Automated Excess Air Control in Fired Heaters - Eliminating Burner Air Register Jackshaft/ Linkage Arm Assembly Reliability Issues with BUSA Compensator Retrofit

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Abstract

As the refining and petrochemical manufacturing industries navigate the transition to decarbonize production, increased attention has been drawn to combustion equipment efficiency and energy consumption. ExxonMobil's commitment to demonstrate leadership in this energy transition, as a responsible community partner, has driven increased efforts to reduce natural gas firing and improve combustion equipment efficiency across its global fired heater fleet. Even when a natural draft heater is properly sealed and the stack damper adequately controls the arch draft at design, there is often more combustion air entering the radiant firebox than necessary for optimal combustion at the targeted firing rate. This is especially true at reduced firing rates. To improve heater performance, operations personnel commonly rely on the ability to adjust the volume of combustion air entering the throat of the burner using the burner air registers. In older refining and petrochemical facilities, it is not uncommon to still find natural draft systems with manual air register control or outdated automated link connection assemblies. These systems often experience component seizing and assembly alignment issues which make it impossible to consistently achieve optimal combustion air and directly limit optimization efforts. Manual systems present a clear case for an upgrade, but automated link connection systems should not be overlooked as they can be prone to reliability challenges and are typically a good candidate for upgrades as well. Burner air register system retrofits can prevent reliability and operability issues experienced with existing air registers and the associated systems used to control them. Individual actuators (one per burner) and jackshaft/ linkage arm assemblies are two approaches to upgrading existing burner air registers. Both offer the ability to automatically adjust combustion air however, each has their drawbacks related to cost and performance. Neither address the issues with the burner registers themselves. ExxonMobil Baytown Refinery experienced many of these challenges on a 211 MM BTU/hr. splitter reboiler furnace with 24 burners actuated by jackshaft linkage/ arm assemblies driven by two pneumatic actuators.

This paper explores the challenges experienced with the automation of traditional burner air registers with jackshaft linkage/ arm technology, retrofit disadvantages of individual actuators, the results of retrofitting the system with the emerging Birwelco USA (BUSA) Burner Compensator technology, and lessons learned in a recent ExxonMobil retrofit.

Introduction

For the past ten years, the industrial sector has typically accounted for about one-third of the total energy consumed annually in the United States[1]. Based on analysis by the U.S. Energy Information Administration (EIA), the industrial sector consumed 35% of energy in the U.S. in 2022[2]. United States manufacturing depends heavily on power generation and combustion processes for production. A breakdown of energy end usage completed in the "Energy Use, Loss and Opportunities Analysis of U.S. Manufacturing and Mining" determined that fuels for boilers and direct fired systems comprise of nearly 60% of total primary energy use in the chemicals industry and 86% in refining[1]. Overall instability in energy prices coupled with alarming spikes has led to a sharp increase in efficiency related losses across manufacturing facilities with energy and combustion equipment performance gaps. Excess air is a key variable for heater efficiency and there can be process and economic consequences if this parameter is not optimized. Additional fuel consumption is required to heat excess air up to combustion temperature leading to unnecessary fuel consumption. Additionally, any excess air present (specifically the oxygen within the air) from lack of optimization promotes the formation of additional CO_2 and NOx greenhouse gasses. Improving the efficiency of combustion equipment translates to reduced fuel consumption for equivalent production, reduced overall emissions, and significant cost savings. For example, a 1 % increase in efficiency for a typical heater with a heat release of 100 MM BTU/hr. results in a fuel savings equivalent to approximately 40K$/yr. (at a fuel cost of 4 $ per MBTU).

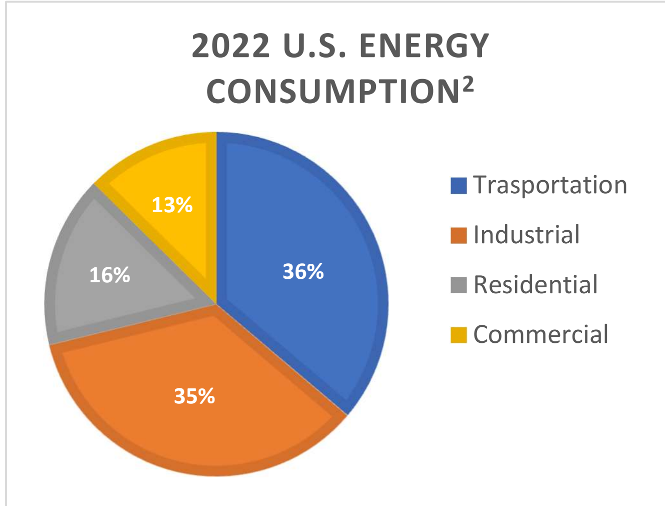

Figure 1: 2022 U.S. Energy Consumption by Sector
Energy Information Administration, Monthly Energy Review[2].

