A User's Experience With Retrofitting An Aluminum Melting Furnace With Low NO_X Regenerative Burners

Prepared by –
Charles R. Lied, Bloom Engineering Company, Inc.
and
Robert W. Klein, Vulcan Aluminum

ABSTRACT – New environmental requirements have resulted in innovative burner design techniques to reduce NO_x. Air-staged and fuel staged combustion techniques are currently being introduced in the marketplace. These techniques are being applied to regenerative burners that are reducing NO_x to a level less than many cold air burner systems achieve.

This paper presents field data comparing the original combustion system with the retrofitted low NO_x regenerative burner system. The data include melt rates, fuel rates, NO_x emissions, and CO emissions. The paper also outlines the importance of burner location and type of flame required to achieve these results.

A key issue in the decision making process is the maintenance factor when evaluating the installation of regenerative systems. This paper will present maintenance data from this installation and other existing regenerative installations.

INTRODUCTION

In early 1994, the management of Vulcan Aluminum decided to investigate the possibility of further reducing their energy costs for melting aluminum. Vulcan is an aluminum fabricator located in southern Alabama. Their primary business is designing, manufacturing, and marketing information signs and traffic signs throughout North America. When the sign says STOP or YIELD, changes are Vulcan is saying it.

PLANT LAYOUT

A single rectangular melting furnace is used in line with a horizontal sheet caster and a single stand rolling mill. This mill is used as both a hot mill and a cold mill.

When the caster is in operation, the furnace is tapped from a pump well raising the molten aluminum several feet to a filter box and caster tundish. Between casts, the furnace holds a small aluminum heel while waiting to be charged again prior to resuming casting.

ORIGINAL COMBUSTION SYSTEM

The original combustion system included two hot-air burners with a total fuel input of 14.6MM Btu/hr. The recuperator was designed to provide 800°F air preheat to the burners. The burners were individually controlled with a mass-flow system with the airflow measured on the hot-air side of the recuperator.

NEW COMBUSTION SYSTEM

The furnace was retrofitted with a new combustion system and controls. A Bloom Gemini Series low NO_X regenerative burner system was installed on the furnace. The Gemini series burner is rated at 8.55MM Btu/hr and produces a high momentum, fast mixing, luminous flame to optimize melt rates and fuel rates. The Gemini series low NO_X regenerative burner features air staging and self-recirculation to reduce NO_X. The self-recirculation is accomplished through optimizing the design of the baffle and port to recirculate furnace gases into the flame.

CONTROLS

Vulcan decided to design and engineer the control system in-house because there was existing equipment that could be reused and Vulcan had the in-hour capability and expertise. Bloom provided the functional specification for the controls.

The control system includes three main parts:

- Flame safety system
- Furnace controls
- Operator's work station

The flame safety system consists of hard-wired relays and timers. This system controls the purge and ignition sequencing and monitors critical process conditions. If any abnormality is detected, the gas to the furnace is shut off.

Furnace controls were added to an existing programmable controller that also controls the caster. The programmable controller was expanded by adding 32 digital inputs, 32 digital outputs and 16 analog inputs. In addition, the ladder program was expanded to perform the furnace control functions.

The following functions are performed by the furnace controls:

- Linearize and scale air and gas flow inputs from DP transmitters
- Control air flow
- Control gas flow
- Control air/gas ratio
- Control bath temperature
- Control furnace pressure
- Perform burner sequencing
- Perform alarming
    - Bed over-temperature
    - Bed plugging
    - Exhaust header over-temperature
    - Flame failure
    - Cycle valves failure
- Format information for display on the operator's workstation.

The existing operator workstation **(Figure 1)** used for the new caster was also expanded to perform and monitor furnace functions. The workstation used an industrial personal computer running a Supervisory Control and Data Acquisition (SCADA) program. Communication with the programmable controller was through an RS-232 port. Since the caster operators must monitor the furnace parameters during the cast, six new displays were added:

Figure 1

- Furnace overview
- Furnace setup
- Temperature control
- Damper/exhaust control
- Cycle display
- Alarm display

FURNACE OVERVIEW

This display gives an overview of the furnace status including furnace temperature, exhaust damper position, and furnace pressure **(Figure 2).**

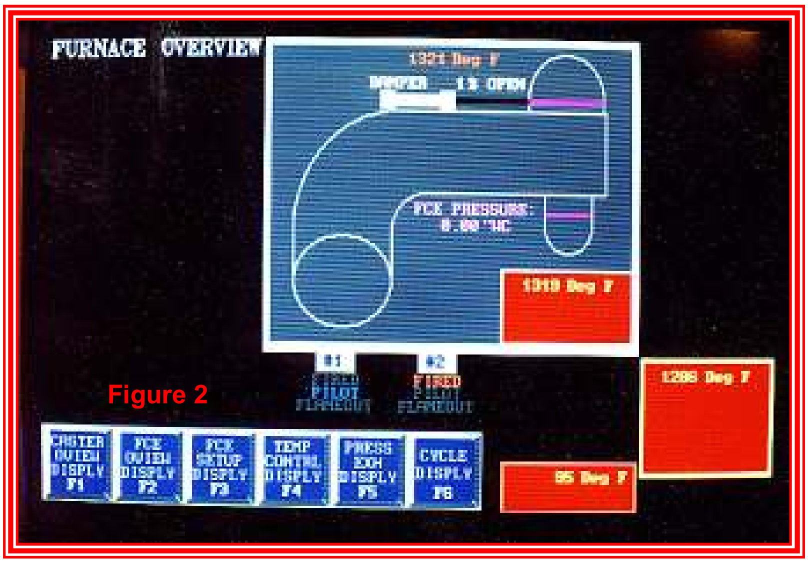

Figure 2

FURNACE SETUP

This display is used to monitor the flame safety controls and the low-fire start system **(Figure 3).** There are two fault-finder indicators that:

