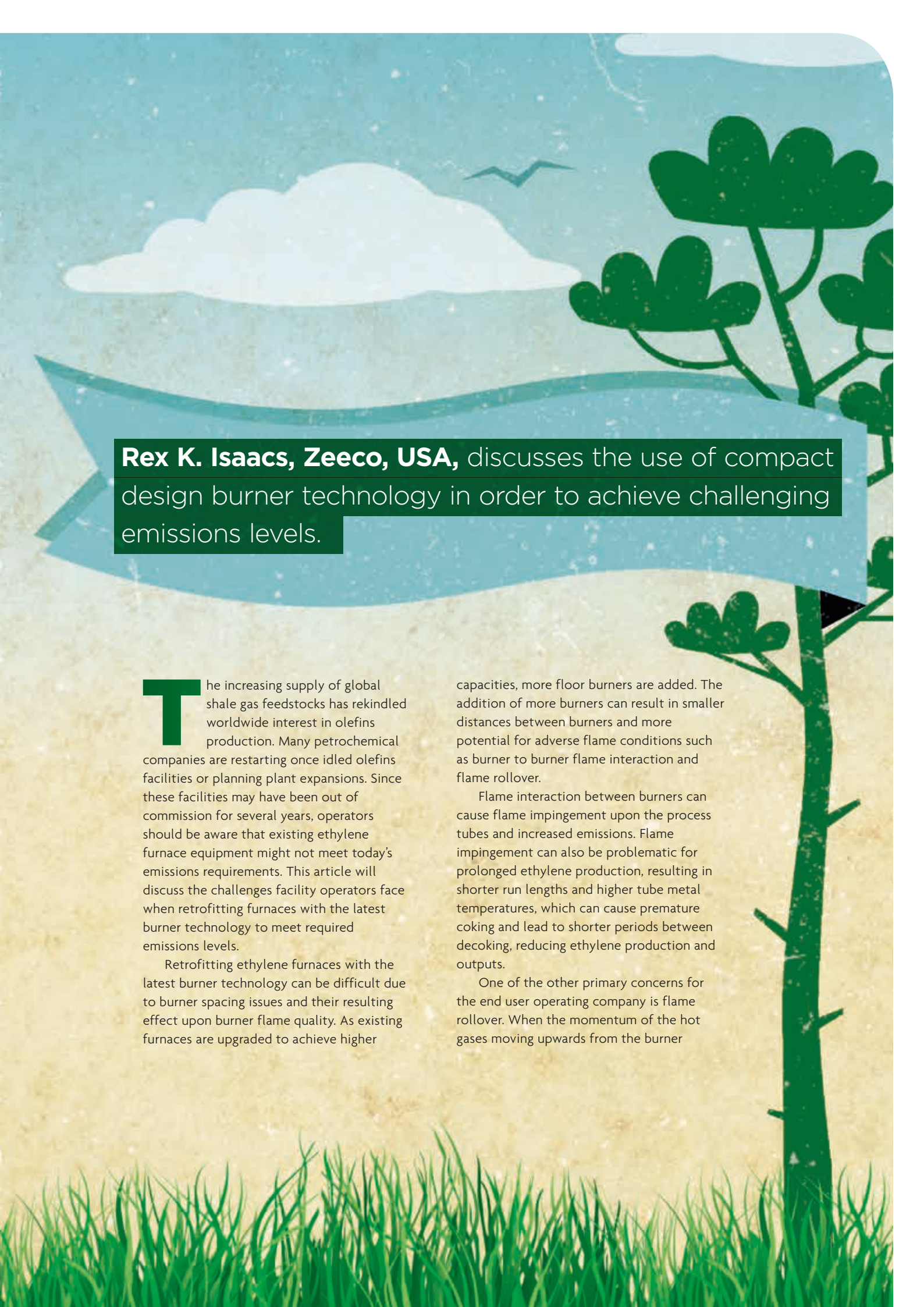




RETROFITTING
FOR LOWER

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EMISSIONS



Rex K. Isaacs, Zeeco, USA, discusses the use of compact design burner technology in order to achieve challenging emissions levels.

