Alternative fuels for glass melting

Tunc Goruney*, Richard Huang**, Jinghong Wang*** explain how the challenges associated with the use of alternative fuels in traditional air-fuel combustion can be overcome via oxy-fuel combustion technology.

While global demand for natural gas continues to rise; an increased share of supply is forecast to come from unconventional sources such as those produced from shale formations (***Fig 1***). This abrupt change in the supply chain has triggered variations in fuel prices across different regions, particularly where they lack a domestic supply of natural gas or where natural gas resources are located in economically inaccessible geological formations. This, in turn, has impacted many energy intensive industries including glass manufacturing that heavily relies on natural gas and fuel oil for glass melting. As a result, a strong demand has emerged to use less expensive alternative fuels while meeting stringent environmental regulation targets without compromising glass quality and productivity.

However, there are many challenges for the use of alternative fuels in traditional air-fuel combustion. These include decreased productivity induced by low heating value fuels, flame stability issues associated with difficult-to-ignite fuels, and the presence of particulate matter leading to lower glass quality and more particulate emissions.

Challenges have also arisen in the attempt to blend multiple fuels to achieve an optimised balance of combustion stability and efficiency, glass furnace productivity and reduced cost.

To address these issues, Air Products has developed an oxy-fuel combustion technology portfolio for glass melting that can use a wide range of alternative fuels including but not limited to coke oven gas (COG), pulverised coal, pet-coke and combinations thereof. In this article, examples on various uses of alternative fuels used in glass melting applications are discussed with an emphasis on how the aforementioned challenges associated with the use of alternative fuels can be overcome via oxy-fuel combustion technology.

Here, the word 'alternative' refers to either any fossil- or renewable fuel other than the traditional fossil fuels (natural gas and oil) used in glass melting, or combined and simultaneous use of traditional fossil fuels used in glass melting.

The first example is a conversion of an air-fuel fired furnace to full oxy-fuel combustion using Air Products' Cleanfire® combustion technology for a pharmaceutical borosilicate glass manufacturer in China utilising coke oven gas with a heating value of less than half that of natural gas.

In this case, the glass manufacturer was looking for a solution to the traditional air-fuel combustion in its glass melting process to meet the local government's emissions regulations. The glass manufacturer recognised that air-fuel combustion of some relatively dilute syngas blend might not be able to attain high enough flame temperature as required for efficient melting of glass.

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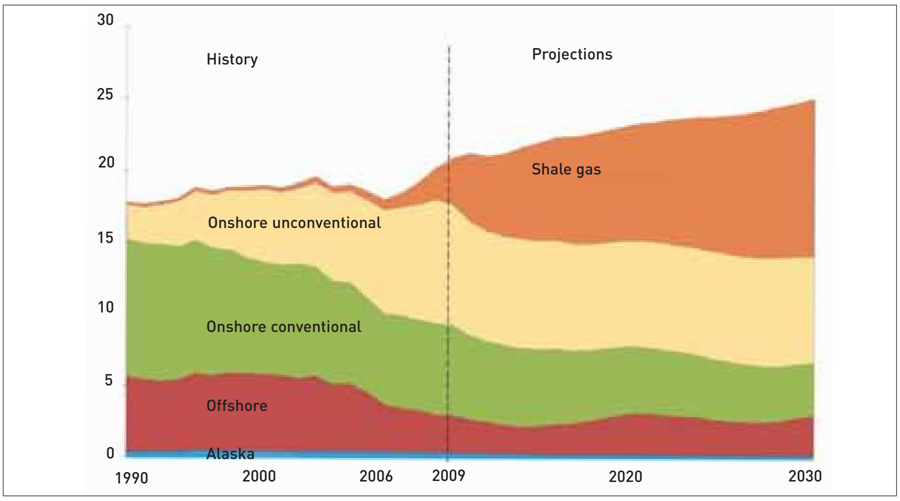

▲ Fig 1. US Natural Gas Production Projection (Trillion cubic feet)
Source: US Energy Information Administration.