Background

Identifying actionable heater efficiency improvement opportunities can be a challenge as there are multiple components/ parameters that can impact heater performance. Heater performance gaps can be a result of issues on both the process and the combustion side of the equipment. This paper focuses on addressing performance gaps associated with lack of optimization of excess air for combustion. Utilizing the stack damper to maintain target draft at the radiant roof (arch) is, typically, not sufficient to keep excess air at ideal levels. Radiant firebox geometry, burner design margins and even prevailing wind direction all contribute to the levels of excess air present inside the firebox during operation. These factors become magnified when the heater is operating at turndown rates as the volume of air required for safe operation is significantly less than that of design. In practice, an oxygen analyzer is used, preferably at the arch, to measure the amount of oxygen (O_2) present in the flue gas that results from the complete combustion of the fuel. Any oxygen being measured by the analyzer is excess remaining from the air introduced through the burner for combustion. Heater operational testing plays a role in the development of the target amount of air needed for complete combustion, minimum emissions, and burner stability. Based on these test results, a corresponding excess O_2 is determined and used as a target to maximize heater efficiency. Determining the appropriate O_2 targets for any heater and consistently maintaining those targets during operation can yield significant improvements in heater performance. The traditional approach to maintain heater target O_2 is to trim the excess air using the existing burner air registers. For most designs in service today, the burner register consists of two blades, each with a central shaft. Opening and closing of these blades, typically opposed movement, is achieved through a linkage between the shafts operated by hand through a locking handle. Overtime, corrosion issues, lack of regular use, and lack of inherent maintainability in the design combined with less than adequate design of burner air register control systems (when automated) has often led to regular seizing/ stiffness of assembly components. This results in inoperability of these systems which effectively disables excess O_2 optimization capabilities. The best way to achieve sustainable efficiency gains from O_2 optimization is to enable the system to automatically adjust air registers to maintain proper O_2 targets reliably for full range of operation, responding to changes in firing rates as they occur. Sporadic, impulsive variation in the flow of combustion air through the throat of a burner will lead to poor burner performance, at best, possibly causing the burner to flame out.

The journey to achieve sustainable heater performance has led to developments in fired heater burner air register controls. The two approaches to automation focused on individual actuation for each burner and group (linked) actuation. In recent years, some heaters have employed the use of an individual actuator at each burner to control the burner air register. This option offers precise control of each burner register but this option can be very expensive depending on the heater and number of burners. It is often required that the existing burner register be upgraded or replaced entirely with a more robust damper design. In addition, for a retrofit there may be challenges such as available input and output (I/O) count, congestion at the heater for hardware, or limited space to accommodate this option. The resulting increase in maintenance and calibration also becomes a factor. As a result, retrofitting systems with individual actuators at each burner can quickly become impractical.

Other heaters have employed a single rotary actuator for a group of burners, typically one actuator per row of burners, commonly referred to as a jackshaft system. This system is a more economically viable option as there are fewer actuators to install and maintain. The actuators are linked to multiple burner air registers via a rotating drive shaft with individual rod linkages to provide the connection between drive shaft and the burner register as shown in figure 2. This system of drive shaft and jackshaft rods, allows the burner air registers to move in unison. This reduces instrumentation, hardware cost, and engineering hour demand. However, beyond potential issues with the burner registers themselves, this approach is