The increasing supply of global shale gas feedstocks has rekindled worldwide interest in olefins production. Many petrochemical companies are restarting once idled olefins facilities or planning plant expansions. Since these facilities may have been out of commission for several years, operators should be aware that existing ethylene furnace equipment might not meet today's emissions requirements. This article will discuss the challenges facility operators face when retrofitting furnaces with the latest burner technology to meet required emissions levels.

Retrofitting ethylene furnaces with the latest burner technology can be difficult due to burner spacing issues and their resulting effect upon burner flame quality. As existing furnaces are upgraded to achieve higher

capacities, more floor burners are added. The addition of more burners can result in smaller distances between burners and more potential for adverse flame conditions such as burner to burner flame interaction and flame rollover.

Flame interaction between burners can cause flame impingement upon the process tubes and increased emissions. Flame impingement can also be problematic for prolonged ethylene production, resulting in shorter run lengths and higher tube metal temperatures, which can cause premature coking and lead to shorter periods between decoking, reducing ethylene production and outputs.

One of the other primary concerns for the end user operating company is flame rollover. When the momentum of the hot gases moving upwards from the burner

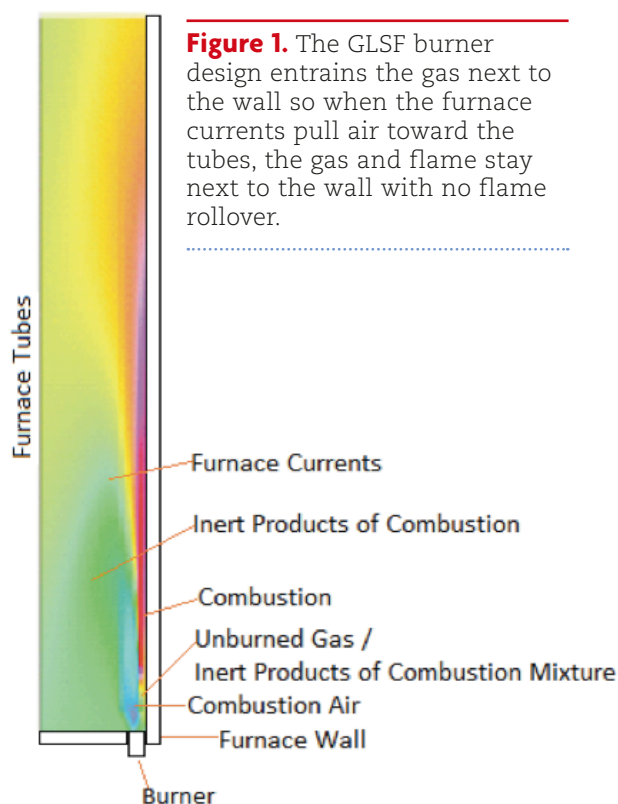


Figure 1. The GLSF burner design entrains the gas next to the wall so when the furnace currents pull air toward the tubes, the gas and flame stay next to the wall with no flame rollover.

becomes less than the momentum of the colder gases moving down the furnace tubes, flame rollover occurs. One product developed to address these concerns is the patented ultra low NO_x GLSF Min-Emissions Enhanced Jet Flat Flame burner. In this article, the author will review the design details for this type of burner, provide specific retrofit installation details in a case study format, review lessons learned during the retrofit, and include results for several of the retrofit applications.

An inherent design aspect of the burner is the fact that the fuel gas is introduced between the furnace wall and the air stream. Consequently, flame interaction between burners is minimised due to the location of the burner tip and the very compact design. Since the gas does not cross the air stream, the tip drilling design can be modified to achieve better heat flux profiles without adversely affecting the thermal NO_x emissions.

Application background

Since the early 2000s, Zeeco and a petrochemical facility have worked together on many ethylene furnace revamp applications where the number of floor burners increased and the burners had to be moved closer. Even in these situations, using the right technology helps avoid problematic occurrences such as flame rollover and interaction.

To achieve the improved flame quality without any flame rollover or flame interaction, the customer selected Zeeco's GLSF Min-Emissions flat flame floor mounted burners. As shown in Figure 1, the GLSF burner is designed to entrain the unburned gas next to the wall to prevent flame rollover as the furnace currents pull the air and products of combustion toward the tubes. As the unburned gas moves up the wall, it mixes with the inert flue gas

products of combustion, burning directly below the unburned gas. As the mixture of unburned gas and products of combustion continues to move up the wall, it then combines with air and burns. Since the unburned gas is mixed with some of the products of combustion before burning, peak flame temperature is lowered, producing lower thermal NO_x emissions. Therefore, not only are flame rollover and flame interaction problems solved, but ultra low emissions can be achieved.