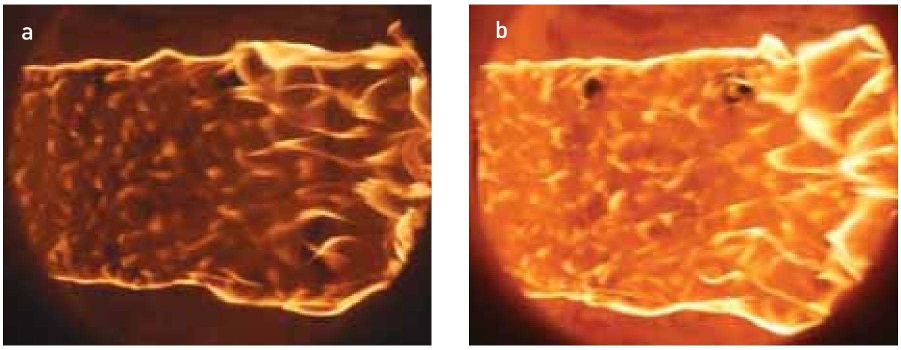

Fig 2. Oxy-natural gas flame produced by a Cleanfire HR*i* burner: a) natural gas only; b) natural gas co-fired with LPG (12.5% LPG by thermal input).

Also, due to the increased syngas fuel volume, the already short air-fuel flue-gas residence time in the furnace would become even shorter, making the use of syngas as alternative fuel a real challenge. The proposed solution to displace air with oxygen was the obvious path to follow.

However, with gaseous alternative fuels of low heating value, it is also important to ensure the burners can produce a stable and luminous flame, desirable for most glass melting applications. It should not compromise the structural integrity of burners and burner blocks, as the fuel discharge volumes and velocities are inversely proportional to the heating value of the fuel, and therefore, can be multiple times higher than that of natural gas.

To verify the compatibility of Air Products' Cleanfire HR*i* gas burners with oxy-coke oven gas firing and optimise burner parameters, extensive tests of simulated blends of the corresponding coke oven gas were conducted at Air Products laboratories. The lab results, confirmed by computational fluid dynamics (CFD) simulations, showed that Cleanfire HR*i* gas burners could deliver sufficient levels of heat flux for glass melting with the coke oven gas blends with a heating value of less than half that of natural gas. The laboratory findings were later validated, and burner performance demonstrated, by a successful commercial installation in the customer furnace.

The second example is a compilation of recent results from testing of burner configurations at Air Products laboratories that blend multiple fuel types for optimisation of flame radiation and melting efficiency. ***Fig 2a*** shows the bottom view of an oxy-natural gas flame produced by a Cleanfire HR*i* natural gas burner. ***Fig 2b*** shows the same view of a 12.5% LPG (by thermal input) in natural gas co-fired oxy-fuel flame produced by the same burner, where the LPG contains approximately 95% propane. Both images were captured using identical imaging parameters. It is qualitatively evident from these images that a small amount of LPG co-firing, approximately 5% by volume, can produce a large increase in flame luminosity. LPG mixed with air is widely used as a backup fuel in glass manufacturing industry and can alternatively be used as a co-firing fuel to increase combustion efficiency and reduce production cost.