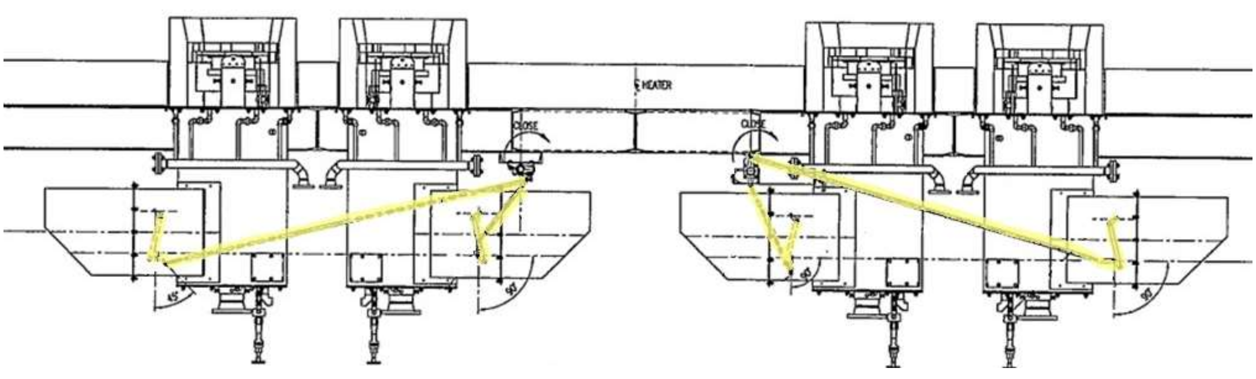

Figure 2: Fired Heater burner with jackshaft linkage/ arm connection assembly.

Figure 3: Fired Heater burner with jackshaft lever rod connection to burner register assembly shown.

often prone to reliability vulnerabilities associated with the multiple jackshaft rods used to join multiple burner air registers to a single actuator drive shaft. This approach to automation is shown in figure 3 with a jackshaft linkage/arm assembly attached to the burner register shaft. Assembly alignment and reliability issues are two major problems with Jackshaft linkage/ arms assemblies. Overtime, these systems are prone to alignment issues associated with shifting, sagging, flexing, and bowing of the linkage arms as well as loosening bolts and increased play (hysteresis) at the linkages knuckles. This deflection/ play is often made worse when the burner registers themselves become difficult to open/ close or freeze in position. The metal assembly components can also experience corrosion issues creating additional vulnerabilities, like component seizing, and other frequent reliability challenges. These issues typically lead to an increased need for maintenance and recalibration together with increased reliability events associated with seizing or hysteresis (where the assembly movements lag controls in a random and unpredictable way). These unpredictable movements impact the ability of the overall system to uniformly respond, ultimately resulting in different burners allowing for a different volume of air to enter at any one point in time. The overall jackshaft system is driven by a pneumatic rotary actuator. Overshoot of the actuator position can often occur as the compressibility of the air works against the operation as the resistance to the movement varies. This makes it a challenge to have smooth adjustment of the air flow through the burners. Due to the frequent reoccurrence of maintenance issues, burners using jackshaft linkages are generally not operating anywhere close to optimum efficiency. ExxonMobil Baytown Refinery is not immune to these challenges. The hydrofining unit operates a splitter reboiler furnace with 24 dual gas burners. This furnace is equipped with a jackshaft linkage/ arm assembly driven by two pneumatic actuators, each controlling twelve burner air registers. The burner registers are connected to the actuator driver bar using a lever arm and connecting rod assembly as shown in figure 4. This furnace had experienced several months of efficiency related loss due to increased maintenance and reliability issues associated with the jackshaft linkage/ arm assembly. Normally, in automatic control the heater could operate within one percent of the excess O_2 target with movement of the air registers. However, due to corrosion issues, reoccurring linkage seizing, and alignment challenges of the jackshaft assembly, the operations team had to switch from automatic to manual

Figure 4: Fired Heater burner with jackshaft rod connection to actuator drive shaft shown.

