New generation end-port furnaces

Part 2

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This second article describes the energy consumptions and emissions of the end-port furnace installed by TECO Europe Ltd in Knottingley in the UK. The results show that a well-designed furnace is capable of both delivering energy consumptions which are comparable with the best in the industry and keeping emissions down to the levels stipulated in the UK.

In the first part of the paper, which was published in International Glass Review in 1996, a general description of the end-port furnaces installed by TECO Europe Ltd at Gregg & Co (Knottingley) Ltd and Stolzle Flaconnage Ltd, both in Knottingley, led on to a few brief comments about the level of emissions to atmosphere from those furnaces. A more detailed account was given in a presentation by the author to the 1996 Glass Problems Conference in Columbus and acknowledgement is due to the American Ceramic Society for permission to include the data then given in this paper.

The Stolzle furnace has provided glass of excellent quality to suit its designated market

Both of the new furnaces were subject to the UK's recently introduced Environmental Protection Act, which laid down guidelines for the emissions of pollutants, and made provision for retrofitting exhaust gas treatment plant, if operating experience indicated that this was required to comply with the regulations. The permitted limits are shown in Table 1 which also appeared in the first part of this paper.

Table 1: UK Limits for Emissions from Soda-Lime Container Furnaces	
Particulate Matter	100mg/Nm^3
Sulphur Oxides	750 mg/Nm^3 with gas firing, expressed as SO_2 1750 mg/Nm^3 with oil firing
Nitrogen Oxides	2700 mg/Nm^3 expressed as NO_2
Chlorides	50 mg/Nm^3 expressed as HCL
Fluorides	5mg/Nm^3 expressed as HF

All concentrations are to be expressed at standard conditions of 273K and 101.3kPa without correction for water vapour content and normalized to 8% oxygen content measured dry.

The local authority Environmental Health Office adopted the reasonable view that the furnaces should be allowed to begin operation, on condition that treatment plant would be installed if necessary. As will be shown, the level of emissions turned out to be well within the regulations, and no retrofitting has been called for. Regular monitoring of the furnaces has confirmed that the performance is consistent.

The data on which this paper is based were taken from normal production records, with the permission of the management of Greggs, and indicated a hitherto unsuspected ability to operate within the statutory limits.

Operational Experience

Both furnaces were started up on the anticipated dates and soon settled down to normal production.

In the case of the Gregg's furnace, the pull has been higher than originally specified, occasionally reaching 170 tonnes/day or more, with the normal level in the region of 135 tonnes/day. Energy consumption is comfortably below the originally requested level, see Figs 1 and 2. Frequent changes in production are normal, and so the furnace has to cope with a wide range of conditions, and is seldom in a stable long-term operating environment. Nevertheless, glass quality is good and the first stage of modernisation of this factory can be judged to have been successful. Figure 1 shows the weekly consumption of fuel, plotted against the average daily output of molten glass in each week over a period of five months. The close correlation is evident and gives a good indication of operational experience.

Figure 2 shows individual daily performances, in terms of net therms per tonne against daily pull, for three typical weeks in January, February and March of 1995. The scatter reflects operating conditions in a short-run regime. The regression line is very close to that derived from the weekly consumption. It is interesting to speculate what results might have been achieved with steady operation, but that would be abnormal for this furnace.

The Stolzle furnace has also been providing glass of excellent quality to suit its designated market. Output is also above the specified level, typically reaching 90 tonnes/day, at which level the energy consumption is slightly lower that that of the Gregg's furnace at the same pull, as a result of taller checker chambers.

Results of the measurements of emissions were gratifyingly lower than predicted, as far as particulate matter and

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nitrogen oxides were concerned. Particulate loading in the exhaust has consistently given a corrected figure in the region of 80-110 mg/Nm^3, while NO_x has been found to be in the range 600-1000 mg/Nm^3. On the other hand, sulphur oxides have been close to the limit of 750 mg/Nm^3. Results from the stack monitor are shown in Figures 3 and 4. These show respectively the particulate and nitrogen oxides results at 6-hourly intervals over a five-day period, taken from the print-out of the recorder chart.

The dog-house design and batch charging method contribute to the very low particulate emissions. A principal source of particulate is evaporation of sodium vapor from the surface of the melt, coupled with release of sulphur oxides by reaction of sulphate with the sand. Sodium sulphate will also evaporate with partial decomposition at melting temperatures. Some of the sulphur oxide will recombine with the sodium to reform sulphate which then condenses to particulate matter. In fact, confirmation of this mechanism is given by the presence of locally recirculated sodium sulphate pellets within the ejector stack. This phenomenon has caused the cross-stack measurement of particulate to be relocated to a position before the ejector.

