successfully to many (most) type of glass
- Furnaces capacities limited by production requirements (not technology) normally **10 - 100 TPD**
- Larger capacities for fibre and insulation products are common
- A few larger container furnaces have been built (~200-250TPD)
- At least one mini-float all-electric furnace has been built to date.

60m² (120 TPD) CTVM furnace for (mini) float
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Electric Melting Today

Fives State-of-the-Art technology
40m² 80-90TPD (cosmetic glass)
Target performance:
• <900kWh/tonne at 7-8 year life
System features:
• Integrated cooling-air,
• low maintenance electrode configuration
The FURNACE is designed to melt low iron SODA LIME GLASS composition at an average rate of 50 to 100 tonnes per 24 hours.

It operates on a cold top VERTICAL MELTING principle with HEXAGONAL melting area.

The system incorporates a single MELTING and REFINING chamber with a bottom entry THROAT and vertical RISER for connection to a DISTRIBUTOR and FOREHEARTH system.
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Electric Melting Today
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A time of uncertainty for fossil-fuel technology

Global Production of Fossil Fuel (Pass and Predicted)

- EU low carbon roadmap:
  - 80% reduction in greenhouse gases by 2050 (from 1990 levels): Milestones to achieve this;
  - 40% by 2030; 60% by 2040;
  - All sectors to contribute

- 2020 EU legislation to ensure climate/energy 3 targets:
  - 20% reduction in greenhouse gases (from 1990 levels)
  - 20% energy from renewables;
  - 20% increase in efficiency

- 2030 EU legislation to ensure climate/energy 3 targets:
  - 27% reduction in greenhouse gases (from 1990 levels)
  - 27% energy from renewables;
  - 27% increase in efficiency
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Application to Container Glass

Why not apply electric melting to high volume container glass?

- EXPENSIVE (High CAPEX and OPEX – high price of electricity)?
- SHORT CAMPAIGNS?
- LESS FLEXIBLE – OUTPUT/COMPOSITION?
- POOR STABILITY (INABILITY TO MELT REDUCED GLASSES)?
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Application to Container Glass

Why not apply electric melting to high volume container glass?

EXPENSIVE (High CAPEX and OPEX – high price of electricity)?
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Application to Container Glass

At 200TPD

- Best oxy-fired tanks get ~3.3 GJ/T
- Best E-F Reg tanks get ~3.8-4.0 GJ/T
- Cold-top all-electric can achieve <2.75 GJ/T
Assessing energy related operational costs on a general basis in quite challenging:

- Many different tariffs and (green) taxes
- Different pricing regimes in different regions, states and industrial sectors
- Prices dependent on consumption and level of security etc.
- Predicting how prices will change (and the relative price E/G) is difficult – many different models based of different assumption

For comparative purposes, let’s take:

- Electricity: 70 € MWh (inclusive of green taxes)
- Gas: 30 € MWh
- C-tax 18 €/T (CO₂)
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Application to Container Glass

TCO: End-fired Reg @4.0GJ/T

- Energy used
- CAPEX (RO)
- APC equipment
- Rebuild/maintenance
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TCO: Electric CTVM @2.75GJ/T

Full cold-repair (7.5 years)
30 days lost production

- Energy used
- CAPEX (RO)
- APC equipment
- Rebuild/maintenance
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Application to Container Glass

TCO: EFR (4.0GJ/T) vs CTVM (2.75GJ/T)

Calculated using today's (typical) high-user energy tariffs (UK)
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Projected change in relative tariffs 5 years (mid-range prediction)
15% change on relative energy cost and 20% increase in C tax

TCO: EFR (4.0GJ/T) vs CTVM (2.75GJ/T)

- Electric
- EF Reg (no CO2 tax)
- EF Reg (CO2 tax)
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TCO: EFR (4.0GJ/T) vs CTVM (2.75GJ/T)

Projected change in relative tariffs 10 years (mid-range prediction) 30% in relative energy costs 30% increase in C-tax
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**Application to Container Glass**

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**SHORT CAMPAIGNS?**

Why are shorter campaigns necessarily a bad thing:
A rebuild is an opportunity to:

- Modify capacity (to take advantage of market conditions)
- Up-date technology (to optimise performance)
- Eliminate prolonged ‘end-of life’ maintenance issues
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Application to Container Glass

Electric CTVM @2.75GJ/T

- Full cold-repair (7.5 years)

Electric furnace repairs typically ~25-30% of Capex, standard duration 30 days (glass to glass)
Why not apply electric melting to high volume container glass?

- LESS FLEXIBLE – OUTPUT/COMPOSITION?
- POOR STABILITY (INABILITY TO MELT REDUCED GLASSES)?
Our understanding of CTVMs have been progressed significantly in recent years through CFD modelling.

FSL modelling is now quite advanced. The fundamental principles and assumptions on which current models are based have been tuned and subsequently validated by extensive comparison against real furnaces; FSL works to improve and develop these models further. It is FSL policy on contracts any new design geometries should be validated through CFD analysis.
Furnace performance relies on maintaining a uniform and stable batch coverage: Furnace geometry and electrode positioning (and associated thermal/convection profiles), and batch charging technology has evolved to ensure a stable and uniform thickness can be maintained under a wide range of conditions.

**NOTE** for reduced glasses (amber) it we need to consider gas evolution within the batch layer and this may impact melt rate.
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Flexibility & Stability of CTVM furnaces

Batch reaction gas evolution vs temperature (laboratory analysis Celsian)

Major SO$_2$ release after liquid phase established = foam

Problem can be improved by use of high cullet ratios and low melt rates (thinner batch layer)
Why not apply electric melting to high volume container glass?

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LESS FLEXIBLE – OUTPUT/COMPOSITION?

POOR STABILITY (INABILITY TO MELT REDUCED GLASSES)?

Today’s CTVM furnaces
1. achieve operation to 50% of design load (without composition change)
2. 10-80% cullet range (with some output restrictions)
3. Stable operation with only one control parameter (kW)
4. Melting of reduced glasses can be realised with lowered melt-rates
Can we extrapolate what we know from smaller units in order to design much larger systems. How can we reduce the risks...

CFD model of 100m² design concept
The answers to these questions will change with glass type, quality requirements and production regimes. For example, the solution for container production will likely be very different from that for float glass.
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CFD model of 100m² design concept (applied to emerald green)
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The dodecahedron design can be accommodated by various electrode connection configurations; heating profile is similar to smaller furnaces.
What happens if the furnace gets much bigger and we move the electrodes further apart – do we still get similar convective profile, can we still maintain the correct thermal transfer?
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100m² furnace (250TPD)
10m electrode separation
EMERALD GREEN
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CFD modelling program includes prediction of refractory wear
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Wear index analysis can be used to design adaptive cooling systems
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Application to Container Glass

Figure 5.11 – Residence Time Distribution (RTD) of the glass.
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Application to Container Glass

One solution is to use the modular approach... many merits....
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Summary

- ENERGY EFFICIENT (already close to achieving TOC cost advantage)
- SHORTER CAMPAIGNS (opportunities to improve and upgrade)
- LIMITATIONS IN FLEXIBILITY CAN BE MANAGED
- EASE OF CONTROL (only one main control input – power)
- EASE OF MAINTENANCE (no heat recovery, APC, combustion etc.)