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Electricity in Glass Making . . . often the Low-Cost Option

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Abstract

Electricity is often considered an expensive option as a source of energy for glass melting and conditioning.
While the cost of electricity per unit of energy is significantly higher than gas or oil in most countries, the low energy consumption of well-designed electric melting and conditioning systems can actually mean a lower operating cost than gas or oil fired systems.
This paper presents and explains examples and brief case histories of all-electric furnaces, electric boosting systems and electric forehearth heating systems that show significant and sometimes huge savings in operating energy costs, bringing the environmental, glass quality and control benefits of electric heating while firmly challenging the perception that it is the expensive option.

Introduction

The theme of the 2015 ASEAN Glass Conference is *"Glass Technology and Innovation: Driving Growth in Traditional and New Markets"*. Within this context this paper looks at one of the most fundamental aspects of the making of glass and promotion of its use: the energy used in its manufacture.

Glassmaking is an energy intensive process and it follows that minimising energy usage, and above all minimising energy cost, are key priorities for the glass manufacturer. In particular this paper considers the role of electrical energy in glass melting and conditioning, challenging the perception that electricity is an expensive choice and showing that electricity can often be the low-cost option.

Energy Costs

Energy and energy usage are measured in a sometimes confusing array of units, some of the most widely used in industrial applications being based on calories, joules, BTU's, watt-hours and their derivatives. For ease of comparison it is necessary to use just one of these and as the focus of this paper is on electricity, most energy and energy consumption figures are expressed in kilowatt-hours.

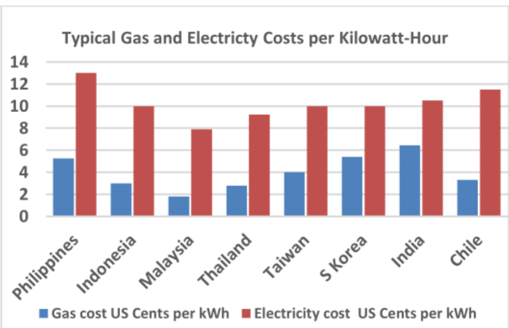

Figure 1: Some typical gas and electricity costs. US Cents per kWh.

In terms of cost per unit of energy, electricity <u>is</u> usually significantly more expensive than gas and oil. Figure 1. shows some typical gas and electricity costs in a selection of countries in and around the ASEAN region, and a few further afield, all presented as the cost in US cents of 1 kilowatt-hour of gas and electrical energy.

Very broadly, except where distorted by availability, oil costs per unit of energy are comparable to gas and are not included here.

In all these cases electricity is more expensive per unit of energy than gas. In some of these countries electrical energy is less than twice the cost of gas; in others it is more than 4 times the cost. The average for the ASEAN countries shown here is a fraction over 3 times.

Electricity in Glass Manufacture

However, the cost of energy for a process depends not only on its unit cost, but just as importantly on how much energy the process uses. It is in this aspect that electricity in glass making differs so greatly from gas or oil.

There are three main areas of electricity use in glass melting and conditioning. These are all-electric melting, electric boosting in fuel or oxy-fuel fired furnaces, and electrically heated distributors and forehearths.

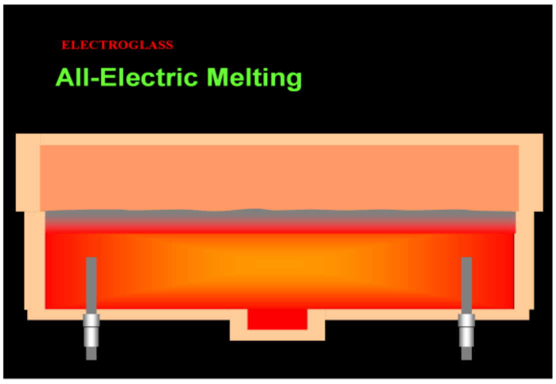

Figure 2: The Electric Melting Concept.

