Oxy-fuel glass melting trends in Asia

Conventional air-fuel plus electric boost has historically been adopted for glass melting furnaces but the past 10 years have shown a progressive increase in conversions to oxy-fuel melting. While this trend has occurred on a global scale, it has been particularly prevalent in Asia, where the number of full oxy-fuel furnaces has increased roughly 10-fold during this period (table 1). Richard Huang et al examine industry drivers behind the trend and highlight recent developments in enabling technology that will provide further benefits for oxy-fuel processes.

A key incentive for oxy-fuel melting is that significantly higher melting efficiency can be achieved, without the use of a heat recovery system. The principal reason is because oxy-fuel combustion eliminates nearly all nitrogen from the oxidiser, which reduces the mass flow rate of flue gas leaving the furnace by approximately 70% relative to air-fuel combustion.

Even when air-fuel furnaces are equipped with relatively efficient regenerators, conversion to an oxy-fuel furnace typically results in a 10%-20% increase in melting efficiency, while substantially reducing the furnace footprint and eliminating the capital and maintenance costs associated with regenerators (figure 1).

More importantly, glass manufacturers are beginning to recognise that converting a regenerative air-fuel melter to an oxy-fuel melter can lead to a higher quality glass product. Oxy-fuel combustion vastly improves process stability by eliminating periodic reversals that introduce thermal cycling into the glass melting process. This cyclic behaviour contributes to accelerated refractory degradation, including spalling of refractory material that leads to glass defects. Additionally, the combination of steady oxy-fuel operation, along with higher temperature oxy-fuel flames, leads to stronger convective currents in the glass melt, thereby promoting enhanced fining and higher glass quality than in air-fuel melting processes.

Another important factor in the trend towards oxy-fuel glass melting is government mandates for reduced pollutant emissions. According to China's 13th Five Year Plan (2016-2020), the emissions of two key air pollutants, sulphur dioxide (SO_2) and nitrogen oxides (NO_x) must be reduced by 15% by 2020.

Conversion from an air-fuel to an oxy-fuel melting furnace normally reduces combustion-generated NO_x emissions by 70%-90% on a kg/MT glass basis. The precise degree of NO_x reduction from air-fuel to oxy-fuel depends on many factors, including oxygen purity, batch and fuel nitrogen levels and burner design. Emissions of CO_2 are also lower with an oxy-fuel furnace since, relative to an air-fuel furnace, less energy is used per ton of pulled glass.

Finally, particulate emissions tend to be lower with oxy-fuel as compared to air-fuel due to lower momentum gas flows in the combustion space, less likelihood of refractory spalling and more rapid glazing of batch material. Although emissions abatement equipment is sometimes still required with an oxy-fuel furnace, the size and cost of the equipment is lower than with an air-fuel furnace since the volume of flue gas being treated is dramatically reduced.>

	Float	Flat and Solar Cell	Container	Specialty and Tableware	Glass Wool	E-glass Fiber	TFT-LCD	Total Number of Furnaces
China	2	>5	2	6	2	>50	>6	>77
Korea	-	-	3	-	3	3	>10	>19
Taiwan	-	-	-	-	-	10	>20	>30
Japan	1	1	-	-	>2	>2	>5	>11
SEA	-	-	-	-	-	2	-	2
% of full Oxy-fuel furnaces, Asia	<2%	30%	<3%	20%	~40%	~90%	100%	>139

- Full oxy-fuel has become mandatory for TFT-LCD glass and E-glass fiber recently
- Full oxy-fuel has been well-adopted by solar cell glass manufacturers
- Full oxy-fuel is preferred by boron-contained glass such as heat resistant glass and glass wool
- Full oxy-fuel installations referenced above are for furnaces with 25-600 metric-ton-per-day glass throughput

Table 1: Air Products sees an increase in the distribution of full oxy-fuel furnaces in Asia.
• Full oxy-fuel installations referenced above are for furnaces with a 25-600 MTPD glass throughput.

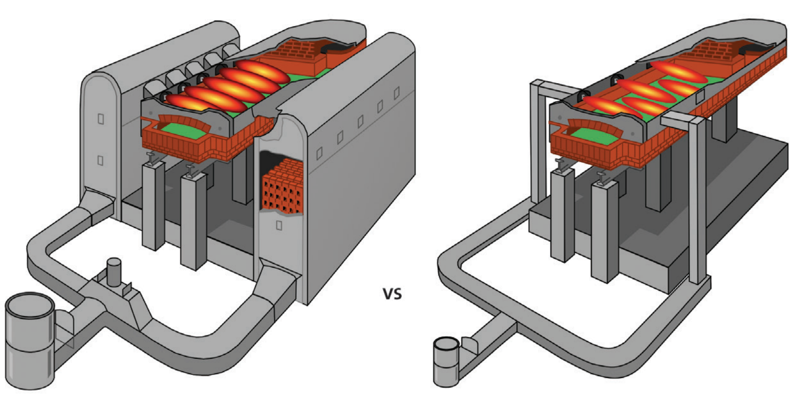

Figure 1: Oxy-fuel furnaces can achieve higher melting efficiency with a smaller footprint and lower capital costs compared to air-fuel furnaces.

