HeatOx technology makes major efficiency strides

Chloé Caumont-Prim, Xavier Paubel, Tâm Lâm, Sarah Juma and Luc Jarry discuss Air Liquide's heat oxy-combustion technology and its use in the glass industry.

The fossil fuel industry has had a very difficult time reducing its carbon emissions. Although industrial intensity has fallen in developed countries since the 1990s, there is still a lack of alternative energy sources and solutions. More than ever, the development of new technologies is critical.

In the glass and metallurgical industries, oxy-combustion has been widely used to improve the combustion process, reduce air pollutant emissions and save fuel. But heat oxy-combustion goes even further, rechanneling the extracted heat from the combustion fumes to heat oxygen and fuel, thus improving overall oxy-combustion performance.

Air Liquide's heat oxy-combustion has become a world-renowned, sustainability-boosting technology in the glass industry. This was especially underscored during the 2015 COP21 conference in Paris, where it was honoured with the Innovation Award focused on 'Climate Solutions'[1].

Compared to regular air combustion, this breakthrough technology provides up to 50% energy savings and reduces carbon dioxide (CO_2) emissions by as much as 50%. It also reduces nitrogen oxide (NO_x) and dust emissions. No other technology on the market offers such a solution for preheating oxygen via hot fumes. And it is applicable to the entire glass industry.

Partnering breakthroughs through collaboration

HeatOx projects are valuable, as they help to strengthen green technologies by training highly qualified staff. By merging individual areas of expertise into a multi-disciplinary framework of innovation, it is believed that HeatOx can become a standard for sustainable business development and environmental protection.

One such project, which Air Liquide has helped lead, is the EU-cofunded LIFE Eco-HeatOx Project, which is dedicated to combatting climate change. Through this project, an in-depth study was conducted at a tableware glass factory owned by Pasabahce Bulgaria, subsidiary of Sisecam. The study compared the performance of a heat oxy-combustion furnace against a traditional end-fired regenerative furnace and also explored next generation solutions expected to boost efficiency and reduce CAPEX.

Putting wasted energy to good use

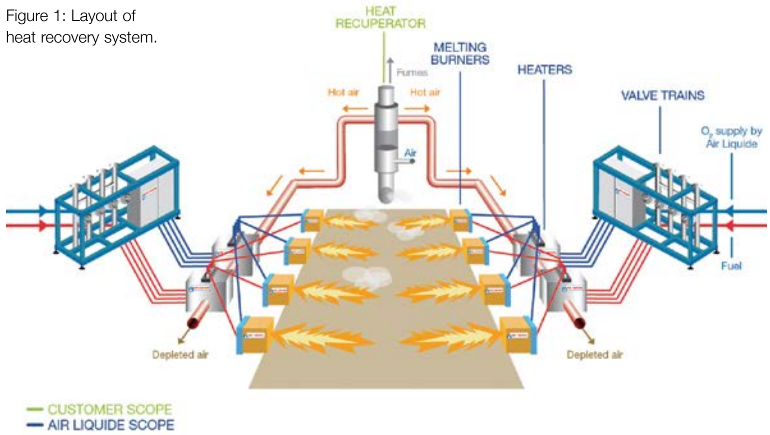
The reactant preheating waste heat recovery system is primarily composed of reactant heat exchangers, recuperators and burners, as shown in figure 1. One key difference compared to the previous float glass references of this system is that the natural gas and oxygen heat exchangers were specifically designed to reduce capital cost and footprint.

More specifically, two heat exchangers (one for natural gas and one for oxygen) are installed on each side of the furnace feeding four HeatOx burners. The multi-channel reactant heat exchangers feed natural gas and oxygen to multiple burners with individual gas temperature control for each burner. Eight burners on 10 have pre-heated reactants. The reactant flow and ratio is controlled by flow control skids that handle room temperature natural gas and oxygen upstream of the reactant heat exchangers.

Tailor-fit installation with zero disruption

The furnace (furnace B) needed to be installed in a building that was originally designed for an end-fired regenerative air-fuel furnace. This required significant construction work and structural modifications under tight space constraints in order to comply with architectural limitations, particularly to obtain the required heat transfer area. In this installation, two recuperators were positioned on top of the horizontal flue gas channels on each side of the

Figure 1: Layout of heat recovery system.



