Oxy-fuel technology offers rapid solution to fouled regenerators

Regenerator fouling in glass furnaces is not uncommon and can cause costly downtime at industrial glass melting plants. Mark D'Agostini et al introduce an oxy-fuel technology that can provide a safe and comprehensive solution for rapidly restoring furnaces to full production.

Regenerator fouling and degradation over the course of a glass furnace campaign, sometimes resulting in collapse of checkers, is not an uncommon occurrence at industrial glass melting plants. While the susceptibility to fouling can vary widely with factors such as batch composition, checker design and furnace operating characteristics, the consequences - typically reduced pull rate and shortening of the furnace campaign - are never welcome. Take, for example, the situation of a fouled regenerator-induced 50 tons/day pull rate reduction on a float glass production line designed for 650 tons/day. The loss in revenue for such a scenario can be as high as $20,000-$30,000 per day. Moreover, the duration of checker repairs, when they can be carried out, can easily exceed a month. The financial incentive for a safe and rapid solution that restores the furnace to full production is therefore extremely high.

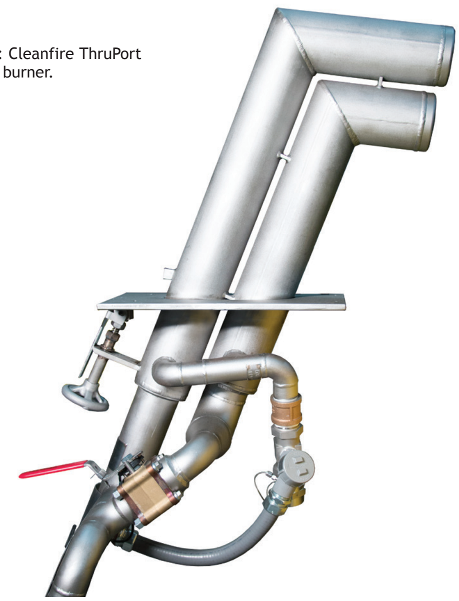
PATENTED SOLUTIONS

In response to this industry need, Air Products offers its patented* Cleanfire ThruPort and ThruPort$_e$ oxy-fuel burner technologies. Shown in figure 1, the water-cooled ThruPort burner, with its signature 'periscope' configuration, comprises two lances; one terminating in a nozzle that delivers precision mixing of (primary) oxygen and fuel (either natural gas or fuel oil) to produce a highly luminous oxy-fuel flame and the other introducing secondary or staged oxygen beneath the flame.

The staged oxygen, which can be varied in proportion to the primary oxygen via an integral manual control valve, allows for variability of flame length, while ensuring that flame radiation is directed principally down to the glass melt. Moreover, flexibility in burner mounting facilitates up-tank or down-tank angling of the flame, while inclusion of a burner tilt angle mechanism enables vertical nozzle adjustments that ensure optimal flame proximity to the glass surface.

Installed upwards through the port bottom as depicted in figure 2, the ThruPort and ThruPort$_e$ burners deliver high efficiency, low NO_x emission, oxy-fuel powered energy across the melting surface (figure 3). When combined with Air Products Express Services' expedited, temporary liquid oxygen delivery service and the company's experienced Glass Applications team, a prompt and comprehensive solution emerges.

Figure 1: Cleanfire ThruPort oxy-fuel burner.



SUCCESSFUL INSTALLATIONS

Recent successful experiences deploying the ThruPort burner solution include a one month application at a 650 tons/day float glass furnace, with compartmentalised checkers undergoing

		Baseline	Fouled Regenerators	ThruPort$_e$™
Pull Rate	TPD	650	600	650
Fuel Firing Rate	MMBtu/hr	163.0	149.9	147.1
Air Flow Rate	scfh	1,681,100	1,512,990	985,000
Air Preheat Temperature	deg C	1250	1250	1250
Oxygen to Boost Burners	scfh	30,000	30,000	30,000
Oxygen Flow Rate to ThruPort$_e$ Burners	scfh	0	0	60,000
Oxygen to Lances	scfh	0	0	40,000
Glass Temperature at Throat	deg C	1296	1270	1286
Flue Gas Temperature	deg C	1501	1476	1321
Specific Energy Consumption	MMBtu/ton	6.02	6.00	5.43

Table 1: Key inputs and results from CFD modeling of the Cleanfire ThruPort burner technology in a 650 tons/day float glass furnace.