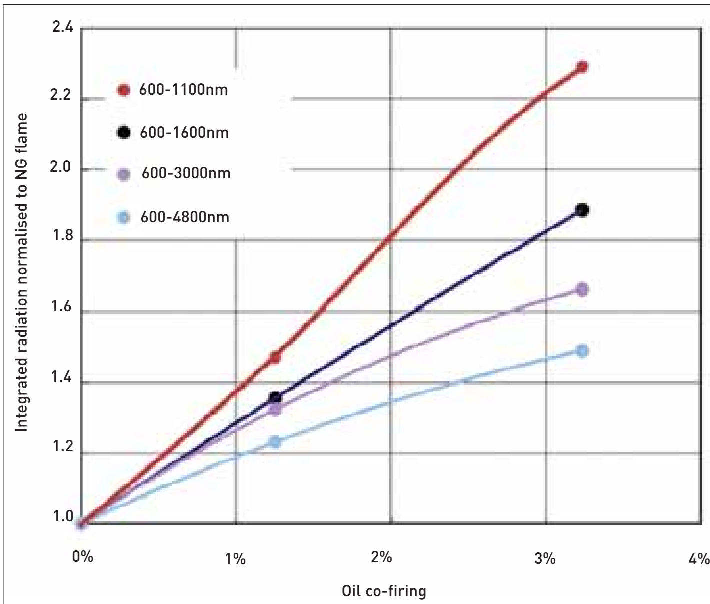

Fig 3. Integrated flame radiation normalised to oxy-natural gas flame as a function of oil co-firing percentage by thermal input.

Similarly, natural gas co-firing with other fuels can lead to increased luminosity and flame radiation. As illustrated in ***Fig 3***, a relatively small amount of oil can significantly increase flame radiation. In both of the co-firing examples, the results indicate that the flame radiation within 600-1100nm (visible and near IR range, which is desirable for glass melting) approximately doubles with only 3% oil or 12.5% LPG co-firing (by thermal input).

Air Products has extended the capabilities of its successful Cleanfire combustion technology applicable to gaseous and liquid fuels to direct combustion of solid fuels for glass melting applications, specifically pulverised petroleum coke (petcoke) and pulverised coal.

The most attractive features of petcoke are its high heating value, relatively low price and little ash content. Petcoke has been around since oil refining began, but booming production of tar sands bitumen and other heavy oils has dramatically raised production in recent years[1]. In 2015, production is expected to grow to 161 million tonnes per year with main sources in Brazil, China, India, Spain, Taiwan, Canada, USA, Venezuela and South Africa[2]. As a result, the increased supply has created new demand and opened markets for this fuel, including glass manufacturing.

One of the major challenges associated with the use of petcoke in traditional air-fuel combustion is the difficulty of ignition and maintaining flame stability due to its low volatile matter content. For that reason, the combustion space of air-petcoke fired glass furnaces generally looks hazy due to unburned fuel and airborne particulate matter, which could have adverse effects on glass quality and fuel efficiency.

The large amount of this 'fugitive' fuel also has a negative impact on furnace refractory life (walls and regenerators) as it creates reducing conditions throughout the furnace. An alternative to air-petcoke firing is the Cleanfire oxy-

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fuel burner technology which generates stable and attached oxy-petcoke flame and produces efficient combustion of pulverised petcoke with a combustion space clear of dust and unburned fuel.

Fig 4 shows the oxy-petcoke flame produced by Cleanfire HR*i* solid fuel burner technology. For increased flexibility, the Cleanfire HR*i* solid fuel burner fits into the same burner block as Cleanfire HR*i* natural gas and Cleanfire HR*i* oil burners, making the on-the-fly conversion between the fuels relatively easy, minimising production interruptions. The combination of a stable luminous flame and a clear combustion space allows fuel savings and increased glass quality compared to traditional air-fuel combustion of petcoke.

Air Products has also developed round flame solid fuel burners that are fully interchangeable with the existing Cleanfire Gen1 natural gas and oil burners. The solid fuel burners can be used as i) primary oxy-fuel burners, ii) oxy-boost burners, and as iii) oxygen-enriched fuel nozzles for under-port and side-port firing in glass melting furnaces.

Several commercial oxy-petcoke demonstrations are currently planned for glass melting furnaces in Asia.

Fig 5 illustrates principal operating cost components of a typical 300 metric TPD regenerative glass furnace before and after converting to oxy-fuel for two different fuels, ie natural gas and petcoke. The analysis reflects current typical fuel prices in China, $18 and $9 per million Btu for natural gas and petcoke, respectively. The price of petcoke includes preparation cost of petcoke, including drying, grinding and transportation, having a sulphur content less than two weight percent.