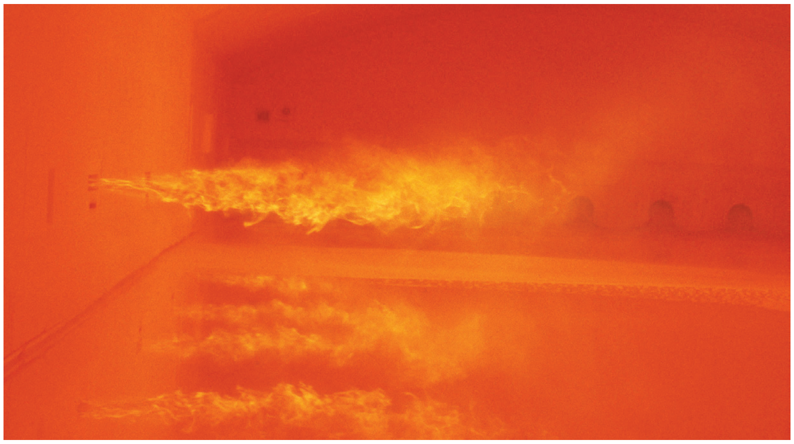

Figure 2: Air Products' Cleanfire HR_i burner has a wide flame and oxygen staging.

PROVEN COMBUSTION TECHNOLOGY

An important step in oxy-fuel conversion is selecting the appropriate mode of supply for the operation. The mode of oxygen supply chosen for an oxy-fuel furnace depends principally on the size of the melter. For smaller units, a liquid oxygen supply is favoured, while larger furnaces typically use on-site cryogenic air separation systems. In the medium size range, on-site non-cryogenic adsorption units produce a more economical supply of oxygen with lower purity than either of the cryogenic or liquid options.

Data has shown that oxy-fuel burner technology employed on a furnace can have a substantial effect on NO_x emissions, thermal efficiency and glass quality. Burner design factors that lead to improved performance largely relate to how fuel and oxygen mix as they exit the burner nozzle. Reactant mixing controls the flame shape, stability, appearance and temperature distribution. The result of these effects determines efficiency of heat transfer to the glass melt and the rate of NO_x formation and destruction within the combustion products.

With precise attention to these details in mind, Air Products developed its patented Cleanfire HR_i burner[1] (figure 2). This burner, with its wide-flame and oxygen staging, has been the leading oxy-fuel burner in the glass industry for more than a decade. The Cleanfire HR_i burner has demonstrated impressive results in a recent air-fuel to oxy-fuel conversion performed in Korea (table 2).

	Air-fuel	Oxy-fuel	Change
Pull Rate	270 MTPD	300 MTPD	11% Increase
Furnace Area	117 m^2	117 m^2	-
Melting Efficiency	4.35 MMBtu/MT Glass	3.6 MMBtu/MT Glass	17% Improvement
Electric Boosting	550 kWh	None	100% Reduction
NO_x Emissions	4.7 kg/MT Glass	0.4 kg/MT Glass	>90% Reduction
Glass Quality	-	-	~1/3 Reduction in Seeds
Cullet	70%	75%	5% Increase

The fuel used in both the initial air-fuel operation and the subsequent oxy-fuel conversion was heavy oil.

Table 2: Results of air-fuel to oxy-fuel conversion for a glass manufacturer in Korea.

- Electronic monitoring of key burner parameters
- Wireless data transfer
- Battery-powered
- CE stamped
- Simple installation while furnace is running
- Data integration with glass manufacturer DCS and PLC systems
- Smart replacement for Cleanfire HR_i burner

Figure 3: Air Products' Cleanfire HR_e burner is the first smart burner for the glass industry.

THE FUTURE OF OXY-FUEL TECHNOLOGY

In keeping with the global trend to extract more information from industrial processes using sensors and wireless communications, Air Products has continued to lead the way in oxy-fuel combustion for glass melting with the introduction of its patent-pending Cleanfire HR_e burner[1,2] (figure 3). This burner is the first smart burner for the glass industry and part of the Industrial Internet of Things (IIoT).

The IIoT is the practice of connecting industrial devices to the internet in order to automate, improve interconnectivity and increase efficiency. This burner development has taken monitoring and control to the next level by conveniently measuring and wirelessly transmitting key burner performance variables. These features enable plant engineers and control room operators to see more clearly the effects that changes in burner conditions can have on the glassmaking process and as a result, take more timely and appropriate actions to optimise their operations.

With the ever-increasing push toward lower pollutant emissions, higher thermal efficiency, higher glass quality and longer furnace campaigns, the incentive for oxy-fuel conversions will continue to grow in Asia and around the world. It is therefore incumbent upon suppliers like Air Products to highlight the proven advantages of oxygen in the attainment of these goals, while developing and introducing innovative enabling technologies to progressively define new limits of performance, stability and reliability of the glass melting process. ■

FOOTNOTES:

1. Cleanfire is a registered trademark of Air Products and Chemicals Inc and HR_i and HR_e are grade designations under that trademark.
2. Three families of patent applications are pending, including US 2015/0316262 AA, US 2016/0238246 AA, and US 2015/0316256 AA and corresponding international patent applications.

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