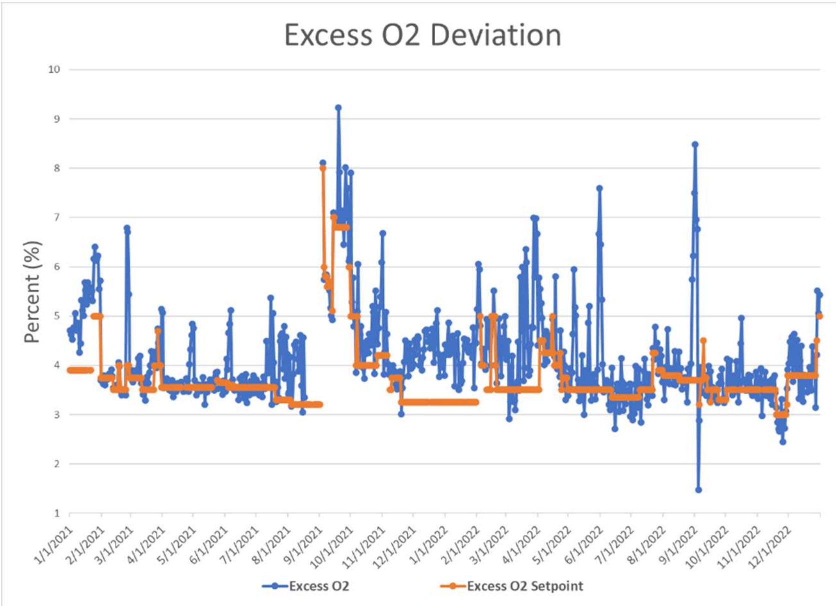

Figure 5: Excess O_2 vs Setpoint for 2021 and 2022.

control of the burner air registers leaving the system incapable of consistently maintaining O_2 targets. In addition, the team was forced to operate the heater with a significant O_2 cushion to mitigate operational concerns associated with reaching insufficient air due to frequent variation in firing rate and fuel composition. Figure 5 highlights the regular challenges experienced with meeting O_2 targets and maintaining setpoints due to corrosion, seizing, and regular operability challenges. From October 2021, the energy loss associated with inefficient operation for the heater rose steadily from 4 MMBTU/hr. to a consistent range of 12 to 20 MMBTU/hr. due to air register reliability challenges. This led to nearly 1 million dollars in losses due to excessive fuel usage for this heater.

Methodology

To mitigate losses associated with the jackshaft linkage/arm assembly alignment and reliability issues the team evaluated three retrofit options, replacement in kind, installation of individual actuators at each burner, and installation of Birwelco USA Burner Compensator technology. A replacement in kind was eliminated solely based on the challenges operations personnel experienced with the jackshaft system assembly shortly after installation in 2003. The cost of installing individual actuators on each of the 24 burners was a major disadvantage for this option. In addition, the congestion under the heater, the lack of spare I/O, and instrument air pressure challenges in the area made this option unfeasible. The team implemented the new Birwelco USA Burner Compensator system which was the more cost-effective option and addressed the reliability challenges typically experienced with the jackshaft linkage/ arm assembly. BUSA's Compensator System consists of individual compensators units (one per burner) linked together with a rigid thrust bar which can be straight or round depending on heater configuration. Each compensator travels in a horizontal motion. The horizontal travel experienced by each compensator's slide plate during operation changes the cross-sectional area of the combustion air openings. This allows the air to enter the burners, and provides the necessary compensation in air control, which is not possible with the stack damper alone. This horizontal motion is driven by a REXA Electraulic linear actuator. Implementation of this simple bolt on application, pictured in figure 6, shows that when applied in retrofit applications BUSA Burner Compensators can eliminate reliability concerns of rotating link connected assemblies. In addition, this technology facilitates smooth control by eliminating position overshoot challenges often seen with pneumatic actuators.

Birwelco USA Burner Compensator technology offered several benefits compared to the previously discussed approaches that relied on the use of the existing burner registers. These benefits include update of actuator technology, elimination of rotating linkage connections, and ability to install the design while the heater remains in operation. The BUSA design as configured for this heater, consisted of four new REXA Electraulic linear actuators as show in figure 7. These actuators offer high response time, accuracy, and the travel repeatability required for the compensators to provide optimum O_2 control. Being a closed system, the hydraulics driven by an electric motor, electraulic actuators do not suffer from the performance and maintenance issues associated with instrument air. As with dampers, the Compensator system can be designed to fail last position or to fail in other modes based on owners control philosophy. Elimination of the jackshaft linkage/ arm assembly improves system reliability by eliminating the multiple failure points of the system. Most importantly, the simple bolt on design allowed BUSA to design, fabricate, test functionality, install and calibrate all 24 burner compensators without interrupting operation. This is a critical benefit allowing the team to capture the value of heater performance improvement while avoiding margin loss and associated outage costs.

