THE NEXT GENERATION OF COMBUSTION TECHNOLOGY FOR ALUMINUM MELTING

Eliminating the Drawbacks of Regenerative Burner Systems

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Abstract

This paper will discuss the latest developments in the area of regenerative combustion systems. Field data from the newest generation of Ultra Low NO_X and High Efficiency Regenerative systems are used to demonstrate that these systems represent the standard by which alternative combustion system types should be judged.

The new generation of regenerative burners will be shown to be technologically superior to other types of combustion systems in the areas of fuel efficiency, emissions (NO_X, CO_2 and particulates) and productivity. Furthermore, the drawbacks to previous regenerative systems have been reduced or eliminated.

The author concludes that the new generation of Ultra Low NO_X Regenerative Burners should be installed on all continuous (sidewell) aluminum melters, and should also be strongly considered for most batch-type melters.

Introduction

Regenerative burner systems have been commercially available for use on aluminum melting furnaces for over 10 years. There are in excess of 80 melters in the US and Canada equipped with regenerative combustion systems of various types. Despite the proven benefits of ultra high fuel efficiency and high productivity, many plants remain reluctant to adopt this technology.

The chief reasons for avoiding regenerative technology have been high NO_X emissions, excessive maintenance and initial cost. For example, some early systems had NO_X emissions well in excess of 840 ppmv @ 3%O_2 (1.0 lb/mmBTU-HHV). Most new projects now require emissions near 84 ppmv @ 3%O_2 (0.1 lb/mmBTU-HHV) or less. Several years ago, exhaust gas recirculation (EGR) systems were developed which achieved acceptable NO_X values, but resulted in additional costs, maintenance and efficiency losses. Maintenance costs for regenerative burners and heat-exchange media have in some cases substantially offset the fuel savings.

Finally, higher initial equipment costs have caused some users to avoid regenerative systems, despite the typical 50-60% fuel savings available.

Clearly, there has been need for improvement in several areas of Regenerative Technology in order to increase the attractiveness of these systems.

Recent Developments

Bloom Engineering conducted a major research and development effort in order to address the problem of high NO_X emissions from regenerative burners. While further research will continue, a major breakthrough in the past two years has lead to the release of the Bloom LumiFlame burner design. The LumiFlame burner concept is shown in Figure 1.

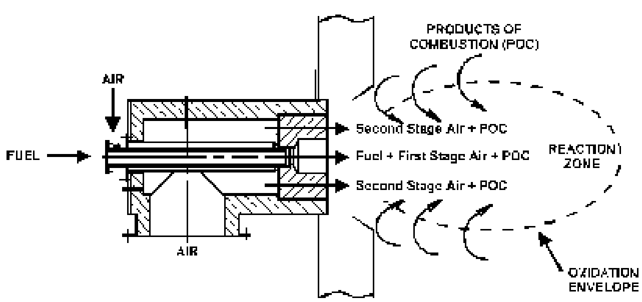

Figure 1: LumiFlame Ultra Low NO_X Concept

The concept of internal furnace POC (products of combustion) recirculation into the root of the flame for NO_X reduction is well known. However, until recently the NO_X levels achieved using this technique with regenerative air preheat levels remained excessive. EGR was therefore required in most cases. Bloom employed its state-of-the-art laboratory facilities in a unique combination of laboratory-scale burner testing and Computational Fluid Dynamics (CFD) modeling to study the problem and optimize burner design and performance. CFD was also utilized to study the impact of burner design on flame heat transfer characteristics, to insure that the resulting designs would produce flames suitable for aluminum melting applications.

Key Design Characteristics of the LumiFlame Burner Include:

1) A simple, rugged high alumina "baffle" which is used to create the necessary air and fuel flow jet patterns for ultra low NO_X emissions, as well as providing support for the fuel nozzle and shielding the burner internals from furnace radiation.

2) "First stage" air port, used to provide stable operation at furnace temperatures below 980^oC. Air is fed to this port to provide cold start and low temperature batch furnace modes, while still achieving extremely low NO_X and good efficiency. Figure 2 illustrates the efficiency of LumiFlame regenerative burners compared with cold air combustion.

3) Unique High Luminosity/High Heat Transfer flames on gas or fuel oil operation.