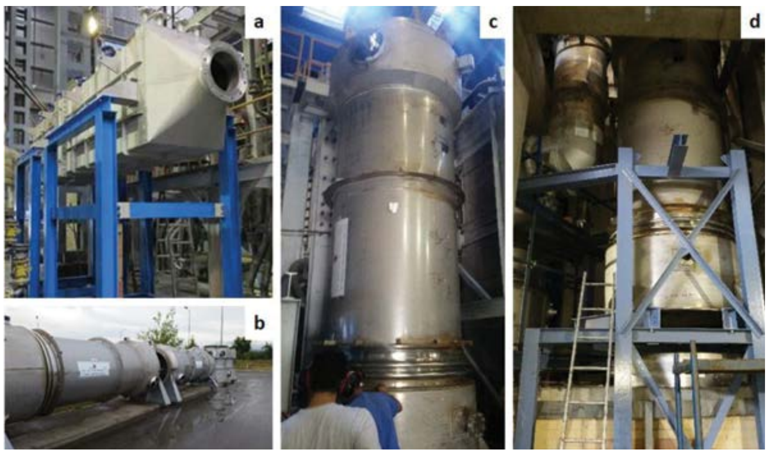


Figure 2: (a) Natural gas and oxygen heat exchangers; (b) Recuperator delivery; (c) Recuperator installation; (d) Recuperators in place.

This article is based on a paper presented at the GlassTrend sessions during the ICG Annual Meeting in Istanbul, Turkey in October 2017.

Glass Worldwide is the preferred journal of GlassTrend **www.glasstrend.nl**

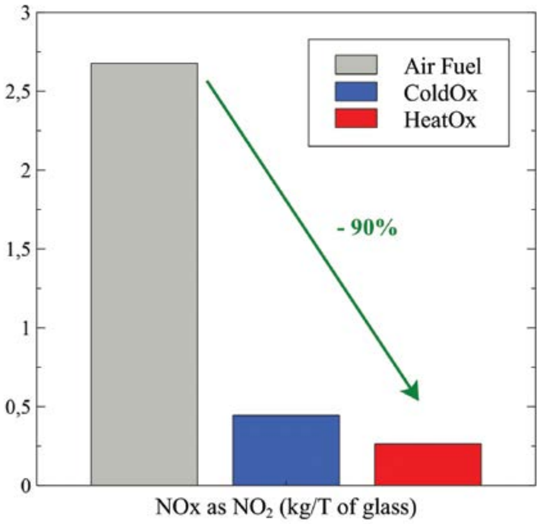


Figure 3: Comparison of NO_x emissions as NO_2.

furnace following the vertical flue gas channels (figure 2). Due to height limitations and interference with the roof of the building, dual-stage recuperators had to be incorporated into the design. The flue gas channels of the first and second stage recuperators were connected via a duct.

The equipment installation primarily involved the modification of the existing flue gas channels prior to the furnace start-up, relocation of interfering pipework and installation of heat exchangers, burners and piping for preheated reactants. Overall, it took about three months to fully install the equipment without any impact on production or glass quality.(2)

	Energy savings calculated*	Energy savings measured*	Natural gas temperature (°C)	O2 temperature (°C)	Fumes temperature at recuperator inlet (°C)
Case 1	8.6%	8.1%	355	445	1085
Case 2	9.1%	9.4%	410	505	1105

Table 1: Results of the two performance tests between HeatOx and ColdOx modes.
* Calculated and measured values represent energy savings associated with preheated burners.

Compelling results

At the end of the LIFE Eco-HeatOx project, Air Liquide and Sisecam conducted two performance tests on furnace B, at various preheating temperatures. The goal was to validate the performance of HeatOx compared to traditional oxy-fuel combustion. The methodology was as follows:

- Full audit of the furnace in 'ColdOx' mode (with reactants at ambient temperature).
- Stabilisation of furnace condition at same pull rate once switched into HeatOx mode.
- Full audit of the furnace in 'HeatOx' mode (with hot reactants).