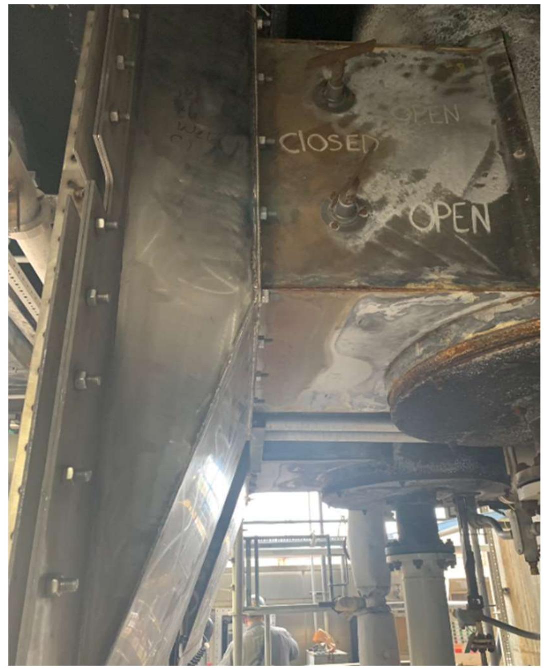

Figure 6: Birwelco USA Burner Compensator fit up to existing burners.

Additionally, all 24 burner compensators can be controlled simultaneously with four electraulic linear actuators. The installation was designed to have one actuator per row of burners firmly attached to a thrust bar which in turn, is pinned directly to each compensator sliding plate assembly. The compensators are designed around the existing burner design, ensuring that any additional pressure drop at the intake of the burner is minimal so as not to impact the burners performance when firing at 100% capacity. The customized air intake, shown in figure 8, is designed to achieve a significantly more linear correlation between position and associated pressure drop. Openings are calibrated in size and shape to allow uniform consistent adjustment of the air entering every burner. The design of each individual compensator is compact, in many cases replacing the existing burner scoop intake duct and extending no lower than the existing burners. Unlike the existing jackshafts, a ridged thrust bar drives one row of the compensators. Each thrust bar runs the length of the heater, and the attachment between the thrust bar and each

Figure 7: REXA Electraulic linear actuator driving Birwelco USA Burner Compensator assembly thrust bar.

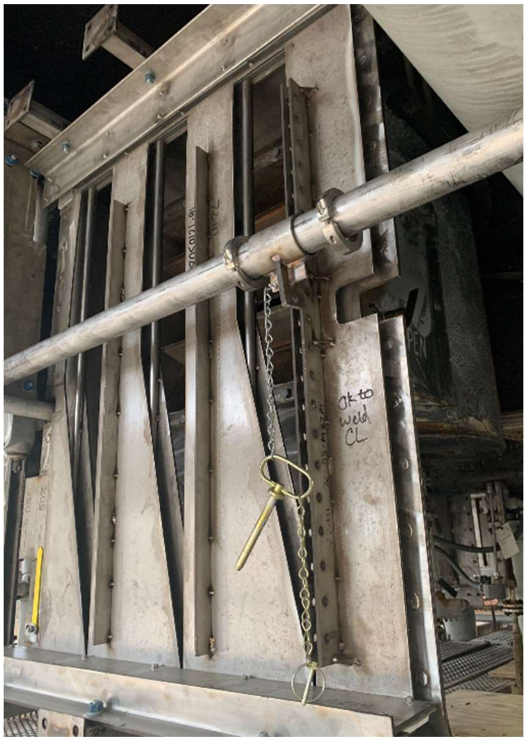

Figure 8: Birwelco USA Burner Compensator sliding plate, thrust bar, and removable pin (wind break removed).

compensator is a removable pin. This allows the detachment of an individual compensator from the rest by operations personnel if a burner needs to be taken out of service or isolated for maintenance. With the compensator 100% closed, the assembly is designed to minimize leakage and offer good shut off comparable to the existing register design. The removable pin is chained to the compensator to allow operators to easily disengage an individual compensator, without misplacement.

Individual compensators are bolted to each burner intake and the existing burner scoop are removed and discarded. The additional weight of the compensator is supported in part by the heater floor steel using standard hardware that will clamp onto existing structural members. This design promotes balanced air flow through each burner regardless of wind direction, with the incorporation of a wind break to minimize the adverse impact of wind gusts. The Lateral movement of the slide plate is guided with Polytetrafluoroethylene (PTFE) wear plates with an expected life of over 20 years based on 50 cycles per day which can be inspected and replaced during operation.

Results and Discussion

At handover, the newly implemented burner compensator assembly delivered precision level control of excess air enabling recovery of 15 MMBtu/hr. (~ 0.1EII) lost opportunity which translates to approximately $1MM in fuel gas savings, based on the past 12 months of loss data. After tuning was completed, the team also reported the overall compensator system showing improved responsiveness to both firing and fuel composition swings.