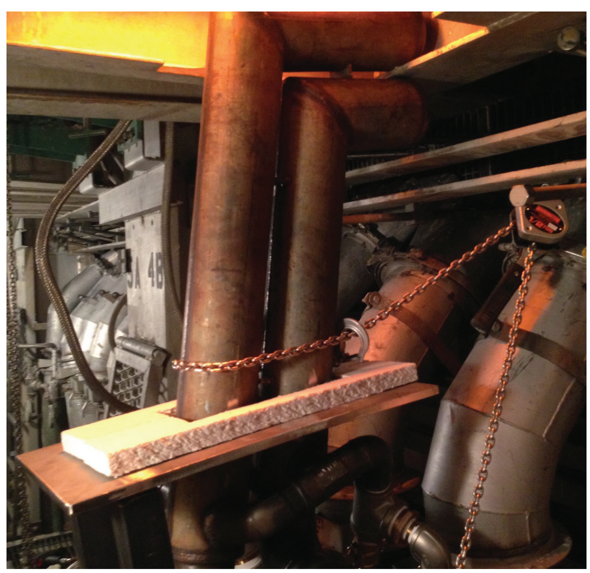


Figure 2: Cleanfire ThruPort burner installation from the underside of regenerator port.

checker repair and a seven month 'end of campaign' service period at another 650 tons/day float glass plant with fouled regenerators. Full production was achieved in both instances with substantially increased energy efficiency relative to baseline operation. In the first case, two ThruPort burners were sequentially installed in different ports of the compartmentalised regenerators as hot repairs were carried out; initially in the #3 right and #4 left ports, followed by the #5 right and left ports, both for two week periods. In the latter furnace, where pull rate had been reduced from 650 to 600 tons/day due to a regenerator-induced combustion air flow restriction, two burners were again installed, this time in the #4 right and left ports, for the duration of the campaign.

Computational Fluid Dynamic (CFD) modeling was carried out for the seven month end of campaign ThruPort burner application to better illustrate performance characteristics and benefits. Three operating scenarios were simulated and validated versus plant data. The first was for baseline full load air-fuel operation with zero-port oxy-gas boost burners. The second case, again with air-fuel plus zero-port oxy-boost, simulated the restricted air flow and reduced pull rate caused by the fouled checkers, while the third case modeled operation of the ThruPort burners in the #4 ports (oxy-boost still operational), with full pull rate restored.

As shown in table 1, the ThruPort burners were each operated (continuously) at a firing rate of nominally 15 MMBtu/h, while oxygen lancing was also utilised. Additional key input parameters and results for the three scenarios are likewise summarised in table 1, while temperature contours in a horizontal plane through the combustion space for the baseline and ThruPort cases are provided in figures 4 and 5.

With reference to these figures, several features are apparent upon inspection. One is that the addition of the two ThruPort burners in the #4 ports (figure 5) generated high temperature flames directly above the hot spot of the glass melting tank, which is ideal for reinforcing critical glass recirculation flow patterns and increasing glass residence time in the melter. The high temperature flame is a key feature of oxy-fuel combustion that proceeds from the elimination of nitrogen and produces substantially higher rates of radiant heat transfer to the glass melt as compared to air-fuel combustion; even when the air is preheated to 1250ºC!

It is important to emphasise in this regard that the ThruPort burners are capable of staging up to 90% of the oxygen beneath the primary oxygen fuel nozzle. Hence, the majority of the flame radiation, which occurs on the underside of the flame, is prevented from reaching and potentially overheating the furnace crown through the shielding afforded by the optically-restrictive fuel-rich mixture.

A second salient feature of the comparison between the baseline and ThruPort cases is that the temperature distribution in the vicinity of the refining zone is more uniform with the ThruPort burners relative to the baseline case. This is beneficial for process stability and reduction of thermal stresses. Finally, use of the two ThruPort oxy-fuel burners resulted in a reduction in the average flue gas temperature of 180ºC compared to baseline. Consequently, the specific energy consumption dropped from 6.02 MMBtu/ton pulled glass for baseline operation to 5.43 MMBtu/ton for the ThruPort case, an efficiency improvement of nominally 10%, representing an additional benefit accrued due to oxy-fuel combustion.

