Looking for energy savings - getting our arms around the big picture

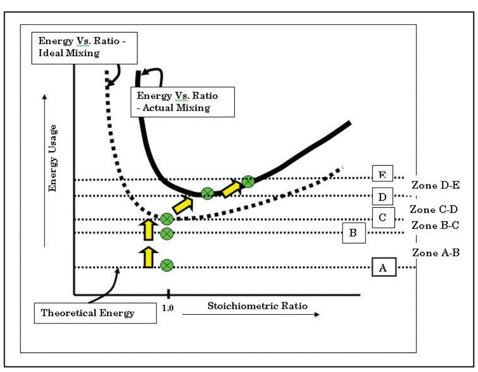
The easy savings in energy use have mostly been made by glassmakers. But as CJ Hoyle, JJ Shea and DH Davis point out, it would be folly not to at least consider taking more steps.*

Since the introduction of modern regenerative furnaces, the energy required to produce glass has steadily decreased as shown in ***Fig 1***. However, the easy fruit has been picked. Future furnace design improvements will be more difficult and manufacturers will need to concentrate on things they can influence.

Fig 2 describes energy use in a fossil-fuel melter. A significant gap exists between total energy used and the theoretical minimum to melt glass, delineated by five distinct energy levels. This chart will differ for individual furnaces depending on many factors, but the trends will remain. These levels are:

- **Level A** - minimum theoretical level, defined by glass chemistry and raw materials alone, independent of the means of delivering the heat
- **Level B** - minimum practical level for glass of Minimum Acceptable Quality (MAQ). This includes energy for refining and energy required by the 'system', eg structural losses. The total depends on heat recovery, type of fuel, etc.
- **Level C** - 'added fuel comfort factor' - energy added to improve glass quality so low swings in quality still meet MAQ.
- **Level D** - added energy made necessary by addition of excess air/O_2 to ensure complete combustion
- **Level E** - 'added air comfort factor' - additional excess air/O_2 to ensure oxidising conditions even during control swings.

Between the theoretical level A and the actual level E are four zones, each using extra energy for a different reason, ie Zones A-B, B-C, C-D, and D-E. These lost energy zones can be reduced, although in some cases the savings will not be worth the cost or the risk. Changing energy prices and limits on emissions and total energy use will change the return on these investments. Further description of these zones follows, with possibilities for reduction.



▲ Fig 2. Zones of lost energy.

Level A - Some reductions might be possible

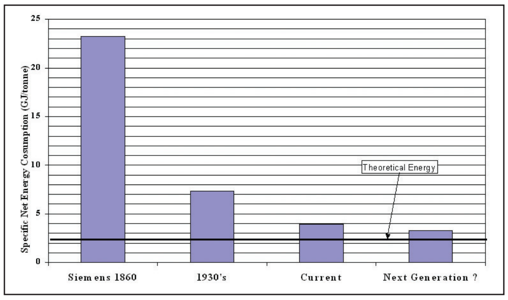
Manufactured raw materials are being evaluated that sidestep basic reactions in achieving a glassy melt. Substituting manufactured materials for cheap mined products is expensive, but the reduced energy requirement may boost tonnage or quality.

Zone A-B - Initial energy addition to theoretical - why?

Zone A-B is established during design, a function of melting/refining thermodynamics and practical limitations of the furnace/combustion system. As shown in ***Fig 1***, designers such as TECO have reduced Zone A-B with improved heat recovery and insulation, better glass flow control and firing with more luminosity and better flame coverage.

Zone A-B - What could reduce it ?

- **Better flame coverage** - Direct heat transfer from flame to glass is the predominating mechanism, due to higher temperature differences. Burner systems can improve surface coverage, extracting more heat from the flames before exhaust.
- **Oxy-fuel – hotter flames** - Heat transfer is proportional to $(\Delta T)^4$. Even luminous oxy-fuel flames will be hotter than in melters with lower-level heat recovery systems (recuperative), transferring more energy with the same Btu's. Hot spots must be avoided.



▲ Fig 1. Developments in energy efficiency: container furnace development.

