Combustion efficiency

Environmental benefits and lower cost too!

Kevin A. Lievre, Julian L. Inskip and Russell J. Hewertson
Air Products Europe
Air Products and Chemicals, Inc.

As previously featured in Glass

Combustion efficiency

Environmental benefits and lower cost too!

Kevin A. Lievre, Julian L. Inskip and Russell J. Hewertson
Air Products Europe

Oxygen firing is generally considered the ultimate technique for reducing furnace emissions, but does it make economic sense?

Initially, oxy-fuel replaced air-fuel combustion in operations with environmental problems or where oxy-fuel offered massive improvements in energy use due to low combustion air pre-heat temperatures (unit melters, recuperative melters, etc.) In both cases the oxygen proved itself without the need for a detailed review of the glassmaker's cost stack. Since then, significant advances in key areas have continued to improve the performance and economics of melting glass using oxy-fuel. Greater environmental pressures, lower capital costs, quicker turnarounds for rebuilds, more efficient oxygen production, higher fuel prices, advances in burner technology, improved oxy-fuel furnace designs/construction techniques and the availability of better refractories have all supported the case for oxy-fuel conversion. With oxygen, glassmakers have reported decreased use of expensive additives, improved operational flexibility, decreased fuel usage, increased specific melt rates, improved glass quality, and improved furnace stability due to continuous firing. This article will address the major cost and benefit differences between air-fuel and oxy-fuel and highlight the benefits which have the largest effect on the economics.

In the area of capital costs, there are significant differences between an air-fuel furnace and an oxy-fuel furnace. The entire heat recovery system is eliminated for the oxy-fuel furnace, but a more expensive crown may be required. For the oxy-fuel furnace, specialized flow controls and burners must be purchased, but NO_x abatement equipment is not needed. While the project scopes are markedly different, the capital costs are usually very close for the two technologies. The second campaign for an oxy-fuel furnace often has a smaller scope with the reuse of burner controls, piping and burners and, in some recent cases, the crown. An additional advantage of oxy-fuel rebuilds is the reduced construction time, often several weeks shorter than an air-fuel rebuild. Getting the furnace back on line more quickly is obviously very lucrative. Even if one technology were more expensive than the other to build, capital cost does not have a big impact on glass production cost. For example, a capital cost difference of 800,000 euros corresponds to less than €0.30 per tonne of glass for a 600 tpd furnace over a 12 year campaign.

Utilities represent another area with major differences in the requirements for the two technologies. The oxy-fuel furnace is more efficient, delivering the lowest total CO_2 emissions of any combustion based melting technique. The glassmaker has to pay for oxygen and the power to run the oxygen plant, but float companies, who use nitrogen to protect the tin bath from oxidation, have an added benefit: large amounts of low cost nitrogen as a by-product from the oxygen plant. The highly efficient air separation plant compressors are often over-sized to provide compressed dry air for the factory, providing significant operational savings and extremely high quality air.

Greenfield sites provide the most direct comparison of the two technologies, because the oxy-fuel option is not burdened with overcoming air-fuel system sunk costs (air fuel burners and flow controls, emissions abatement equipment, designing the building for housing regenerators, etc). Often the environmental benefits of oxy-fuel dictate its use in these situations because there is no existing permit.

Two factors that have a large effect on the economics are the production rate and the glass yield. State of the art oxy-fuel burner technology can provide significant improvements to both production and glass yield compared to air-fuel furnaces. These benefits come from a variety of factors, including: faster melting of the batch, increased refining zone and improved furnace stability. Results achieved in full oxy-fuel conversions in various segments have ranged from 10% to 30% production increases and yield improvements in excess of 5%.

Environmental considerations have always favoured oxy-fuel with its lower Nox, particulates, flue gas volumes and eliminating the need for regenerators and their subsequent disposal. NO_x emissions from a properly designed oxy-fuel furnace, using state of the art burners are 10 times lower than those of a typical air-fuel furnace. These lower emissions result from eliminating nitrogen from the combustion gases and carefully controlling mixing rates at the burner. In an air-fuel furnace, approximately 70% of the atmosphere is nitrogen leading to very high levels of NO_x. The higher efficiency of oxy-fuel, combined with the elimination of nitrogen, means that the exhaust gas volume is almost 80% lower than air-fuel. Significantly lower particulates are also achieved, because of the low burner momentum. Thus, any emissions treatment equipment required is much smaller and has lower operating cost.

The environmental benefits of oxy-fuel technology are obvious, but the economic value can vary significantly. In the USA the environmental variable with the largest range of potential benefit is the value of NO_x credits. The market has a very wide range of value depending on local conditions, proof of reductions, regulators' willingness to allow credits, and the cost of implementing mandated environmental improvements at neighboring companies, to name a few. The value of a tonne of NO_x reduction can range from €100 to €3000. The important thing to remember is that the environmental improvement is a key area to investigate to maximize the economic benefit.