To ensure the consistency of measurements, heat and mass balance were calculated with AirLog, a proprietary tool developed for glass applications. For this purpose, heat losses of furnace B were calculated in all types of operating conditions (pull rate, cullet, electrical boosting, natural gas and oxygen flows) over a one year period. These heat losses are assumed to be fixed for the heat and mass balance calculations. The other inputs of heat and mass balance include the geometry of the furnace, raw material composition, natural gas composition, reactant temperature, oxygen content in the flue gases, pull rate, cullet ratio and electrical boosting value, as well as flue gas temperatures. All these values were measured during the audit and always in both configurations: ColdOx and HeatOx. The heat and mass balance aims to calculate the expected consumption and compare it to the measured oxygen and natural flows.

Table 1 presents the results of energy savings between HeatOx mode (preheated reactants) and ColdOx mode (without heat recovery). Throughout the testing phase, electrical boosting and cullet ratios are almost identical and their variation effect is corrected in the ▸

	Savings (taking into account ageing) effect HeatOx versus air
Energy consumption (GJ/ton)	19%
NOx (kg/ton)	90%
CO2 from combustion (kg/ton)	19%
CO2 process (kg/ton)	10%

Table 2: Results of HeatOx technology versus air.

comparison. Also during this phase, O_2 and natural gas (NG) temperatures have evolved depending on fume temperature at inlet of heat recovery system, which remained below the design condition due to the architectural limitations. At design (1125°C), O_2 and NG temperatures reached 450°C and 550°C respectively. These results confirmed previous observations regarding energy efficiency gain with oxygen and NG preheating: 100°C of one reactant preheating yields a 1% efficiency gain.

Significant drop in NO_x emissions

The environmental impacts of the project have been measured with reactants at ambient temperature and with heated reactants throughout 10 testing phases and compared to a furnace running with air, representative of regenerative furnaces; figure 3 shows the NO_x emissions average throughout the 10 testing phases. An oxy-fuel furnace with heat oxy-combustion technology exhibits NO_x emissions reduced by 90% compared to an air furnace, whatever the temperature of oxygen and natural gas.

Additionally, the various fume measurements clearly demonstrate that despite the preheating of the reactant, NO_x emissions are equivalent to the operation with reactants at ambient temperature – around 0.3 kg/Tglass below regulation (0.5-1.5 kg/Tglass). NO_x is expressed with an oxygen reference of 8%.

The results are summarised in table 2.

The traditional air regenerative end-port furnace A is similar to HeatOx-equipped furnace B in terms of glass-type production, pull rate and melting area. After analysing the operation of both furnaces for approximately one year, the results were significant:

- Energy consumption reduced by 19%.
- Direct pollutant emissions reduced by 19% for CO_2 and 90% for NO_x.
- No unfavourable effects observed on furnace pressure management, glass quality or colour.

Further efficiency gains via fuel-oil injectors

Heavy fuel oil (HFO) is used as the main fuel or back-up fuel on many industrial furnaces and is particularly appreciated for the outstanding radiative properties of its flame. Over the years, Air Liquide has developed several fuel-oil injectors that integrate easily into its oxy-fuel burners, using air or water vapour as atomisation fluid.

For customers wishing to operate with HFO instead of natural gas, Air Liquide has focused on optimising the designs of its fuel-oil injectors in order to integrate them into heat recovery systems (particularly heat oxy-combustion), while continuing to increase burner efficiency and decrease pollutant formation.

Initial results show that the use of a heat oxy-combustion system along with a specifically designed HFO injector allows for efficiency gains as high as 7% and NO_x emissions as low as 500 ppm (in exhausts at 8% O_2 content) for 1000kW nominal power.