4) Adjustable directivity, to optimize the flame for various furnace types. For example, flames can be directed toward the aluminum bath of a sidewell melter, without the problem of excessive burner velocity (which can lead to excessive dross formation by constantly exposing fresh metal). The luminous, medium velocity flame pattern is similar to previous versions of Bloom melting furnace burners.

5) The oxidizing medium (in this case high-preheated air) shrouds the fuel, such that contact between reducing atmosphere gases and product to be heated is minimized.

6) Exhaust Gas Recirculation equipment is not employed. Essentially, the "vitiation" effect of EGR is accomplished using the internal burner/port geometry.

The LumiFlame system has now been successfully installed on two 108,844 kg (240,000 lb). sidewell-charged melters at Alcan Rolled Product's Oswego, New York plant. The preliminary operating test results indicate that the systems produce extremely low NO_X emissions and extremely low CO emissions at very high air preheat levels, combined with excellent heat transfer capabilities due to Bloom's proprietary luminous flame technology.

The systems recently installed at Alcan-Oswego consist of one pair of Bloom model 1151-200 LumiFlame Ultra Low NO_X burners. The burners are configured to fire natural gas, light oil or both simultaneously, allowing substantial flexibility depending on fuel costs and availability. The furnaces are controlled using PLC hardware and PC-based HMI software in a network configuration designed to accommodate additional auxiliary equipment (current and future). Electronic mass flow controls for air/fuel ratio include lead/lag and cross-limiting logic, as well as several proprietary logic enhancements.

The widespread adoption of PLC control systems is making it easier than ever for plants to install and maintain the type of controls needed for regenerative burner systems. PID loop control, cycle-valve switching, alarming, trending, start-up/shutdown and trouble-shooting functions can now be incorporated into PLC/HMI equipment. The number and type of devices, which the electrical maintenance personnel must handle, is significantly reduced versus earlier systems.

In addition to the Ultra Low NO_X burner development program, Bloom has addressed other major drawbacks of previous regenerative burner systems as well. For applications with salt fluxing, the Bloom regenerative media beds can be provided with either a hinged easy-open cleanout door or completely removable media case (with compression-type no-bolt quick connector option). In either case, a spare amount of media on hand allows quick replacement and minimal burner downtime. The contaminated media is then cleaned off-line and can be reused many times.

Our maintenance history experience shows that concerns about high maintenance costs are unfounded (for direct-fired regenerative systems). Spare parts sales for Bloom regenerative systems applied to aluminum melters have averaged a small percentage of system initial cost per year, covering all burner and cycle valve hardware.

Performance

As shown in Figures 2 and 3, the Bloom LumiFlame concept employing High Internal POC Recirculation produces extremely low NO_X emissions, while maintaining high combustion efficiency.

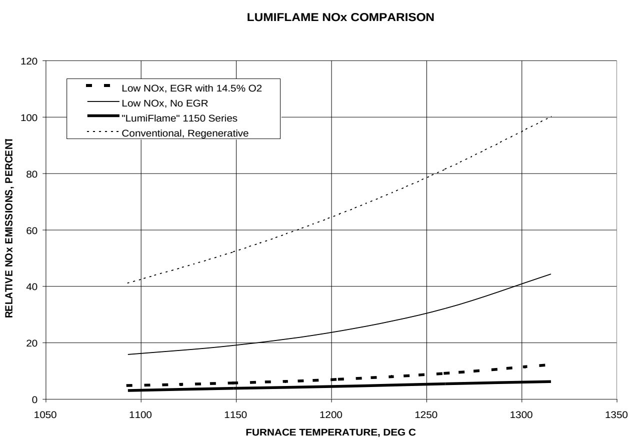

Figure 2: NO_X Curve

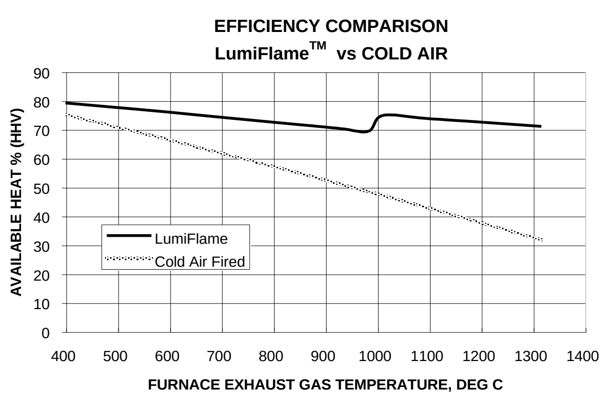

Figure 3: Efficiency Curve

Other "Low NO_X technologies" such as oxy-fuel or POC post-treatment have significant practical drawbacks in aluminum melter applications. For example, while pure O_2/CH_4 mixtures would produce zero NO_X emissions, nitrogen (N_2) will enter the process via the fuel, as well as tramp air into the furnace chamber in most real-world systems. Furthermore, the cost for oxygen must be factored in to any comparison with regenerative firing. Table 1 illustrates that oxy-fuel operating costs are more than double those of regenerative systems.