SMART BURNER TECHNOLOGY

In keeping with its vision of developing the Industrial Internet of Things (IIoT) by deploying 'smart' burner technology, Air Products offers the ThruPort$_e$ burner with the option of state-of-the-art on-burner diagnostic sensors and wireless communications technology. This technology enables key operating personnel to instantaneously view burner operating parameters such as oxygen and fuel pressure, percentage of oxygen staging, cooling water flow rate and discharge temperature. At the user's discretion, data is conveniently and securely streamed from the on-burner transmitters to the control room or remote computers and smart devices, providing up-to-date information concerning stability of burner operation, which is so crucial to this type of emergency operating situation. ■

**Cleanfire is a registered trademark of Air Products and Chemicals Inc and ThruPort / ThruPort$_e$ are grade designations under that trademark covered by one or more patents and pending applications, including US 9,221,704.*

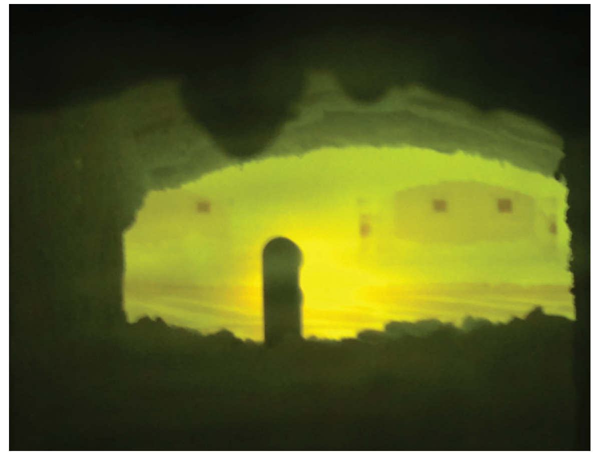


Figure 3: Cleanfire ThruPort burner in service during a regenerator repair.

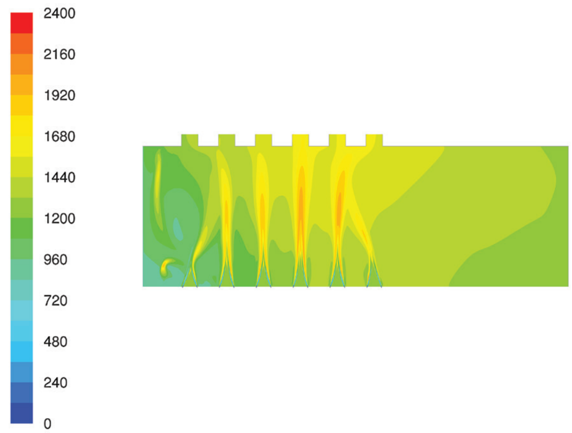


Figure 4: CFD-predicted combustion space temperature profile (ºC) for baseline air-fuel operation with zero-port boost burners.

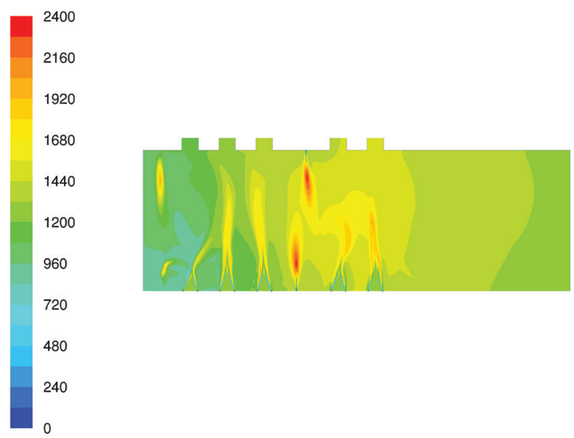


Figure 5: CFD-predicted combustion space temperature profile (ºC) with Cleanfire ThruPort burners in ports 4, right and left.

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