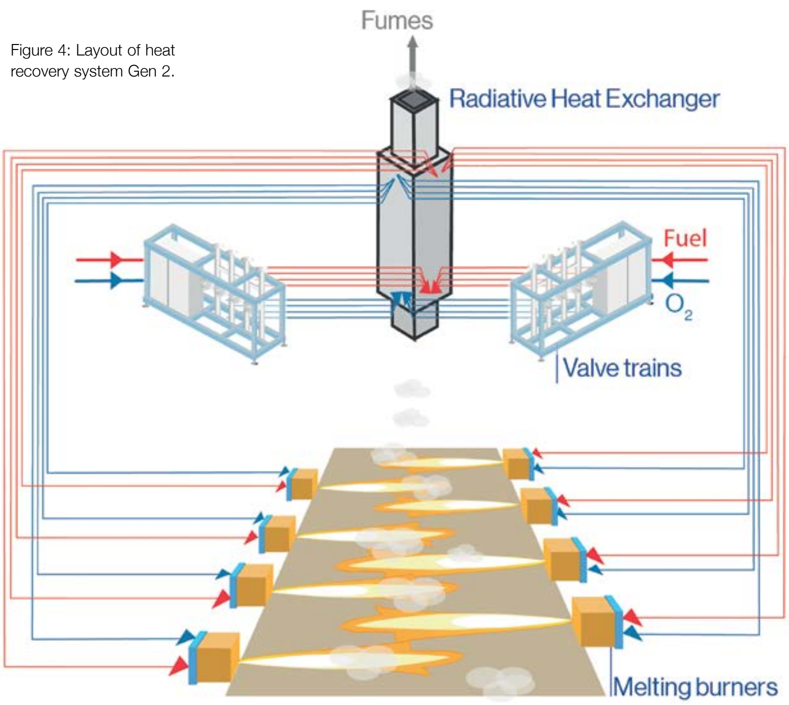


Figure 4: Layout of heat recovery system Gen 2.

Major enhancements

The first generation of HeatOx technology provides up to 50% energy savings and up to 50% CO_2 emission reduction compared to air combustion. However, its financial viability assessment was performed based on 2012-2013 NG prices. But since the inception of the project, NG prices have plummeted to historic lows. According to the IMF, NG prices will remain stable for the foreseeable future, which means HeatOx technology will have to perform even better to be economically attractive.

And that is where HeatOx 2G comes in! With additional efficiency gains, the second generation HeatOx solution is targeting a 50% CAPEX reduction compared to HeatOx 1G, thus ensuring the technology remains cost-efficient, even with low fuel prices. The success of HeatOx 2G will help to change the long-lasting paradigm of air-fuel combustion in glass furnaces to oxy-fuel combustion.

At the heart of HeatOx 2G technology is direct preheating of NG and O_2 with flue gas, which could not be done in the previous generation due to safety and reliability concerns (figure 4). Going forward, the HeatOx 2G innovation will help industries overcome previous hurdles and achieve higher efficiency gains all around.

Aknowledgment:

Air Liquide thanks European Commission for supporting Eco-HeatOx & CleanOx projects through its LIFE+ funding programme. Please visit the websites www.ecoheatox.com amd www.lifecleanox.com. ●

References:

1. Press release, Paris, 7 December 2015, COP21: air liquide wins an Innovation Award from the France-China Committee for its heat oxy-combustion technology.
2. Oxy-fuel tableware furnace with novel oxygen and natural gas preheating system, Tunc Göründey, Neset Arzan (Sisecam R&D, Kocaeli, Turkey), Süleyman Koc (Pasabahce, Istanbul, Turkey), Osman Öztürk, Hakan Sahin (Pasabahce Bulgaria EAD, Targovishte, Bulgaria), Hwanho Kim, Taekyu Kang (Air Liquide R&D, Newark, Delaware), Youssef Joumani (Air Liquide R&D, les Loges-en-Josas, France), Xavier Paubel (Air Liquide ALTEC, Paris, France) and Luc Jarry (Air Liquide, Shanghai, China), 77th Conference on Glass Problems.

About the authors:
Chloé Caumont-Prim is R&D Combustion Engineer, Xavier Paubel is Altec WW Manager, Tâm Lâm is HeatOx Program Manager, Sarah Juma is R&D Combustion Engineer and Luc Jarry is Global Glass Market Director, all at Air Liquide

Further information:
Air Liquide SA, Jouy-en-Josas, France
tel: +33 86 21 6090 3076
email: luc.jarry@airliquide.com
web: www.airliquide.com