Comparison to low emissions burners

Low emission burners found in ethylene cracking units typically use staged fuel technology. These particular burners have staged fuel tips strategically positioned for fuel to exit the orifices and pass over the combustion air stream before reaching the furnace wall. In order to modify the flame pattern to achieve an even heat flux in the lower portions of the flame envelope, the orifices must be drilled at increasingly abrupt angles toward the furnace wall. These orifice angles cause the air and fuel gas to mix at a faster rate, thus increasing thermal NO_x , and requiring a compromise between the heat flux profile and thermal NO_x production. As the heat flux profile is made more uniform, with an average above 90%, the NO_x emissions typically increase along with the increase in flux percentage. In the same respect, as the NO_x is decreased, the heat flux percentage is also decreased.

It is important to note that the location of the staged gas tips also affects the flame quality of the burner. For example, if the burner is required to make very low NO_x emissions, the staged orifices must be aimed in a more vertical direction. This vertical direction, coupled with the combustion air stream located in between the unburned gas and the furnace wall, increases the likelihood of flame impingement. The mixing of the fuel gas energy becomes so reduced at higher elevations that the furnace currents can easily influence the flame toward the tubes. In general, the lower the NO_x emissions when the staged gas has to pass completely over the combustion air opening, the higher the tendency for flame impingement or hot spots on the tubes.

The latest in low emission burner technology, such as Zeeco's GLSF Min-Emissions Flat Flame Burner, incorporates staged gas tips with gas ports aimed toward the wall in a pattern that provides a very uniform heat flux profile in the middle to upper regions of the flame envelope. The mounting of the burner's flame shaping tips on the side of the combustion air stream allows the gas to avoid passing directly over the combustion air stream. The primary gas tips and gas lance provide the necessary heat distribution in the lower regions of the flame envelope. Since the burner mixes internally inert flue gases, the flame is stretched over a longer distance, enabling a more uniform heat flux distribution on the furnace wall. With the flame shaping tips located on the side of the combustion air stream, the burner heat flux profile can be changed without adversely affecting NO_x or causing flame impingement on the tubes. The burner can then evenly transfer heat to the process tubes, and reduce the possibility of localised hot spots while producing lower NO_x emissions.

Figure 2 shows a comparison between the GLSF Min-Emissions burner and a typical staged fuel burner. The typical staged fuel burner shown on the left, with staged gas tips that normally comprise 70% of the heat release positioned on the back side of the tile, requires that the unburned gas cross the combustion air stream before reaching the furnace wall. The Min-Emissions Burner, shown on the right, illustrates that the staged gas does not directly cross the combustion air stream. This type of burner design allows the angle of the staged gas port to be changed without adversely affecting the thermal NO_x emissions. Since the volume of air can be around nine times greater than gas, it is very important that the gas be injected between the furnace wall and the combustion air stream to keep furnace currents from affecting the flame quality.

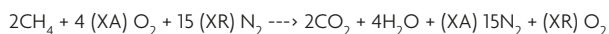
Small burner size for retrofit applications

Another critical design detail when retrofitting for emissions control without sacrificing flame quality is the compactness of the burner design. Operators should seek a combustion company who engineers a burner that is compact in design with no metal located in the throat of the burner, excluding the gas tips. Gas tips are required on each burner to distribute the fuel and mix it with the combustion air stream so that it burns completely. Eliminating any other metal from the burner throat results in a design with fewer items that can fail and require replacement. In addition, by simply eliminating metal from the burner throat, the burner can be designed with a smaller external dimension. When the external dimensions of the burner are smaller, it can normally replace conventional NO_x and staged fuel NO_x burners with only minor furnace modifications. This compact footprint allowed the petrochemical plant operator to install more burners mounted more closely together in revamped furnace applications without adverse flame impact or major modifications to the furnace.

