Optimelt set to reduce emissions at Libbey’s oxy-fuel fired furnace

J. de Diego*, H. Kobayashi**, S. Laux, and M. van Valburg and G. Wijbenga*** discuss the implementation of Praxair’s Optimelt system at Libbey’s Leerdam plant in The Netherlands. The system was originally installed at Pavisa’s container glass site in Mexico with successful results, as published in a paper in Glass International May 2015 by U. Iyoha.

Libbey Holland (Royal Leerdam) has been at the forefront of new technology implementation to ensure competitive and sustainable production, based on the Vereniging van Nederlandse Glasfabrikanten (Dutch Glass Maker Association) roadmap ‘Routekaart 2030’.

By cooperating with technology providers, Libbey has pursued its goal of increased glass furnace efficiency and reduced emissions.

Because of the strict emissions legislations on NOx, SOx, and particulates44, there is a need for CO₂ emissions reduction to meet the Paris Climate Accord goal for a carbon neutral environment by 2050.

Due to the unpredictable outcome of the ETS system development period after 2020, a pro-active approach is required. The conversion of air-fuel furnaces to oxy-fuel combustion is generally known to improve furnace energy efficiency and reduce natural gas consumption.

Recovering waste energy from oxy-fuel flue gas has the potential to further improve energy efficiency and to reduce the operating costs of oxy-fuel glass furnaces.

Praxair’s Optimelt thermochemical regenerator (TCR) heat recovery system provides a compelling solution to maximise the heat recovery from oxy-fuel fired glass furnaces, to improve energy efficiency of the furnaces, and to minimise furnace emissions.

Its Optimelt TCR system is similar in the cyclic operation to conventional air-heating regenerators, but unique in its design to combine the conventional preheating step with a thermochemical reforming process without using a catalyst.

An industrial scale Optimelt system has been installed at the Libbey Royal Leerdam plant in The Netherlands to reduce energy costs in the glass melting process and to address future stricter environmental reduction requirements. The project is partly funded by the European Union under a Life grant.

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**Optimelt recovery process**

The heart of the technology is to recover waste heat by the well known endothermic reforming reactions of methane with steam and carbon dioxide in regenerators, Fig. 1. Hot flue gas from the oxy-fuel furnace is directed to a regenerator chamber to heat and store heat in the checker pack and is cooled to about 650°C before exiting the regenerator.

A portion of the cooled flue gas is then recycled, mixed with natural gas and introduced at the bottom of a second regenerator. This mixture absorbs energy stored in the refractory checkers.

When the gas mixture is heated above a certain temperature, various endothermic chemical reactions occur at atmospheric pressure to form 'syngas' containing hydrogen, carbon monoxide, soot and other hydrocarbons without the need of a catalyst. The reformed gas or syngas leaves the regenerator at the top and is combusted with oxygen in the furnace.

The ability to upgrade the energy content of the natural gas fuel into higher energy-content hot syngas results in fuel savings of about 20% to 30% compared to conventional oxy-fuel and regenerative air-fuel furnaces, respectively.

**TCR-Syngas burner design**

The oxy-syngas burner produces a bright and luminous flame due to a high concentration of soot in the syngas.

The burner is designed to provide an adjustable temperature profile in the combustion space by using separate injection of oxygen jets. By using the deeply staged combustion concept, NOx emissions are reduced and a long flame can be obtained to avoid hot spots over the glass/batch surface near the burner.

The direction and the velocity of each oxygen jet are carefully designed to avoid flame impingement in the batch area and to keep a low gas velocity over glass melt to minimise batch carry over and alkali vapour volatilisation. Fig. 2 shows a picture of the syngas flame in the 50tpd furnace at Pavisas, Mexico.

**Reduced energy and emissions at Leerdam**

The project timeline for the industrial scale Optimelt system being installed at Libbey Royal Leerdam is in Fig. 3.

The new oxy-fuel furnace is designed to operate either as the standard oxy-fuel fired furnace or as the oxy-syngas fired furnace with the Optimelt TCR.

The furnace will start as the oxy-fuel fired furnace in mid-2017 and this furnace operating condition will be optimised first. The TCR operation will start about three months later and the performance evaluated over one year.

**Natural gas savings and CO₂ reduction**

The Optimelt system fuel savings are, in general, about 20% relative to the oxy-fuel baseline without heat recovery, but vary +/- 3% depending on the glass type, cullet ratio, furnace type, furnace age and furnace size.

At Leerdam, the projected energy reduction and associated CO₂ emissions reductions are about 45-60% compared to the existing recuperative air combustion furnaces. Compared with air fired regenerative furnaces about 28% fuel savings are expected for furnaces less than 150 tpd and about 30% for furnaces greater than 300 tpd at the mid furnace campaign.

