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Furnace upgrades for CO_2 and fuel savings

Converting glass furnaces to run on oxy-fuel and implementing waste heat recovery technology offers an economical solution to achieving 2030 CO_2 emission targets. Shrikar Chakravarti looks at how Linde and Johansson are working with glass furnace operators to promote a more energy-efficient method of glassmaking.

Process industries – refineries, steel mills, cement kilns and glass furnaces are looking for ways to substantially reduce CO_2 emissions from their operations. As part of the Science Based Targets initiative, several glass companies have made commitments to sizeable reduction in CO_2 emissions by 2030[1].

Converting air-fuel furnaces to oxy-fuel furnaces with waste heat recovery provides an expedited and economical means to meeting all or a significant portion of the CO_2 reduction objectives. Oxy-fuel technology is commercially proven with over 300 glass melting furnaces operating in this mode[2]. Flue gas typically exits the oxy-fuel glass furnace at 1400–1500°C. With flue gas heat recovery, fuel consumption is estimated to decrease by 20–30% with a corresponding reduction in CO_2 emissions from fuel.

Under its OPTIMELT trademark, industrial gas and engineering company Linde offers multiple heat recovery technologies: batch and/or cullet preheating (through an exclusive arrangement with Johansson Industries) and Thermo-chemical Regenerator Systems (TCR).

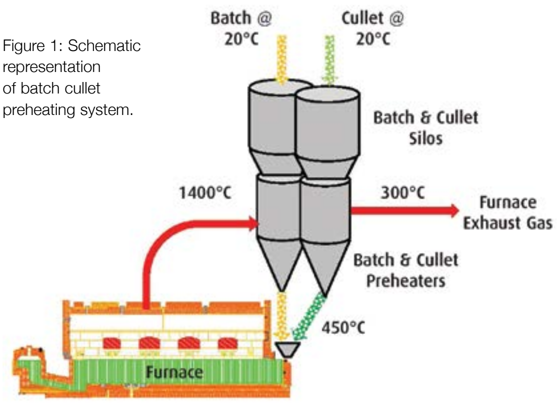

Figure 1: Schematic representation of batch cullet preheating system.

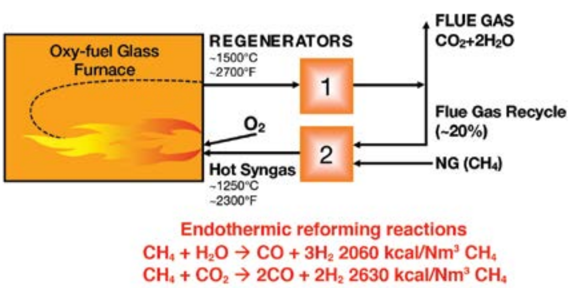

Figure 2: Schematic representation of OPTIMELT TCR Process.

Batch and/or cullet preheating

Producer of batch and cullet preheaters for gas-oxygen fired glass furnaces Johansson Industries has developed batch preheating (BPH) and cullet preheating (CPH) systems uniquely adapted to oxy-fuel fired glass furnaces.

Early on, two concepts that directed its development were recognised: 1) exhaust gases from an oxy-fuel furnace have heat available at much higher temperature than from air-regen, and 2) batch and cullet are physically quite different materials. Treating batch and cullet separately and designing specifically for the oxy-fuel exhaust gas stream enabled many advantages in the system design. Competing technologies for raw material preheat were originally designed for air-fired regenerative furnaces with mixed batch and cullet with cullet ratios greater than ~60%. The larger flue gas volume and lower flue gas temperature from an air regen furnace required a very large bed size and the maximum batch preheat temperature was limited to about 250–300°C. Equipment size, cost and performance can be significantly improved with the batch cullet preheating system from Johansson Industries. With five furnaces in long-term operation (see Table 1), Johansson Industries leads the industry in applying batch and cullet preheating to oxy-fuel fired glass furnaces.