- **More luminosity** - Luminous flames transfer more energy into glass, better matching the near-infrared transmission of glass. Higher carbon fuels such as oils naturally provide more luminous combustion. Natural gas systems can be designed to provide diffusion mixing for long, luminous flames. Staged combustion systems force luminosity with fuel-rich conditions. Flame luminosity is not generally compatible with higher temperatures, but artificial inducement of cracking in oxy-fuel flames may change this.
- **Improved convection where useful** - Of the three mechanisms, radiation dominates for heat transfer into glass, but convection does play a part. Each heat transfer component must be optimised.
- **Pre-heating of cullet/gas/oxygen** - Recent developments increase practicality.
- **More tonnage** - Higher pulls minimise heat losses per ton.
- **Improved refractories** - Improvements allow higher temperatures and increase efficiency.

Zone B-C - Added fuel comfort zone - why?

Having determined the minimum fuel usage required with the furnace to produce glass of suitable quality, most operators add fuel for a slight melting improvement. The goal is to improve average quality, so even at low points in quality swings the product still meets

MAQ. This 'added fuel comfort zone' helps maintain production despite perturbations from ideal operation.

Zone B-C - What could reduce it?

■ **More manpower/attention** - Operating closer to the edge requires more attention, identifying and correcting trends earlier and spending more time on maintenance.

■ **Supervisory computer control (expert) system** - Such a system will reduce inherent variations. With closer temperature control, less comfort factor is needed.

■ **Improved QC** - Strict use of a good QC program will reduce variation in glass quality. This must extend both to raw materials and melting.

■ **Melter sealing maintenance** - Inspirated cold air is expensive, even if used in combustion. Normal cracks from aging and rat holing from corrosion can let in tramp air.

■ **Better pressure control** - will minimise tramp air.

■ **Continuous firing (oxy-fuel)** - The purge period and changing preheat of a regenerator creates a continuously unsteady state. Oxy-fuel allows continuous firing without an energy penalty. With less variation, less safety margin is required.

Zone C-D - Initial offset from stoichiometry - why?

Manufacturers never operate at the balanced ratio between fuel and oxygen. To control flame length the reaction is spread over time and space, mainly by controlling the mixing rate of fuel and air/oxygen. Diffuse mixing (more laminar flow) results in significant concentrations of both reactants and waste products coexisting over much of the melter space. With only stoichiometric amounts of air/oxygen, unburned fuel would exit the furnace. Wasting fuel is more expensive than providing extra air, and some furnace zones must remain oxidising. Manufacturers choose to err on the added oxidant side, creating Zone C-D.

Zone C-D- What could reduce it?

■ **Continuous firing** - As discussed before, oxy-fuel firing makes continuous steady-state firing practical. Steady-state operation allows lower excess O_2.

■ **Compartmentalised regenerators** - Controlling air port-by-port can reduce the average excess O_2 required. However, the smaller checkerpack of current compartmentalised systems will actually result in an energy loss compared to the larger size of an open system.

■ **Optimising combustion** - Computer modelling of the melter plenum and burners can minimise the excess air/O_2 requirement.

Zone D-E - Added air comfort zone - why?

On top of added air/oxygen ensuring complete combustion (Zone C-D), even more air/oxygen beyond stoichiometry is normally maintained to create an 'added air comfort zone' for practical operation. This prevents transient reducing conditions during the 'down' swings from variations in gas composition, air/gas volumes, temperature, etc. The added air/oxygen does result in an increased energy bill.

Zone D-E - What could reduce it ?

■ **Control and maintenance issues** (As in Zone B-C)

- more manpower
- melter sealing maintenance
- pressure control

■ **More frequent excess oxygen readings** - Increased reading frequency allows faster corrective action and less variation.

■ **Continuous oxygen monitoring** - Installation of this system can give closer control. These are not maintenance-free, but can yield energy savings.

■ **Supervisory computer control (expert) system** - Less variation permits lower excess O_2 without risk.

Conclusion

Possibilities exist to reduce energy use. Some are worth the investment now, others may be in the future. An experienced furnace design firm such as TECO can be a big help in evaluating the possibilities. The big mistake would be not to think about it. Glass INTERNATIONAL

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