All-Electric Melting

The energy efficiency advantages of all-electric melting are easily understood. In a well-designed cold-top electric furnace the melting energy is applied directly into the glass by means of immersed electrodes as illustrated in Figure 2. and the entire surface of the glass is covered by a layer of batch, the batch blanket. A typical electric furnace batch blanket is shown in Figure 3.

Figure 3.

Batch has extremely good thermal insulating properties, so the heat losses from glass to superstructure are very low, and typical superstructure temperatures in a furnace such as this will be little more than 100°C.

In contrast the superstructure temperature in any fuel-fired furnace must by definition be not just high, but higher than the required glass temperature in order to transfer the melting energy to the glass. The inevitable results are high heat losses both through the crown and breastwalls (as illustrated in Figure 4), and in the exhaust gases.

The very best of fuel-fired furnaces and heat recovery systems cannot compete with cold-top electric melting in terms of energy efficiency. Energy efficiency in this context means the proportion of the total energy used that actually goes into converting cold batch into fully molten and refined glass, the rest being lost to the environment in structural heat losses and combustion gases.

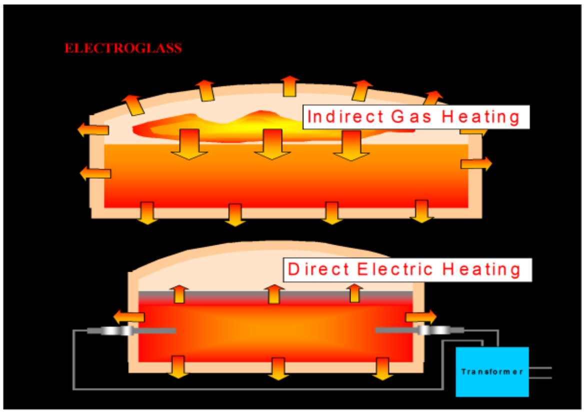

Figure 4.

A typical fuel-fired container glass furnace of say 250 tonnes per day capacity might have a thermal efficiency of at best about 45%. That is to say 45% of the total energy input goes into the glass and 55% is lost.

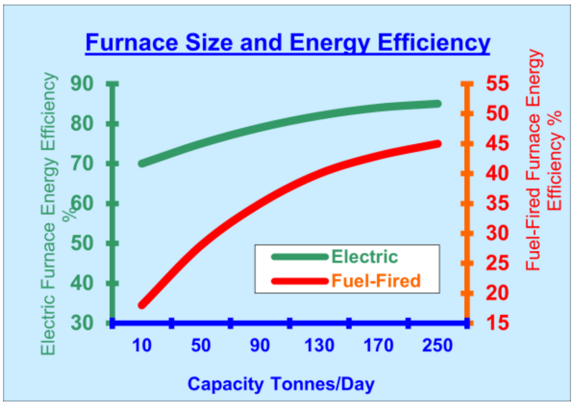

Figure 5.

In contrast, a well-designed all-electric furnace of similar 250 tonnes/day capacity, which is at the top end of electric furnace experience, has a thermal efficiency of close to 85%, with just 15% of the total energy input being lost. These figures vary somewhat with cullet percentage in the batch mix, as re-melting cullet uses approximately 30% less energy than melting pure batch.

Figure 5. shows the typical range of thermal efficiencies of fuel and electric melting furnaces of up to about 250 tonnes/day capacity.

As we have already stated, energy consumption is not the same as energy cost. For furnaces in the upper part of the size range shown in Figure 5., say over 100 tonnes per day, the higher unit cost of electrical energy in most areas means that despite the much higher energy efficiency, on grounds of energy cost alone, electric melting is unlikely to be competitive.

However, at the lower end of this size scale the picture becomes very different. As furnace size decreases, the energy efficiency of a fuel-fired furnace drops dramatically, again as shown in Figure 5. A 30 or 40 tonnes per day fuel-fired furnace may have a thermal efficiency of just 20-25%, and melting costs per tonne of glass rise sharply as a result.

In contrast, a 30 tonnes per day all-electric furnace can still have a thermal efficiency as high as 75%. This is not just a theoretical figure; it is the actual operating efficiency of a number of 30 tonnes per day Electroglass electric furnaces, with typically 30% cullet, producing tableware quality glass.