It turns out that the production of sulphate pellets is a common but unmentioned occurrence with ejector stacks. The volume of air used by the ejector fans means that the final exhaust has relatively high levels of oxygen, in the region of 13-14%. The results given by the stack monitor are illustrated in Figure 5. The corrected and reported concentrations at 8% oxygen content are therefore higher than the actual levels in the stack.

The dog-house design and batch charging method contribute to the very low particulate emissions

The works took regular measurements at the top of the regenerator with a portable analyzer, as part of its regular testing of furnace conditions, and the results of these were studies in some detail. The instrument used gives values for oxygen, carbon monoxide, nitric oxide, nitrogen dioxide, sulphur dioxide and excess air, correcting to 8% oxygen. During the initial operating period, the operators explored the limits of working with various amounts of excess air. There are consequently some interesting data.

Results

The graph of nitric oxide (NO) concentration against oxygen content in Figure 6 indicates a straight line relationship, with about 500 mg/Nm^3 at 0% oxygen and 2000 mg/Nm^3 at 8% oxygen. Typical levels have been confirmed to be 800 to 1000 mg/Nm^3 in normal operation with both furnaces. The use of sealed-in underport burners is thought to be the reason for this low level of nitrogen oxides, with the possible entrainment of furnace combustion gases into the gas jet, leading to delayed combustion. The long flames obtained with end-port furnaces also contribute to the effect and minimise the penalty of less-than-ideal combustion geometry.