Description of thermal NO_x creation and reduction

In order to understand why the Min-Emissions Burner design was successful in this application, formation of thermal NO_x emissions must first be examined. For gaseous fuels with no fuel bound nitrogen (N₂), thermal NO_x is the primary contributor to overall NO_x production. Thermal NO_x is produced when flame temperatures reach a high enough level to 'break' the covalent N₂ bond apart, allowing the 'free' nitrogen atoms to bond with oxygen to form NO_x.

Below is a stoichiometric equation describing typical combustion in a natural gas fired burner, methane and air with excess air:



Natural air is comprised of 21% O₂ and 79% N₂. Combustion occurs when O₂ reacts and combines with fuel (typically hydrocarbon). However, the temperature of

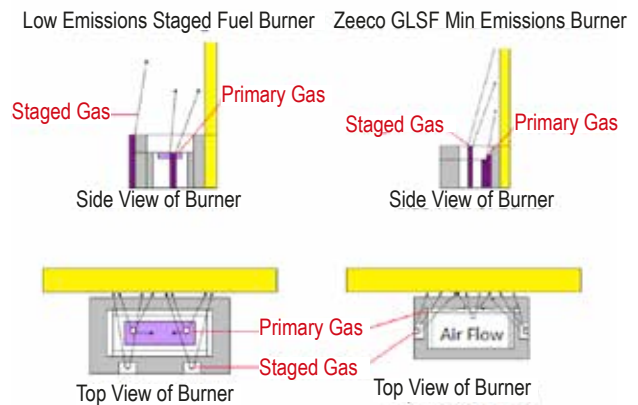


Figure 2. Side by side comparison of a low emissions staged fuel burner and Zeeco's GLSF Min-Emissions Burner.

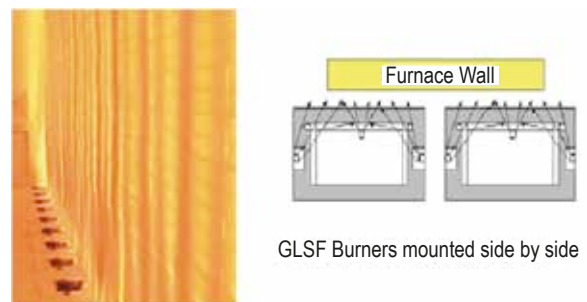


Figure 3. As shown on the left, the GLSF burner in operation with no flame rollover or flame interaction issues.

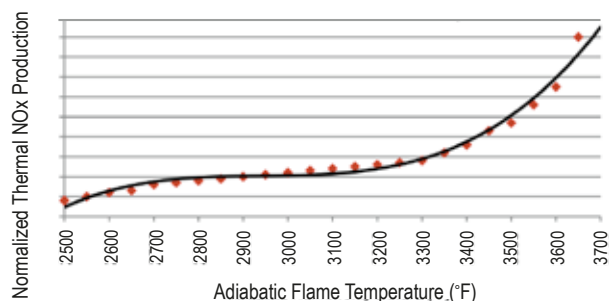


Figure 4. Calculated peak flame temperature versus thermal NO_x production.

combustion is not normally high enough to break all of the N₂ bonds, so a majority of nitrogen in the air stream passes through the combustion process and remains diatomic N₂ in the inert combustion products. Very little N₂ is able to reach high enough temperatures in the high intensity regions of the flame to break apart and form 'free' nitrogen. Once the covalent nitrogen bond is broken, the 'free' nitrogen is available to bond with other atoms. Basic chemistry dictates that free nitrogen, or nitrogen radicals will react to other atoms or molecules that can accept them to create a more stable atom. Of the possible reactions with the products of combustion, free nitrogen will most likely bond with other free nitrogen to form N₂. However, if a free nitrogen atom is not available, the free