Air Products has developed a comprehensive economic model for evaluating the relative effects of the benefits of oxy-fuel. Using information from over 100 oxy-fuel conversions using Air Products burner technology, in all segments of the industry, the range of achievable results is well known. The model shows the relative effect of each variable on the economics, helping the glass customer to understand the areas to concentrate their efforts. In the following example the model is used to compare an air-fuel base case to two achievable oxy-fuel scenarios, one more conservative and one less conservative. Table 1 shows the "Total Annual Benefit" calculated by comparing both the "Oxy-Fuel Base Case" and "Oxy-Fuel Case #2" with the "Air-Fuel Base Case."

The air-fuel base case included the following inputs:

1. 500 TPD glass furnace
2. 80% pack rate
3. €275 per tonne product price
4. €2.75 natural gas per million BTU
5. €0.04 per KWh electricity
6. 3.63Kg/t_{glass} NO_x emissions

The more conservative oxy-fuel case, (oxy-fuel base case) is based on the following assumptions:

1. 300 TPD oxygen plant
2. €1.5 million adder for crown refractory upgrade package
3. 82% pack rate
4. 12.5% lower fuel usage per tonne of glass than air fuel
5. 5% production increase (525 TPD)
6. 0.91Kg/t_{glass} NO_x emissions (value assumed = €345 per tonne of NO_x credit)

The less conservative case "Oxy-Fuel Case #2" assumes the following:

1. That the furnace is a float operation and that Nitrogen is supplied from the new oxygen plant
2. €3.3 natural gas per million BTU
3. €0.8 million adder for crown refractory upgrade package
4. 5% production gain over the oxy-fuel base case (550 T/D)
5. 7.5% additional fuel savings (a reduction of 20% compared to air fuel)
6. 2% yield increase (pack rate = 84%)
7. 5% lower oxygen plant monthly fee
8. €800 per tonne increase in NO_x credit value (€1200)
9. 10% increase in electricity cost (from €0.04 to €0.045 per KWh)

The results in Table 1 show the combined effects of all the changes specified in the cases above, however it is instructive to look at the relative effects of each cost and benefit, one by one, to highlight the most important areas to achieve. Figure 1 uses the model to perform a sensitivity analysis to do just this. In each instance one variable, such as natural gas cost, is changed from the base case by an realistic amount and the effect on overall economics is seen.

Figure 1 shows that the factors that have the biggest effect on the economics are: production, yield, and fuel savings. For areas of the world where NO_x credits or other environmental improvements have a monetary value, this value can also have a significant impact. It is worth noting that all four of these factors are directly affected by the combustion controls and burners selected for the furnace.

Furnace selection to produce the lowest possible amount of pollutants is just plain good for the environment. It is only a matter of time until environmental agencies around the world insist that furnaces be rebuilt using oxygen and some glassmakers are working now to gain the necessary experience for that day. The economics of air-fuel versus oxy-fuel are case specific, depending on site, furnace and local conditions, as well as the value placed by the glass manufacturer on the operational gains projected for oxy-fuel. Recent conversions from air-fuel to oxy-fuel have saved the glass companies millions of euros per year. Today, a better understanding of <u>all</u> of the benefits of oxy-fuel technology has led to an accelerated acceptance in glass melting.

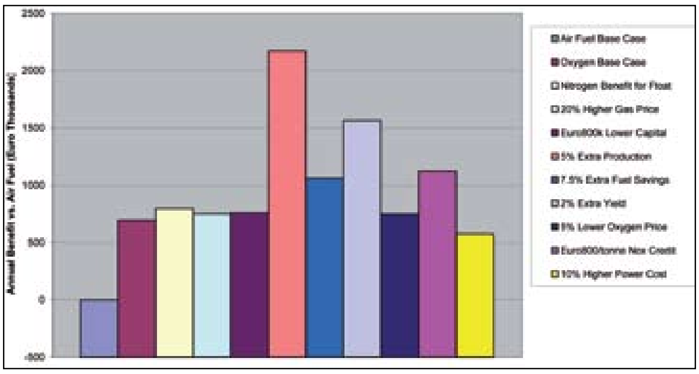

Figure 1. The relative effects of various changes to the oxy-fuel base case annual benefit.

Table 1: Economics: Total annual benefit – air-fuel versus oxy-fuel			
Variable	**Air-fuel base case**	**Oxy-fuel base case**	**Oxy-fuel case #2**
Production	500	525	550
Yield (%)	80	82	84
NO_x credit value (€/t)	Not present	€400	€1200
Fuel savings	Base	12.5%	20%
Incremental sales (€/yr)	Base	€3,072,000	€6,246,000
Incremental costs (€/yr)	Base	€3,016,000	€2,837,000
Emissions savings (€/yr)	Base	€216,000	€648,000
Total annual benefit (€)		€698,000	€4,055,000

tell me more
www.airproducts.co.uk/glass

Air Products PLC, Hersham Place, Molesey Road, Walton-on-Thames, Surrey KT12 4RZ, UK.
Tel +44(0)1270 614314. Email apbulkuk@airproducts.com

337-06-013-GB (rev1 09/08)