Table 1
Operating Cost Comparison Per Hour For
10 mmBTU/hr (2.52 x 10^6 Kcal/hr) Net Heat Input to Furnace

	Cold Air	Recuperative 500°C Preheat	Regenerative	Oxy Fuel
Equivalent Burner Input (10^6Kcal/Hr)	8.09	5.27	3.54	3.54
Natural Gas (NM^3)	909	594	399	399
Fuel Cost ($)	96.20	62.90	42.20	42.20
Oxygen (NM^3)	-	-	-	913
Oxygen Cost ($)	-	-	-	80.52
Electrical Cost for Blowers ($)	1.97	2.67	2.74	-
Total Cost/Hr ($)	98.17	65.57	44.94	122.72

Basis:
- Efficiencies calculated on furnace exhaust gas temperature of 1300°C
- Fuel Cost $3.00/MM BTU
- Oxygen Cost $0.25/ccf (liquid oxygen)
- Electricity Cost $0.075/kWh

Since oxygen production itself consumes substantial energy, the cost comparison results are unlikely to change for the foreseeable future. The net environmental 'benefit' for oxy-fuel is also questionable when the power generation required for oxygen production is factored in.

Catalytic or other post-treatment systems typically require specific reaction temperature windows, which are difficult to achieve continuously on process furnaces such as aluminum melters. We are currently unaware of any domestic industrial melting furnaces utilizing a post-treatment NO_X suppression system for the POC gases.

Carbon monoxide (CO) emissions from a properly tuned conventional combustion system are generally below 50 ppmv (corrected to 3% O2). Field data from the Alcan-Oswego furnaces have confirmed that the Bloom LumiFlame system produces significantly less than 50 ppmv even at low excess air levels.

Carbon dioxide (CO_2) is emitted in direct proportion to the amount of fuel consumed for all hydrocarbon (fossil) fuels. Since regenerative firing results in the highest available combustion efficiencies, CO_2 emissions are minimized, as illustrated in Table 2:

Table 2
Efficiency and CO_2 Emissions
Basis: 1300°C Furnace Exhaust Gas Temperature

Type of System	Air Preheat Temp °C	% Available Heat-HHV	kg CO_2 Emitted per kcal x 10^6 Net to Process
Cold Air	21	32	675
Recuperative	500	49	440
Regenerative	1130	71	300

Another area of advantage for regenerative systems on melting furnaces is that the regenerator media acts as a filter of POC particles, such as salt fines and dross particles. By filtering and returning much of this material to the furnace, particulate emissions are significantly reduced compared to conventional burner systems. Furthermore, the POC exhaust volume and temperature is much lower than conventional systems, so that in the event that baghouse collection were required, its size would be only a fraction of that needed when using cold air or recuperative systems.

Applications

Sidewell charged continuous-type aluminum melters represent the single best application of regenerative burners in the aluminum industry. We believe that Ultra Low NO_X regenerative burners can be justified for all new sidewell-charged aluminum melters. Also, retrofits will be economically justified in nearly all cases on these furnaces, due to the dramatic efficiency advantage for regenerative systems on continuous high temperature processes.

Batch-charged furnaces also are often good candidates for these systems. The economics of applying regenerative burners should be evaluated when planning new furnaces or modifications to existing combustion systems. Productivity increases can often be achieved via the proper application of regenerative burners. The LumiFlame system has been proven to provide excellent heat transfer rates while maintaining its low NO_X emissions over a wide range of design chamber temperatures.

As we have seen, the recent advances in Ultra Low NO_X Regenerative Burner Systems have eliminated or reduced nearly all of the perceived drawbacks for aluminum melter applications. The initial system costs can be quickly recovered in most cases due to reduced operating (fuel) costs, and the environmental benefits provide further justification for this technology.