Based on these efficiency figures, Figure 6. shows the approximate ratio of energy consumptions of fuel and electric furnaces according to furnace size.

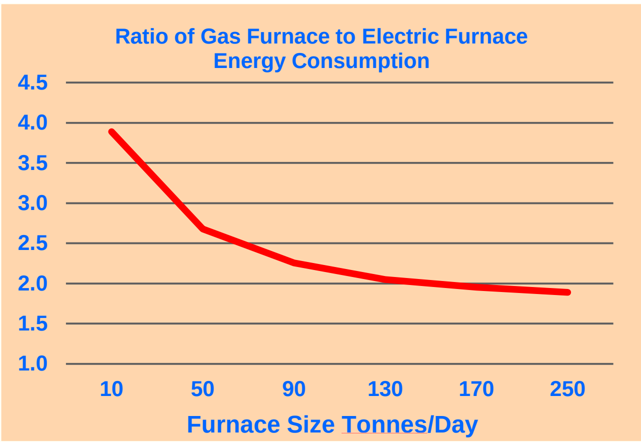

Figure 6.

As stated above, the ratio of electricity cost to gas cost varies considerably from country to country, but if we take the average figure for the ASEAN countries shown in Figure 1, where the cost of electrical energy is approximately 3 times that of gas, that coincides with the ratio of energy used in gas and electric furnaces of about 40 tonnes per day capacity. In other words, with that ratio of electricity and gas costs, for a furnace of less than about 40 tonnes per day capacity, then purely on the basis of energy cost an electric furnace is the lower cost option.

Electric Boosting

A more widespread use of electricity in glass making is electric boosting in fuel-fired furnaces. Although the glass quality and output flexibility benefits of electric boosting are well recognised in most sectors of the industry, from tableware to containers, fibreglass and float glass, electric boosting has also often been viewed as a necessary but expensive alternative to building a bigger furnace.

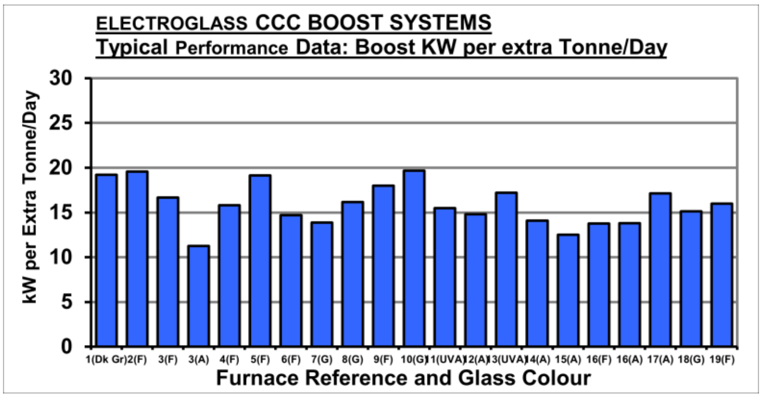

Figure 7.

A well-designed electric boost system can melt 1 additional tonne per day of glass with a continuous power input of just 20 kilowatts and often less. Figure 7. shows the operating boost energy consumptions in a selection of 20 or so furnaces large and small. Each of these shows an actual boost energy consumption of 20kW or less per additional tonne per day.

20kW per additional tonne per day equates to 480 kilowatt-hours of energy per tonne of glass produced. That is equivalent to just 413 kilo-calories per kilogram of glass. If electrical energy is 3 times the cost of gas energy (the average figure for the ASEAN countries in Figure 1), then 413 kilo-calories of electrical energy costs the same as about 1240 kilo-calories of gas energy. In other words if a furnace without electric boost is operating at more than about 1240 kilo-calories of gas energy per kilogram of glass produced then the glass produced by the boost is costing less than the glass produced by gas. As a gas-fired container glass furnace of say 150 tonnes/day capacity might typically require about 1500 kilo-calories of gas energy per kilogram of glass, electricity once again becomes a low cost option. In a typical float glass furnace the unboosted fuel energy consumption per kilogram of glass can be significantly more and electric boost becomes even more cost effective.