▼Fig 4. Oxy-petcoke flame produced by Cleanfire HR*i* solid fuel burner.

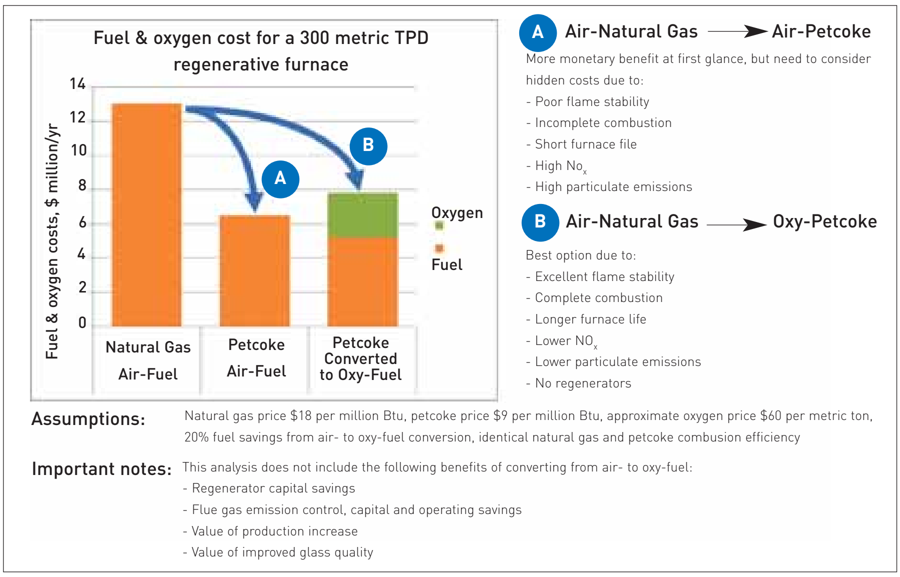
The assumed price of oxygen is approximately $60 per metric ton (on-site supply such as VSA). This analysis does not include multifaceted benefits of converting from air- to oxy-fuel, such as elimination of regenerators, reduction of gaseous and particulate emissions, value of production increase and improved glass quality. Rather, it solely represents a comparison of the cumulative fuel and oxygen cost (where applicable), which are the principal operating costs.

Fig 5 shows that, replacing natural gas with petcoke in a natural gas fired 300 metric TPD regenerative furnace can provide annual savings in excess of $6 million. However, as mentioned earlier, traditional air-fuel combustion of petcoke in glass furnaces introduces challenges with an unfavourable impact on glass quality, fuel efficiency, gaseous and particulate emissions and furnace refractory life. One way of overcoming these challenges is, converting these furnaces to oxy-fuel via the Cleanfire combustion technology to achieve a stable luminous flame with minimal carryover of unburned particulate, as depicted in ***Fig 4***. Accordingly, replacing natural gas with petcoke in a natural gas fired 300 metric TPD regenerative furnace, and concurrent conversion to oxy-fuel can bring annual operating cost savings in excess of $5 million.

Results suggest a potentially strong economic case for replacing natural gas with petcoke, with reliance on Cleanfire oxy-fuel burner technology to assure high efficiency, reliable combustion and minimisation of upset to glass product quality.

In today's volatile global economy, it is more important than ever for glass manufacturers to be well prepared against large fluctuations in fuel prices and diversify their process capabilities.

Air Products can help mitigate the glass manufacturer's risk by offering fully integrated oxy-fuel combustion solutions that can effectively utilise less expensive alternative fuels. ■



▲Fig 5. Fuel and oxygen cost for a 300 metric TPD regenerative furnace.

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[2] Goral D, Wylenzek A, "The efficient coal alternative. Petroleum coke fired CFB boilers in Europe" Coal Gen Europe, Warsaw, Poland, February 14-16, 2012

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