**NOx Emissions**

NOx emissions depend on burner type selection (staged versus unstaged), air leakage control (sidewall cooling, batch charger openings, peephole openings and furnace maintenance), fuel and/or oxidant nitrogen content and niter used in the batch.

Projected NOx reductions will be in the range of 25 - 35% lower than currently and well below the target value of 0.9kg/ton.

The Optimelt TCR burner system uses the deeply staged combustion process and has demonstrated low NOx emissions at Pavisas’ 50 TPD furnace in Mexico, even with high N₂ concentration in the furnace atmosphere.

Fig. 4 shows NOx emissions from oxy-fuel fired container glass furnaces. Green data points show measured NOx emissions at different N₂ partial pressures(*) in the furnace and the light green band shows the projected NOx emissions as a function of % N₂ concentration in the furnace at sea level.

(Note: Due to the high elevation of Mexico City the atmospheric pressure is only about 0.76 atmosphere. The N₂ concentration of 30% wet corresponds to 23kPa at Pavisas.)

Dutch natural gas contains a high nitrogen concentration of about 13% and the projected furnace N₂ concentration ranges from 10 to 16% wet depending on the amount of air leakage into the furnace at Leerdam.

In spite of the relatively high N₂ concentration in the furnace NOx emissions below 0.6 kg/t are projected.

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Furnaces

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*0.65, 0.88 lb/ft³ in separate stack measurements

Table 1. $SO_3$ emissions from container furnaces.

Particulates emissions
Alkali vapour volatilisation is the main cause for particulates emissions and silica crown corrosion.

Typically 80 to 90% of particulates emissions are sub-micron particles of Na$_2$SO$_4$. Furnace and burner designs are known to make large differences on the alkali volatilisation rate and particulates emissions.

Preventing high local glass surface temperature and high gas velocity over the glassmelt by proper furnace and burner designs are key factors controlling alkali vapour volatilisation and particulate emissions.

In early furnace conversion projects from air fired regenerative furnaces (red data points) to oxy-fuel furnaces (yellow data points) about a 30% reduction in particulates emissions was measured.

Oxy-fuel furnace and burner designs have been improved since then with taller crown height and low gas velocity as $SO_x$ emissions. Sulphur retention in the glassmelt depends on glass redox (i.e. glass colour) and the amount of sulphate required for good fining reactions depends on the operation of the glass furnace.

Thus, many factors influence the ultimate emission of gaseous SO$x$.

In oxy-fuel fired furnaces the higher water vapour pressure in the furnace atmosphere increases the water dissolution in the glassmelt, which in turn lowers the sulphate dissociation temperature and leads to a start of the fining reactions at a lower glassmelt temperature.

Since dissolved water acts as a fining gas and enhances the fining reactions of sulphate in the glassmelt, it allows a reduction of the amount of other fining gases (mostly $SO_2$ and $O_2$) required for fining. Thus, the fining agent (Na$_2$SO$_4$) input amount is typically reduced by 20 to 30% under oxy-fuel firing to achieve the same level of fining.

recover waste energy from the flue gas and to produce a hot syngas stream which has about 1.2 to 1.3 times the heating value of the natural gas fed into the bottom of the regenerator.

This technology has been in operation on a commercial 50 tpd container glass furnace in Mexico since late 2014 and is now being implemented on a larger tableware furnace at Libbey Leerdam in The Netherlands.

A 45 to 60% reduction of CO$_2$ emissions compared to the existing recuperative furnaces is projected. NOx, CO, SOx and particulates emissions are also expect to be reduced.

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Oxy-fuel furnace and burner designs have been improved since then with taller crown height and low gas velocity burners.

A 50% reduction on particulates emissions (data points in other colours) has been achieved in comparison with the emissions from earlier oxy-fuel fired furnaces.

The light green highlighted area in Fig

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Since dissolved water acts as a firing gas and enhances the fining reactions of sulphate in the glassmelt, it allows a reduction of the amount of other firing gases (mostly SO₂ and O₂) required for fining. Thus, the firing agent (Na₂SO₃) input amount is typically reduced by 20 to 30% under oxy-fuel firing to achieve the same level of fining.

By reducing the sulphate input under oxy-fuel firing sulphur emissions can be reduced.

Combustion conditions in the furnace also affect SOx emissions. Reducing atmosphere over glassmelt and flame impingement on the batch are known to recover waste energy from the flue gas and to produce a hot syngas stream which has about 1.2 to 1.3 times the heating value of the natural gas fed into the bottom of the regenerator.

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References

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