As shown in Figure 1, batch and cullet are independently heated by direct contact with furnace gases, ensuring high heat transfer rates and high material preheat temperatures in the range of 400–450°C. The heat exchangers are positioned in place of the normal day bin at the furnace; the day bins/silos are positioned directly above them. The two preheated materials are mixed directly above the charger so that normal furnace charging operations are maintained with little heat loss.

Besides the obvious fuel and oxygen savings to the furnace, there are several additional advantages:

- Preheated batch/cullet results in faster melting within the furnace and thus a shortening of the batch line,
- Furnace crown temperatures are reduced at the same pull rate, extending the lifetime of refractories, and producing fewer particulates emissions,
- Electric boost can be reduced or production rate can be increased by 10–20%, and
- Organic contaminants, e.g. paper, food residue, plastic, in post-consumer recycled cullet are pyrolysed and the fume is fully oxidised in the flue duct. This reduces the net carbon content of the cullet entering the furnace allowing for more stable glass redox control and significantly reduced foam versus typical oxy-fuel furnaces.

Thermo-chemical Regenerator System technology

Linde's OPTIMELT Thermo-chemical Regenerator (TCR) process is an advanced heat recovery technology for oxy-fuel fired glass furnaces[3–4]. The technology is based on a unique waste heat recovery concept called thermo-chemical regeneration in which heat stored in a regenerator checker during the flue gas exhausting cycle is recovered during the reforming cycle by preheating and reforming a mixture of natural gas and recycled flue gas. Figure 2 shows this cyclic heat recovery process.

The flue gas cycle in regenerator 1 is similar to the conventional regenerator ▸

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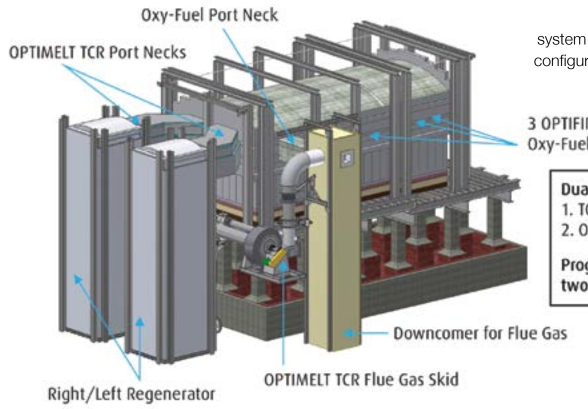

Figure 3: OPTIMELT TCR system arrangement in end-fired configuration at Libbey Leerdam.

heating cycle in which flue gas waste heat is transferred to and stored in the checker. The unique feature of the TCR process occurs during the reforming cycle where a portion of the cooled flue gas is recycled (Recycled Flue Gas or RFG) to the bottom of an already preheated regenerator (regenerator 2) and mixed with natural gas (NG) fuel. When the gas mixture is heated above a certain temperature, CH_4 is non-catalytically reformed by CO_2 and H_2O in the RFG to form H_2, CO and soot. The reformed gas or 'syngas' is combusted with oxygen in the glass furnace thus providing thermal energy for glass melting. When the regenerator in reforming mode is getting colder the regenerators are switched and the regenerator that was previously in reforming mode is heated with flue gas. The regenerators are similar in design to conventional air heating regenerators, but the checker volume is only one-third the size of the air-regen case, making the retrofit or rebuild an economically attractive option. For a larger scale commercial furnace expected fuel savings are about 20% compared to oxy-fuel and 30% compared to air-regenerator furnaces.

Libbey Glass

Following successful commercialisation on a 50tpd container glass furnace in Mexico, the TCR system has been in commercial operation on an oxy-fuel fired tableware glass furnace at Libbey Leerdam in the Netherlands since 2017. Figure 3 illustrates how the TCR system is integrated with the oxy-fuel furnace. TCR system operation commenced in late 2017[3–4].