A 150 tonnes per day fuel-fired container glass furnace with a 50 tonnes per day electric boost system can be significantly more economic than a 200 tonnes per day fuel furnace without boost. It is also far more flexible, allowing total pull to vary between 150 and 200 tonnes per day without reducing melting efficiency. A well-designed 100 tonnes per day electric boosting system in a 600 tonnes per day float glass furnace can not only deliver lower melting energy costs than a 700 tonnes per day furnace without boost; it can greatly assist tinted glass production in terms of both quality and in maintaining furnace output at a level that matches the downstream line capacity.

All-Electric Distributors and Forehearths

The final major application of electricity in glass making to be considered here is in the distributor and forehearths.

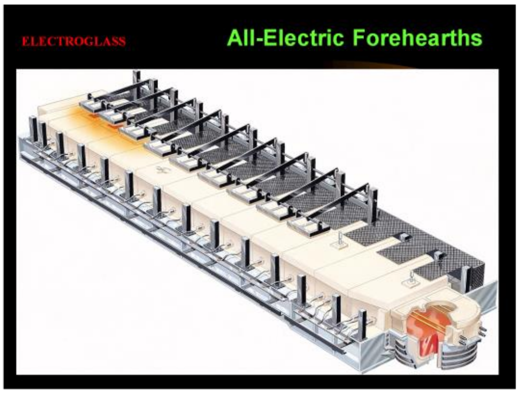

Figure 8.

Electrically heated distributor channels and forehearths, such as illustrated in Figure 8, have been in use in certain sectors of the glass industry for many decades. The author was involved in their design and installation more than 40 years ago, and in the years of development since then they have been installed in large numbers particularly in volatile glass applications, - for lead crystal, fluoride opal and borosilicate glasses, as well as soda-lime glasses.

However except in regions where gas is not or has not been readily available, such as large areas of China and Africa, the overwhelming majority of the distributor channels and forehearths used in the container glass and other soda-lime glass sectors have been gas fired.

We have already seen that despite electricity being almost always more expensive per unit of energy, the energy efficiency of electric heating technologies can often make them the economical choice. This has proved especially so in the case of distributors and forehearths.

The best way of illustrating this is again by actual case histories, and in particular ones where there are now several years of proven operating experience. After a number of years of operating two conventional European-designed gas forehearths on amber and green container glasses, Hite Industries of South Korea took up our proposal to convert them to all-electric heating. This was carried out at a scheduled cold repair, maintaining the previous channel lengths, 22 feet in each case, and channel widths, 36-inch and 48-inch.

Gas consumption for the two forehearths prior to redesign was reported by Hite Industries to be approximately 1050 m3 per day, at a cost of 0.464 US$ per m3. This gives a unit cost of gas energy of 4.43 US Cents per kWh, and a daily gas cost of US$ 487.

Figure 9: Electroglass All-Electric Forehearths

Figure 9. shows the two forehearths after their conversion to all-electric heating. On re-commissioning, the electrical energy consumption of the re-designed forehearths quickly stabilised at 1535 kilowatt-hours per day for both, at a cost of 0.051 US$ per kilowatt-hour or 5.1 US Cents per kilowatt-hour, and a daily electricity cost of US$ 78.3, an extremely impressive 84% energy cost saving.

Those electric forehearth redesigns were six years ago. Energy costs have risen since, especially electricity costs in Korea. Applying today's energy costs to these consumption figures, their gas forehearth operating cost would be US$ 600 per day, compared with US$ 154 for the electric forehearths, still a highly impressive 75% energy cost saving, totalling about US$ 163,000 per year, just on two forehearths.

Breaking this electrical energy consumption down, the 48-inch forehearth operates under steady state conditions at 40 to 45 kilowatts of total power input, and the 36-inch at about 25 kilowatts, making close to the total of about 1535 kilowatt-hours per day stated above. Some sample individual operating readings are shown in Figure 10.