- Monitor the safety limits
- Monitor the purge permissive.

In addition to the low-fire start system display, the operator can also select the mode of burner operation, i.e., bottled, conventional, or regenerative.

Figure 3

TEMPERATURE CONTROL

Figure 4

This display is used to set the bath temperature desired and also indicates the air/gas ratio of the burners (Figure 4). The bath temperature is controlled by changing the burner operation mode. There are four modes of burner operation used during the charging/casting cycle:

- ***Flux -*** The operator, prior to fluxing the furnace, switches the burners out of the regenerative mode to the fire forward mode and the burners are driven to low fire. This prevents the fluxing agent from being drawn into the beds and causing premature plugging.
- ***Charge -*** The bath temperature set point is set to the maximum operating limit.
- ***Normal -*** The operator sets the bath temperature set point within the operating limits.
- ***Low fire -*** The air and gas control valves are driven to their minimum positions.

These modes can be selected from the temperature control display or from a separate panel with illuminated push buttons.

DAMPER/EXHAUST CONTROL DISPLAY

This display **(Figure 5)** gives the operator access to the furnace exhaust stack damper and the burner exhaust valve controls. These controls are generally left in automatic; however, the controls can be changed to position the dampers manually if desired.

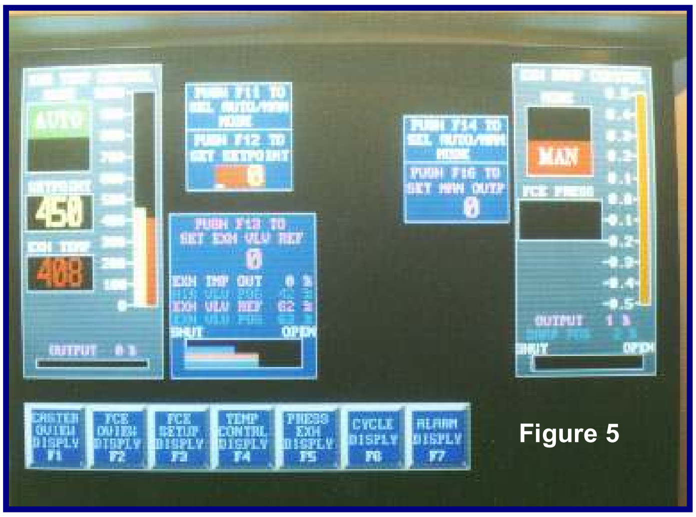

Figure 5

CYCLE DISPLAY

This display (Figure 6) is used to check and verify selected burner system functions including the cycle valve position, bed temperatures and cycle times of the burners.

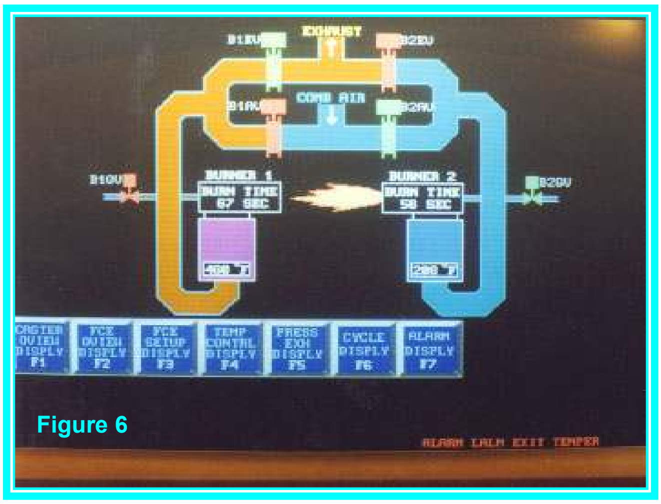

Figure 6

ALARM DISPLAY

This display **(Figure 7)** shows the following points:

- Alarm *(red)*
- Alarm, but acknowledge *(yellow)*
- Normal *(green)*

An alarm horn sounds when unacknowledged alarms are present.