The three year operating experience with the new furnace has reportedly been very positive. The TCR system has been in continuous operation meeting or exceeding Libbey's glass production and quality needs. Should the TCR system need to be taken offline for inspection/maintenance or experience a shutdown, the flue gas damper between furnace and downcomer is opened and operation can proceed with the oxy-fuel burners. Glass production can continue uninterrupted.

Other benefits of the technology include:

- Substantial reduction in NO_x emissions[4]
- Reduction in foam relative to oxy-fuel furnaces
- 'Self-cleaning' mechanism that results in minimal deposits on the walls and checkers in the regenerators[5]
- Ability to maintain pull rate while reducing level of electric boost.

Location	Pull Rate (t/d)	Year Installed (BPH/CPH)	Glass	Cullet Ratio	Cullet Rate (t/d)
US	250	1997 (CPH)	Flint	50%	130
US	330	2011 (BPH)	Flint	50%	160
Europe	270	2014 (CPH)	Flint	50%	135
Europe	170	2015 (CPH)	Flint	80%	140
Europe	410	2016 (CPH)	Green/Amber	75%	310
Europe	340	2017 (CPH)	Flint	70%	240

Table 1: List of commercial references for batch and cullet preheating from Linde and Johansson Industries.

Cullet rate (% of glass pulled)	Waste Heat Recovery System Options
>70%	CPH
50% - 70%	BPH + CPH, TCR + CPH
30% - 50%	BPH + CPH, TCR + BPH
<30%	TCR, BPH

Table 2: Potential options for heat recovery systems.

Summary

By combining the heat recovery technologies mentioned previously, it is possible to achieve specific energy consumption in the range of 2.5–2.8 GJ (LHV)/metric ton container glass depending on the cullet rate[6]. Table 2 provides an example of possible combinations of heat recovery systems for different cullet rates.

Depending on the project specifics, e.g. fuel prices, cullet rate, internal vs post-consumer recycled cullet, CO_2 avoidance costs and capital constraints, Linde and Johansson can work with glass furnace operators to identify the optimal heat recovery technology combination to cost-effectively achieve a near-term goal of 20–30% reduction in CO_2 emissions. Taking this step will also make the glass furnaces future-ready when low/zero carbon fuels such as green H_2 become more economically viable. ●

OPTIMELT is a registered trademark of Linde

References

1. Verheijen, O., 'CO_2 Emission at Glass Furnaces', Glass Trend virtual seminar – 'Decarbonization technologies for the glass industry', 18 November 2020.
2. Kobayashi, H., 'Future of Oxy-Fuel Glass melting: Oxygen production, Energy Efficiency, Emissions and CO2 Neutral Glass Melting', 80th Conference on Glass Problems, Columbus, OH, October 2019.
3. M. van Valburg, E. Sperry, S. Laux, R. Bell, A. Francis, and H. Kobayashi, 'Design and Implementation of OPTIMELT Heat Recovery for an Oxy-Fuel Furnace at Libbey Leerdam', 78th Conference on Glass Problems, Columbus, OH, October, 2017.
4. M. van Valburg, F. Schuurmans, E. Sperry, S. Laux, R. Bell, A. Francis, S. Chakravarti and H. Kobayashi, 'Operating Experience with the OPTIMELT Heat Recovery Technology on a Tableware Glass Furnace', 79th Conference on Glass Problems, Columbus, OH, October, 2018.
5. Orawannukul, P., Kobayashi, H., Verheijen, O., van Kersbergen, M. and Zheng, A., 'Deposition and Evaporation of Condensable Vapors in Thermo-chemical Regenerators: Self-Cleaning Mechanisms in the OPTIMELT System', International Conference on Glass, Boston, 2019.
6. S. Chakravarti, J. Alexander, and H. Kobayashi, 'Waste Heat Recovery in Oxy-Fuel Glass Furnaces – A Path to Sustainability and Lower CO_2 Emissions', 81st (Virtual) Conference on Glass Problems, October 2020.

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