Number of burners	2 furnaces x 24 per furnace (=2 rows x 12 per side)
Type of burner	GLSF minimum emissions burners complete with internal fuel gas recirculation
Type of fuel (gas/oil/dual oil gas)	Gas only
Location in furnace (roof/floor/side wall)	Floor
Firing orientation (down firing/upshot/radiant wall/against wall)	Upshot (against wall)
Flame shape (round flame/flat flame)	Flat flame gas burner assembly
Air supply system (natural/forced/induced/balanced/GTE)	Induced draft fan with natural draft burners
Maximum available combustion air pressure at burner, KPa (a)	Atmospheric
Ambient temperature (minimum/normal/maximum), °C	-40.2/+4.5/+36.6
Relative humidity, %	70% at 4.5 °C
Ambient pressure, KPa (a)	99.3
Altitude above sea level, m	N/A
Atomisation (mechanical/steam/air)	N/A
Fire box data	
Flue gas temperature at cross-over, °C	1143
Average flue gas temperature in firebox, °C	1252
Firebox volume, m ³	568
Firebox dimension (LxWxH), m	2 boxes, each 10.21 x 2.8 x 9.93

nitrogen will react with the oxygen atoms to form thermal NO_x. As the flame temperature increases, the stability of the N₂ covalent bond decreases, allowing the formation of free nitrogen and subsequently increasing thermal NO_x. Burner designers can reduce overall NO_x emissions by decreasing the peak flame temperature, which can reduce the formation of free nitrogen available to form thermal NO_x.

The varied requirements of refining and petrochemical processes entail the use of numerous types and configurations of burners. The method utilised to lower NO_x emissions can differ by application. However, thermal NO_x reduction is generally achieved by delaying the rate of combustion. Since the combustion process is a reaction between oxygen and fuel, the objective of delayed combustion is to reduce the rate at which the fuel and oxygen mix and burn. The faster the oxygen and the fuel gas mix, the faster the rate of combustion and the higher the peak flame temperature.

Figure 4 plots peak flame temperature against thermal NO_x created. NO_x emissions increase as the adiabatic flame temperature increases. Slowing the combustion reaction reduces the flame temperature, which results in lower thermal NO_x emissions. The challenge in achieving lower thermal NO_x emissions is not the theory; however, it is in retrofitting the latest burner technologies into older existing furnaces without adding expensive external components or processes.

The industry's standard method to reduce thermal NO_x is to mix the fuel gas together with the inert products of combustion to recondition the fuel before combustion occurs. Since the reconditioned fuel is mainly comprised of inert components, the

resulting composition burns at a lower peak temperature. To best utilise the inert products of combustion (flue gas) within the furnace, the fuel gas is introduced along the outside perimeter of the burner tile in an area where flue gas is present while the furnace is in operation. As the fuel gas passes through the inert products of combustion, mixing naturally occurs. This changes the composition of the fuel, and stabilisation occurs at the tile exit. Since the reconditioned fuel mixture is 15 - 50% inert in most cases, the resulting flame burns at a lower peak temperature and generates less thermal NO_x.

The mixing of the fuel gas with flue gas prior to combustion is called internal flue gas recirculation (IFGR). When IFGR is too aggressive, it can result in an increased blower power usage, decreased burner turndown, and increased flame destabilisation. Through min emissions theory, maximising IFGR while maintaining flame stability and flame length can become a challenge.

Description of application and results

The petrochemical plant chose to retrofit GLSF Min-Emissions burners in the following cracking furnace design. Each heater required 24 hearth (bottom) burners per furnace. 12 burners were mounted on each side of the tubes located in the centre of the furnace. The floor burners were designed to fire up the furnace wall, which in turn, radiates heat to be absorbed by the furnace tubes.

The hearth burners were mounted in the floor of the heater and fired up the firebrick wall. Since the burners fired directly on the firebrick wall, the wall transferred heat to the process tubes that are located in the centre of the cracking heater. The furnace has two rows of tubes and burners located on each side of the tubes.

The radiant wall burners or 'trim' burners were located in the upper regions of the furnace wall. Each radiant wall burner was mounted in the furnace wall horizontally and produced a radial flame pattern on the furnace wall. The radiant wall burners are a pre mixed design where air and gas mix together before combustion occurs.

The hearth burners provide most of the heat while the radiant wall burners are the remaining heat release. In order for the heater to work properly, the hearth burners must provide an even heat flux profile for where the tubes are located.

Conclusion

As petrochemical companies continue to revisit their olefins facilities through plant expansion or construction of new facilities, it is important to keep in mind the complex interactions of flame, fuel, and lower emissions. As shown in the example petrochemical plant installation, using a compact design burner technology to achieve challenging emissions levels without sacrificing flame quality is possible through a retrofit, but it does require careful consideration of options and possible pitfalls. 