FOREHEARTH 1:2 36" WIDE			FOREHEARTH 1:1 48" WIDE		
Date	12/21	12/22	Date	12/21	12/22
PULL(T/D)	57.2	56.8	PULL(T/D)	73.2	71.8
GLASS COLOUR	E.G	E.G	GLASS COLOUR	E.G	E.G
power(KVA)			KVA		
Rear	4.3	4.5	Rear Left	10.4	8.7
Middle	9.4	10.3	Rear Right	6.4	3.6
Conditioning	2.2	2.4	Middle Left	10.7	10.4
Electrodes Left	3.8	3.8	Middle Right	11.3	11.6
Electrodes Right	3.9	3.9	Conditioning	1.9	2.3
TOTAL POWER	23.6	24.9	Electrodes Left	3.6	3.1
			Electrodes Right	3.7	3.2
			TOTAL POWER	48	42.9

Figure 10.

A well designed electric forehearth has the same life expectancy as a good gas forehearth. Minimal maintenance and spares are required. Out of 60 heating elements in the above 2 forehearths, just 5 have "failed" in over six years, 3 of which were believed accidentally broken during commissioning. None have actually needed replacement as operation has been un-affected. From the same long operating experience, temperature response time has been declared to be as good as or better than the gas predecessors.

Distributor channels can also greatly benefit from gas to electric conversion. A few years ago an existing all-electric furnace in East Asia was replaced with a 60 tonnes/day Electroglass furnace, for flint soda-lime perfume bottle production. At the same time the very long existing gas-fired distributor channel was converted to Electroglass electric design. Part of this is seen in Figure 11.

Previous gas consumption for the distributor was given as 3400 m3 per day, at a cost of $1,836 per day. Following conversion to electric heating, energy consumption was approximately 242

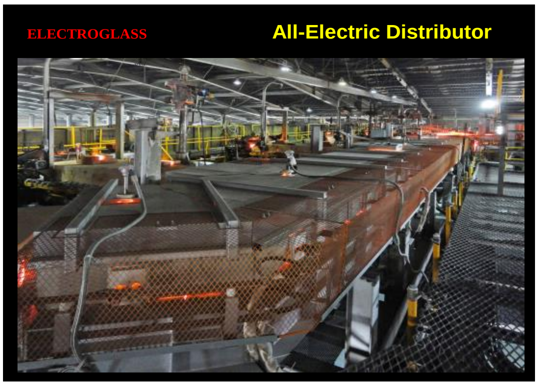

Figure 11.

kilowatts or 5808 kilowatt-hours per day, at a cost of US$ 407 per day, once again a remarkable 78% energy cost saving. Updating these figures with today's energy costs, the previous gas distributor operating cost would be US$ 1,428 per day, compared with US$ 580 for the electric distributor, a very worthwhile operating cost saving of 60%, equivalent to US$ 310,000 per year on one long distributor channel.

Other such gas to electric conversions have followed, with the equipment for the latest three being shipped just before publication of this paper.

Summary

There are many glass melting applications for which electricity is not the most cost effective principal energy source, - for instance as the main source of energy for float glass and medium to large container glass furnaces.

All-Electric Melters are, however, usually the lower cost option for smaller melting capacities. This is in addition to the glass quality and environmental benefits of cold-top electric melting for high quality and/or volatile glasses.

Electric Boosting in fuel-fired furnaces, provided the right technology is selected, is largely economic as well as providing flexibility and glass quality benefits, reducing both total energy consumption and energy cost per tonne of glass produced.

Finally, All-Electric Distributors and Forehearths have proved and are continuing to prove highly effective in greatly reducing operating energy costs in a high proportion of cases, with equal or better lifetime, temperature response and ease of operation compared with conventional gas designs.

Energy is the largest single variable cost in glass melting and conditioning. It is a priority of every glass maker to minimise that cost to survive, to prosper and to promote the environmentally friendly use of glass. In this, Electric Melting and Conditioning Systems have a very important part to play.

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The Author

Richard Stormont *is Chairman and Managing Director of Electroglass Ltd, UK-based specialists in electric glass melting and conditioning systems, and has over 30 years' experience in this field.*