Nitrogen dioxide (NO_2) is found to be 2-3% of the

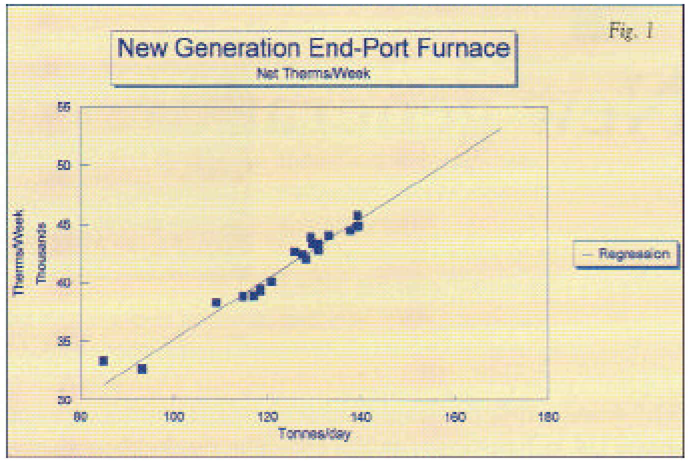

Fig. 1

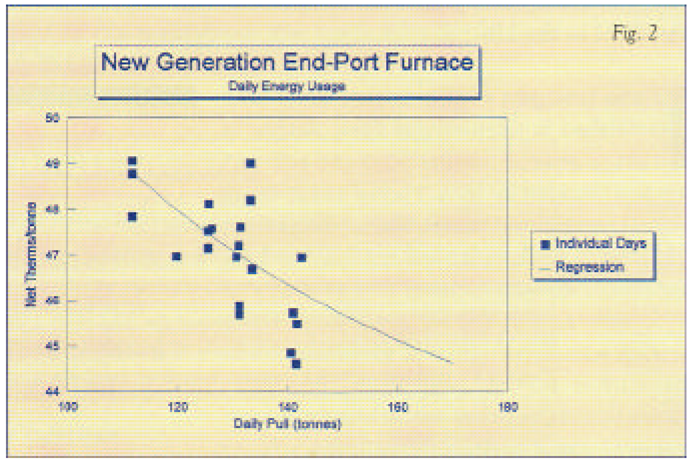

Fig. 2

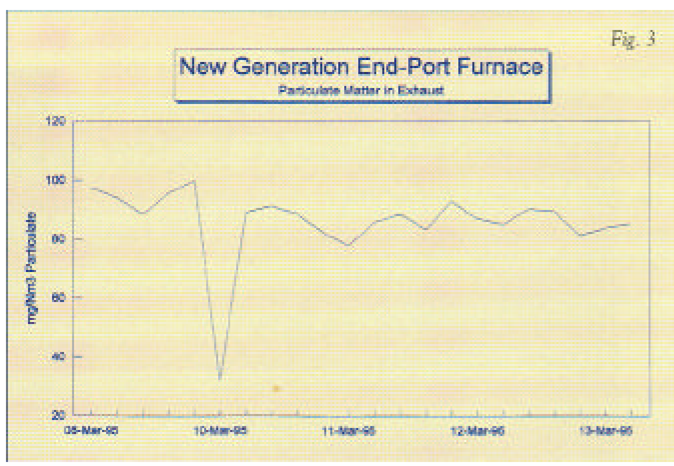

Fig. 3

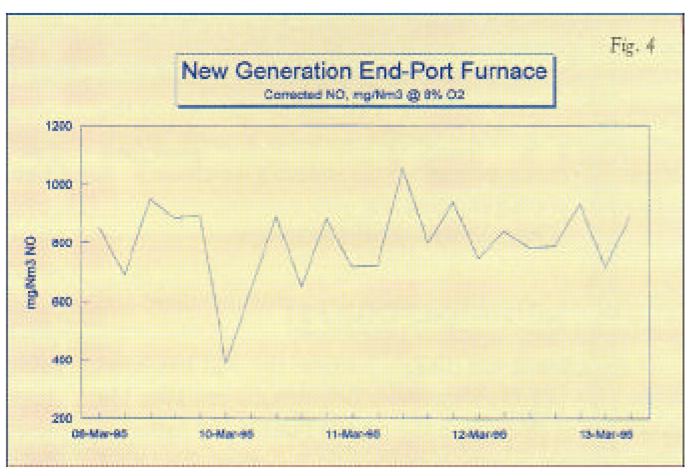

Fig. 4

total nitrogen oxides at the regenerator top. When the data is plotted logarithmically, a straight line is found with a slope of about 2, which would be predicted by the equilibrium between NO_2, NO and O_2. The intercept is about 0.3 mg/Nm^3 of NO_2 at 1% oxygen. This is illustrated in Figure 7 which

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also shows the carbon monoxide levels.

Carbon monoxide (CO) concentration falls as the oxygen content rises, as is to be expected. Below 1% oxygen quite high levels are observed. The apparent slope of the line in a logarithmic plot is about -3.5. This indicates that using limitation of excess oxygen to minimise nitrogen oxide production has a downside but is a valid approach to the problem.

Sulphur dioxide concentration varies but is a reflection of the batch composition, use of ecology cullet and the content of sulphur in the fuel used. The average figure with gas firing, with no contribution from the fuel, is 746 mg/Nm^3. With high sulphur heavy fuel oil, valves up to almost 4000 mg/Nm^3 were seen. The batch content of saltcake has to be adjusted to compensate for the reducing agents in the ecology cullet, which cause the sulphate to decompose and so reduce its refining action, leading to higher than desired seed levels if no action if taken. It really is hard to be kind to the environment. Figure 8 shows the results obtained at the regenerator top and indicates no correlation with oxygen level, as would be expected.

To allow comparison with other regulatory regimes, calculations have been made of the effective emissions at a typical level of output, expressed in a number of ways in which limits have been set, shown in Table 2. It can be seen that the results offer comfort to furnace operators under various environmental regimes. Furthermore, even if limits are tightened, the level from which emissions have to be reduced will be close to those limits.

Conclusions

A well-designed, no-frills furnace is capable of delivering energy consumptions which are comparable with the best in the industry for a similar unit, while keeping emissions down to the levels stipulated in the United Kingdom.

This is done without recourse to weir walls, deep refiners, bubblers, electric boost or oxygen enrichment, and with minimal changes to the batch formulation.

The key features of the furnace are adequate insulation, good sealing to minimise air in-leakage, excellent heat recovery from efficient regenerators, a well-designed doghouse and charging system, a sunken throat and, not least important, a precise and accurate control system.

Low levels of nitrogen oxides can be achieved by running at low excess air levels, and even lower under sub stoichiometric conditions but at the cost of producing carbon monoxide.