The lessons learned in this technology implementation provide a blueprint for flawless execution of the BUSA Burner Compensators to future retrofits. The complexity of potential interferences beneath the floor of the heater were significant but does demonstrate the many potential interferences one could expect on other heaters. It is recommended to conduct a digital scan or detailed survey of the area under the heater at a minimum. It is important to capture detailed dimensions of process piping, fuel gas piping, steam piping, conduit, supports, burner orientation/ misalignment, lighting, and other instrumentation in the area. Confirming location, dimensions, and detailed configuration data can save time in detailed design, prevent field commissioning discoveries, and avoid costly changes. A digital scan or detailed survey of the area under and around the heater can prevent delays related to thrust bar alignment, actuator placement, conduit routing, placement of assembly supports and local actuator control boxes.

Once implementation is complete it is essential to tune controls for the air system to enable appropriate response. It may be necessary to switch the method of control used in tuning a retrofit application for the new compensators especially if transitioning from existing pneumatic control.

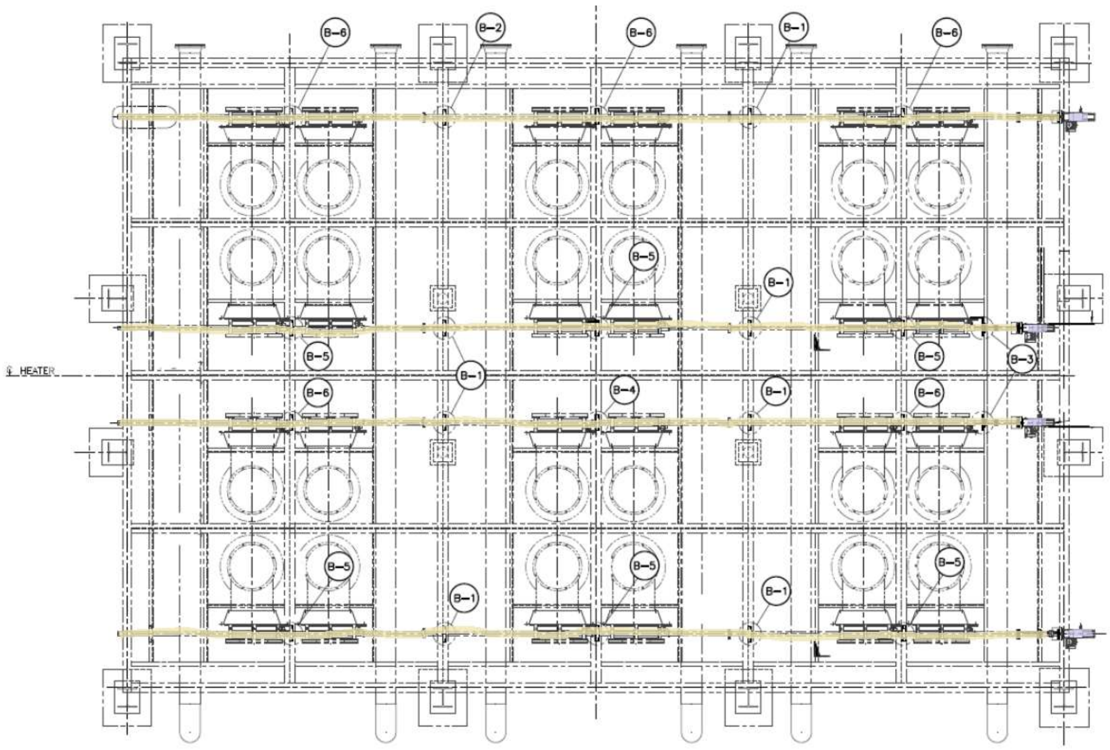

Figure 9: Splitter Reboiler Furnace with Birwelco USA Burner Compensator assembly for 24 burners.

Conclusion

It is possible to safely achieve consistent excess air control at optimal levels on any natural draft heater when the flow of the air through the throat of the burners is properly controlled and working in harmony with the stack damper. The BUSA Burner Compensator system effectively addresses the shortcomings experienced with other existing methods to automate combustion air controls (burner register failure/ seizing, linkage failure, system hysteresis, actuator overshoot) by providing reliable, repeatable smooth control. This retrofit enabled improved heater performance, reliability, and response of air to dynamic operation. This technology has been recommended for additional implementations at Baytown Refinery due to the ease of installation, improved operability, and value realization.

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