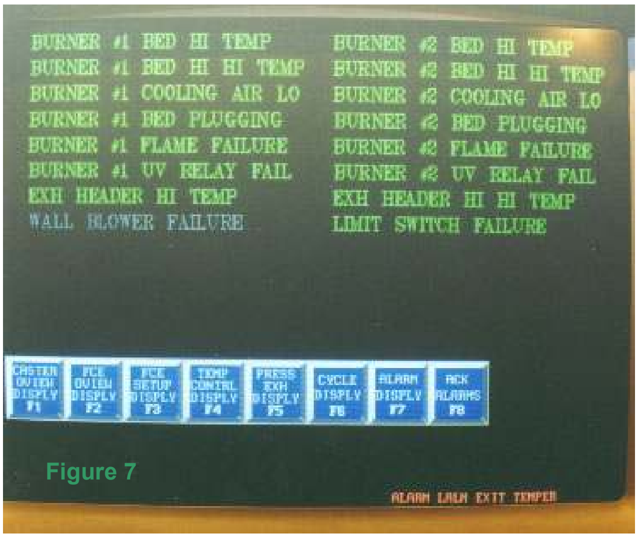

Figure 7

FURNACE DESIGN

The melting chamber of the furnace is L-shaped. The burners are mounted on a 12-foot wall on the east side of the furnace **(Figure 8).** Scrap is charged through a door on the south side of the furnace around the corner from the burners **(Figure 9).** There is a pumping well that is fed with molten aluminum through a port near the base of the burner wall.

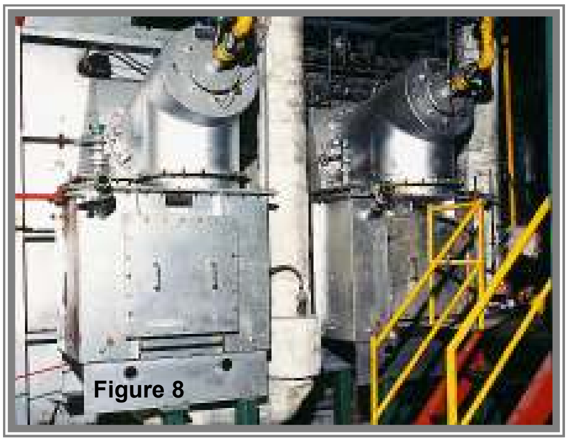
Figure 8

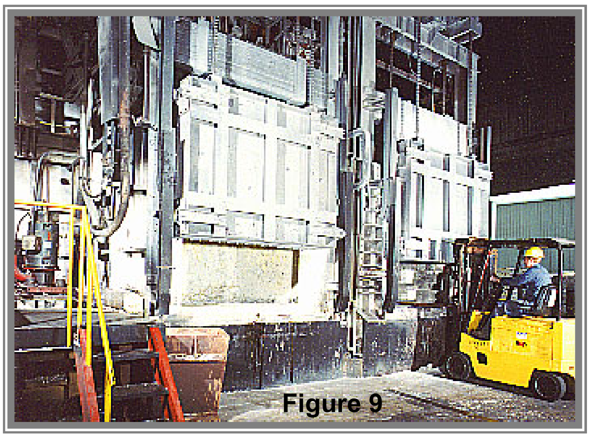
Figure 9

Aluminum is tapped and then pumped to the caster from this well during casting cycles. Metal is also circulated through this well, through a scrap charging well, and to the charging area of the melting chamber.

Only runaround scrap and some alloying metals are introduced into the furnace through the charging well. Other scrap is charged onto a shelf through the charging door, allowed to dry for approximately 20 minutes and pushed into the main bath.

The specifics of the furnace are as follows:

- Furnace capacity: 170,000 pounds
- Hearth area: 402 square feet
- Burner input: 8.5MM Btu/hr (instantaneous)
- Type of scrap: Baled prime; runaround
- Pump speed: 750 rpm, 6,000 pounds aluminum per minute
- Fuel: Natural gas
- Cycle time: 60 seconds

MELT RATE, FUEL RATE AND EMISSION TESTS

After the retrofit, melt rate, fuel rate and emission tests were performed. The furnace was charged with prime scrap pieces measuring 28” long by 6 ½” wide by 3” high and weighing 32 pounds each. These prime scrap pieces were bundled into a total scrap charge weighing between 4,100 and 4,600 pounds. The bundled scrap was charged onto a dry hearth through the side door of the furnace and allowed to dry for 20 minutes. At the end of 20 minutes, the bundle was pushed into the bath and melted. The resultant melt rate was 10,365 pounds with a fuel rate of 933 Btu/pound.

A 59% increase in melt rate was realized when data from a three-month period before the retrofit were compared to data collected for a three-month period after the retrofit.

Emission data were recorded at the following conditions:

- Firing rate: 8.5MM Btu/hr
- Excess air: 10%
- Furnace hot face temperature: 1800ºF

The amount of CO and NO_x produced was within the required specifications.

BED CLEANING

Salt is used as a fluxing agent in this furnace. Because of the salt fluxing, maintenance of the beds is required. The beds are cleaned approximately every four months and cleanings take about four hours per bed. When spare beds are available, the change takes one hour per bed.

CONCLUSION

The installation of new low NO_x regenerative burners and controls resulted in the following:

- A 59% increase in aluminum produced
- A 33% decrease in Btu per pound of aluminum produced
- Low NO_x per pound of aluminum produced

The test results prove that the installation of the low NO_x Gemini series regenerative burner system is economically feasible for a low production furnace with long period of holding time.