Although sodium sulphate pellets are produced in the

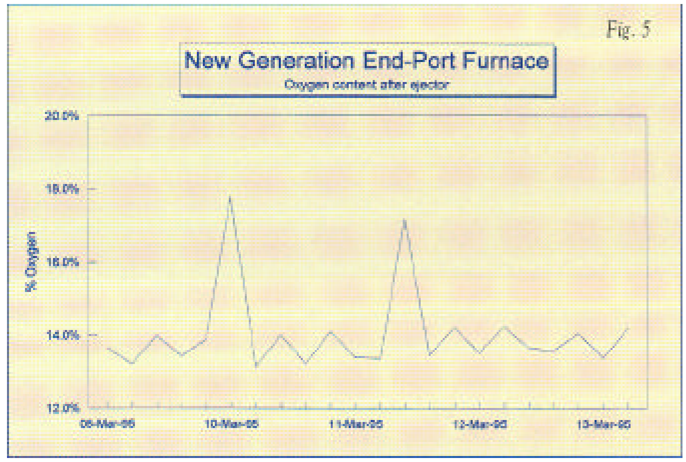

Fig. 5

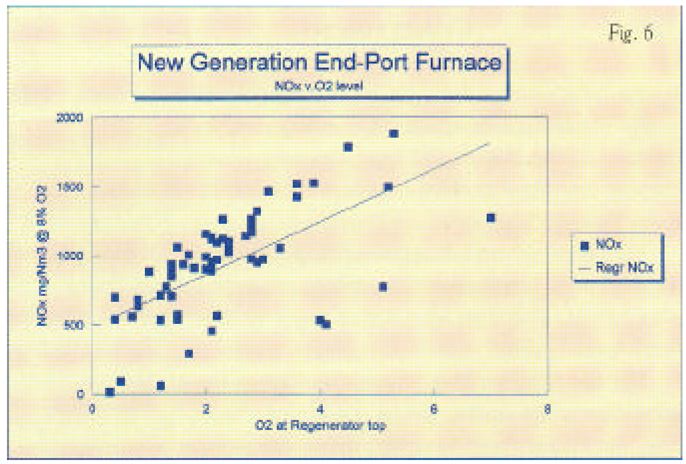

Fig. 6

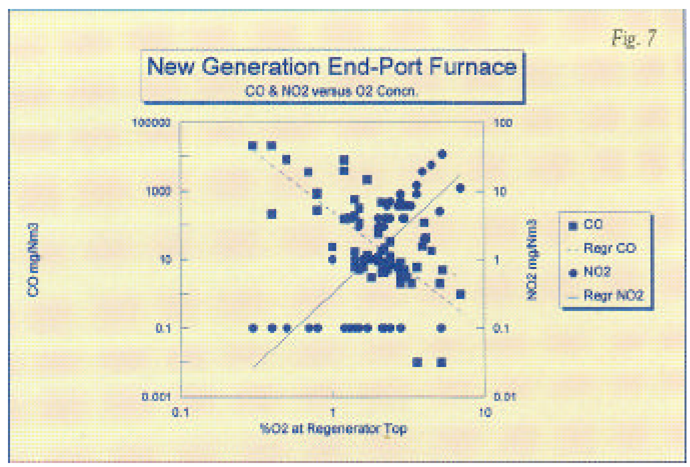

Fig. 7

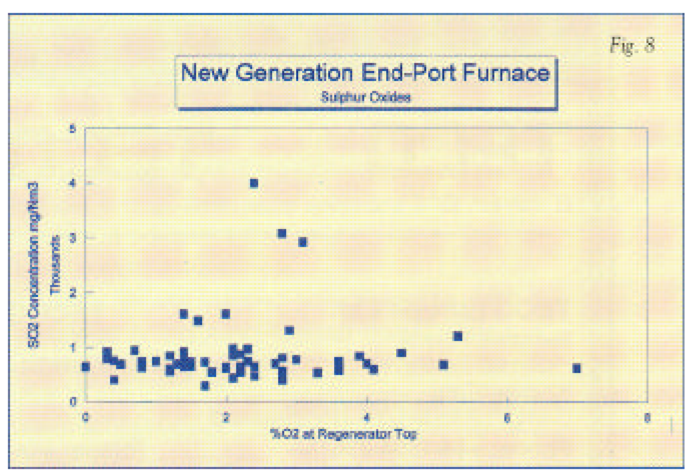

Fig. 8

ejector stack in a transient form, levels of particulate emissions remain at a relatively low level. If lower levels are specified by the regulations, the volume collected by a capture device will be minimal.

Table 2: Typical Emissions at 130 Tonnes/Day, assuming 1180 Kcal/kg or 47 Net Therms/Tonne

Pollutant	mg/Nm^3	kg/h	lb/h	USton/yr	lb/USton
Sulphur Oxides	750	11.5	25.3	110.7	4.2
Particulates	85	1.3	2.9	12.5	0.5
Nitrogen Oxides	850	13	28.6	125.4	4.8

Biography

Terry Harper is Sales & Marketing Manager of TECO Europe Ltd. Prior to joining them in 1990 he worked for 22 years for Woodall Duckham Ltd And its successors in the Babcock International organization, having previously been with turner brothers Asbestos Co Ltd BGIRA. He is a Fellow of the Society of Glass Technology and is currently Recorder of the Board of Fellows. He is also a member of British Glass Environment and Energy

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