Flexible all-electric furnace design

Brian Naveken emphasises the importance of bottom electrodes in the design of all-electric melting systems.

Figure 1: Production proven all-electric furnace.

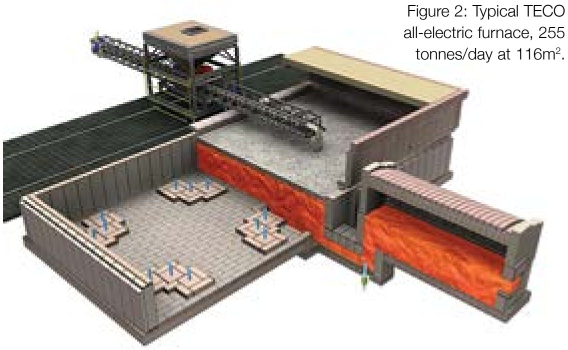


Figure 2: Typical TECO all-electric furnace, 255 tonnes/day at 116m^2.

With sustainability in the glass business, there has been a heavy emphasis on all-electric furnaces (AEF) and flexible (or hybrid) furnaces. With these concepts come changes in furnace designs and associated electric melting systems. So the question becomes, whether to design the furnace around the electrical melting system or design the electrical system around the optimal furnace design? Hopefully everyone answered the latter.

With a properly designed and optimised AEF, one would also expect to have the electrical melting system design optimised. When using through the sidewall or top entry electrodes, this is not possible. The use of bottom electrodes gives this flexibility. Bottom electrodes and consequently the phasing and transformer types are not limited by the geometry of the furnace.

This has been the TECO Group's AEF engineering design philosophy and technologies, built on the technologies of TECO, KTG Engineering and Elemelt. This is backed by production proven experience for over 60 years in top entry, side wall and bottom electrodes. A typical TECO AEF with a maximum melting capacity of 275 tonnes/day is shown in figures 1 and 2.

Optimal Joulean heat release

Joule heating is defined as the process by which the passage of an electric current through a conductor produces heat and is governed by Joules' Law and Ohm's Law, which relates power, voltage, current and resistance. When electrically melting glass, the molten glass acts as the resistor and adjusting the spacing of the electrodes, without changing power, will increase or decrease the resistance affecting the Joulean heat release into the glass. Depending on glass compositions, spacing electrodes too far apart can result in unwanted currents and voltages, as well as phase imbalances, which can have detrimental effects.

To illustrate the concept of Joulean heat release, a series of models of a square AEF were developed with varying electrode spacing and arrangements, with the power remaining constant. Model 1 is with electrodes at the sidewalls, Model 2 is with electrodes spaced in thirds and Model 3 is a standard TECO Scott-T design. The results can be seen visually in figure 3.

Figure 4 contains the Joulean heat release values, measured at the centre of the glass melt.

Figure 3 also shows that a good portion of the heating effect is done in close proximity of the electrodes and causes the heat release not to be uniform between the electrodes. This results in convection flows and is a mechanism of melting, mixing and fining of the glass. Figure 5 shows an example of this and the optimisation afforded by bottom electrode design. Table 1 contains the results of these parameters. As can be seen, electrode position significantly affects convective flows and an optimal design can only be achieved with the flexibility offered by bottom electrodes.

Safety, operation and maintenance

One of the benefits, often overlooked, is that a furnace with bottom electrodes can easily employ fenced off containment. Enabling state-of-the-art safety cannot be understated. The complete area underneath the furnace around all of the electrodes can be enclosed with redundant access point gates that contain a shut off switch if not properly accessed by ▸

Figure 4: Joulean heat release in kW/m^3.

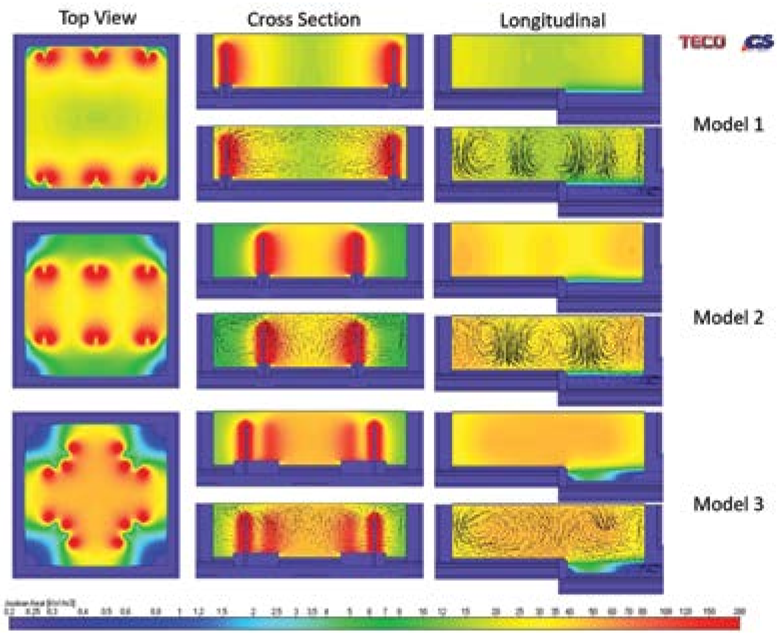


Figure 3: Joulean heat release and convective flows.

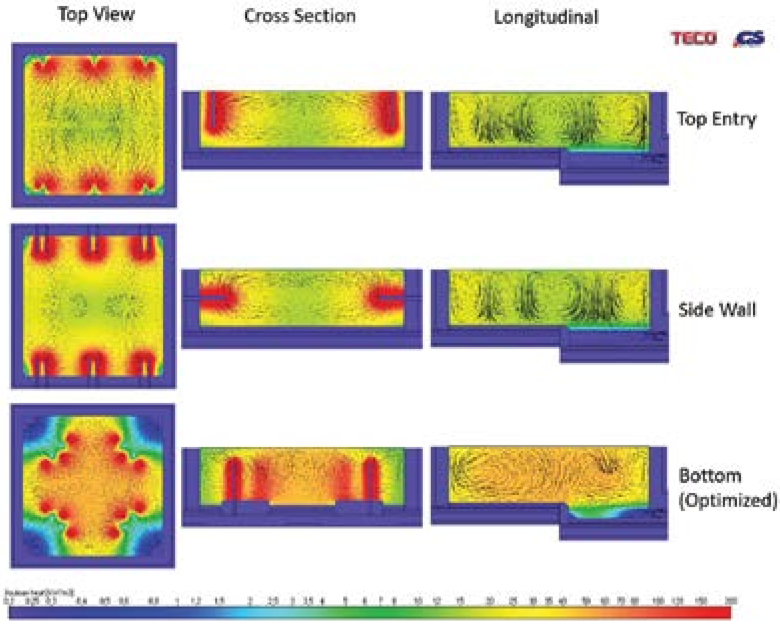


Figure 5: Optimisation of electrical melting system.

limited qualified personnel. Additionally, with all of the electrode access being underneath, it allows for accessibility and far less clutter around the remainder of the furnace.

Sidewall electrodes have to be rotated periodically to prevent them drooping under their own weight. Plus, the refractory block is a maintenance wear issue.

Top entry electrodes have additional operational issues not found with bottom electrodes, which are batch charging and accurate electrode positioning. Top entry electrodes impede batch chargers, since the common method of charging is from the top using a rotational spreader, resulting in uneven batch coverage. If molybdenum electrodes are exposed to the atmosphere, they will oxidise quickly and fall off into the glass.

Not all top entry electrodes are located along the sidewalls but can move within the glass area. For example, in the case of a delta or double delta (star) phasing arrangement, getting these triangular arrangements accurate is often tricky and non-symmetrical power results. Also, with electrode position, in relationship to sidewalls, comes design limitations of AEF lengths and widths. Too large an electrode spacing and improper phasing results in higher operating costs.

Economics

Plant utility costs are affected by inefficiencies of design. The correct and efficient application of electrical energy through the Joulean heating process is a combined product of plant power service, distribution, Joulean connectivity, electrode placement, electrode quantity and power quality factors such as phase current and voltage imbalances. Inefficient application of power to the process, by usual means cited above, can cause demand factor or transformer power factor issues, increasing electrical consumption per ton melted by up to 20%.

Misconceptions

One of the biggest arguments against bottom electrodes is interaction with metal contaminates. If this is truly an issue, would it not be seen more often in boosted fuel-fired furnaces? There are considerably more fuel-fired boosted furnaces in the world than AEFs.

Another concern is a glass leak at the electrode and electrode holder. Advances in electrode designs, such as the KTG Engineering SX holder (figure 6) and a raised electrode block have eliminated such problems.

Conclusion

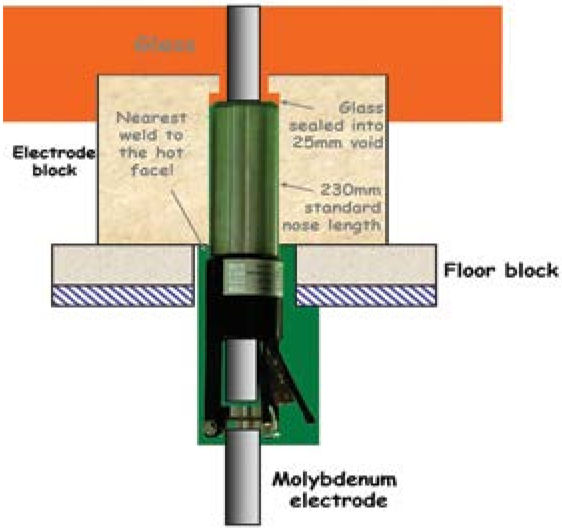
Bottom electrodes allow for flexible AEF and electrical melting system design. Electrode locations are not restricted, which allows for varying or multiple phase and transformer configurations. The bottom of the furnace access can easily be restricted for safety, allowing for ease of accessibility and maintenance.

The TECO Group's AEFs are optimally designed, first without the restrictions created by top entry and sidewall electrodes. Then, TECO designs the optimal electrical melting system to provide the lowest energy consumption, lowest emissions, extended life and high glass quality, resulting in production proven customer satisfaction. In order to optimally design an AEF complete solution, the benefits of flexible bottom electrode design is undeniable.

Model	Description	Residence Time (hrs)	Mixing Index	Melting Index	Fining Index
1	Top Entry	1.00	1.00	1.00	1.00
2	Sidewall	1.27	0.99	1.04	1.78
3	Bottom	1.64	1.80	1.16	1.82

Table 1: Normalised quality indices of modelling results.

Figure 6: KTG Engineering's production proven electrode holder.



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