



# EMISSION STATEMENT

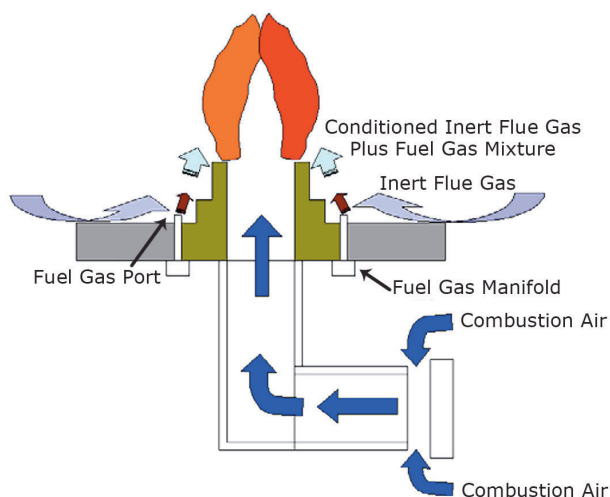
Nigel Palfreeman, Zeeco Europe, UK, and Ryan Roberts and Greg Seefeldt, Zeeco Inc., USA, describe how various technologies can be utilised to reduce total refinery emissions through a series of case studies from refineries around the world.

**T**he majority of new combustion equipment installations in the refining industry worldwide consist of new individual pieces of equipment, or sometimes systems, installed into an existing or expanding plant. Many retrofit and revamp applications are driven by emissions control efforts and meeting ever tightening regulations; nearly all must be done with emissions targets in mind. Given the industry's necessary emphasis on new equipment installed into existing facilities, it is easy to lose sight of the possibilities that exist in a new plant, built from the ground up with the latest in combustion technology. This article looks at refinery combustion equipment using the latest emissions control technologies, including highly efficient burner designs and reliable, environmentally sensitive flaring technology. In addition, the discussion covers flare gas recovery systems and ultra low NO<sub>x</sub> burners used in a sulfur recovery unit (SRU) thermal oxidiser system.

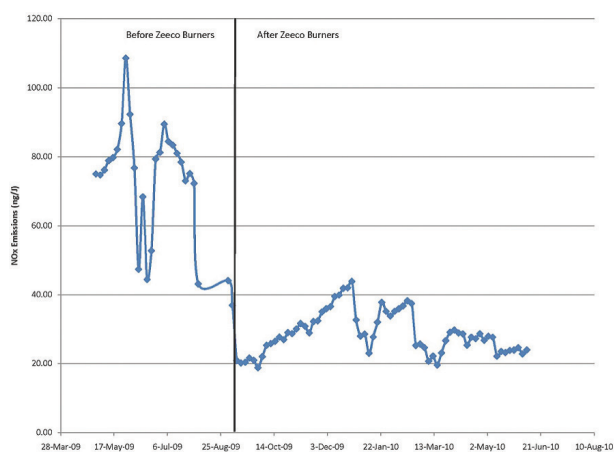


Oil refineries convert crude oil from different sources into a wide variety of refined products for the petrochemical industry, and as such they vary in processes employed and equipment used. Kerosene, diesel fuel, gasoline and feedstocks are just a few of the many products that are produced from crude oil. Many refinery processes require the addition of heat and that necessitates the extensive use of combustion equipment.

Controlling plant emissions is accomplished through efficiency, control of the various combustion processes in the refinery, and by reducing or eliminating atmospheric and fugitive emissions sources. Process heaters fired by industrial burners are considered one primary source of emissions in the normal operation of a refinery, so better control of these burner emissions throughout the refinery can result in significant overall pollutant reductions. Other primary sources of air pollution from refineries include incomplete combustion during normal flaring or flare events and gases vented to or escaping directly into the atmosphere. Thermal oxidisers are another source of



**Figure 1.** Ultra low  $\text{NO}_x$  GLSF Free-Jet burner using free jet mixing theory and combustion stabilisation ledges to reduce thermal  $\text{NO}_x$  formation.



**Figure 3.** Emissions levels before and after burner retrofits.

emissions in a refinery and must also be considered when evaluating total plant emissions reduction. Each of these areas (burners, flare gas recovery, flares and thermal oxidisers) is examined here in a series of compact case studies designed to show how retrofitting in each of these areas in a refinery can improve a plant's total emissions.

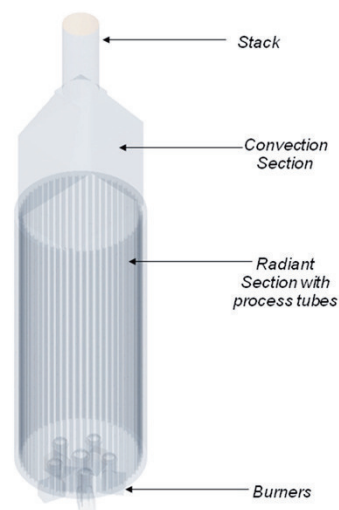
## Ultra low $\text{NO}_x$ burners

Regardless of the source, one pollutant that refineries worldwide focus on reducing in order to meet local emissions targets is  $\text{NO}_x$ . While the primary method utilised to reduce  $\text{NO}_x$  emissions can differ in each application, reducing the rate of combustion to lower thermal  $\text{NO}_x$  production is one way burners can achieve low and ultra low  $\text{NO}_x$  emissions levels. 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 together and burn. The faster the oxygen and the fuel gas mix, the faster the rate of combustion, resulting in higher peak flame

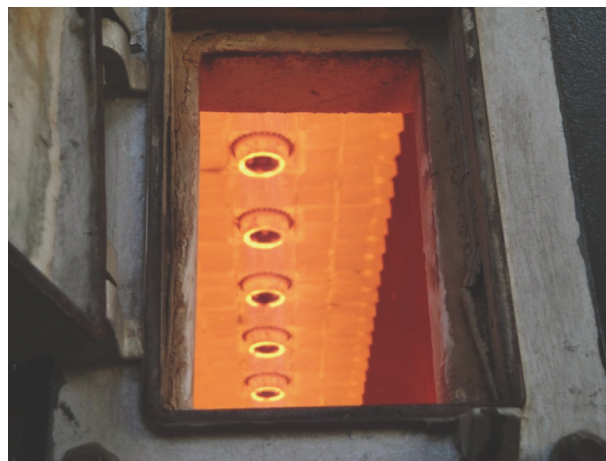
temperatures.

The industry's standard method to reduce thermal  $\text{NO}_x$  is to lower peak flame temperature by mixing the fuel gas together with the inert products of combustion to precondition the fuel before combustion occurs. The mixing of the fuel gas with flue gas inside the burner prior to combustion is called internal flue gas recirculation (IFGR).

Building new refineries equipped with burners that maximise IFGR while maintaining stable



**Figure 2.** Heater and burner configuration, UK refinery isostripper reboiler unit.



**Figure 4.** GLSF downfired burners firing with mixed fuel gas.

flame patterns and good turndown reduces the overall plant emissions footprint. Retrofitting these burners into existing equipment can be a challenge depending upon the configuration and cutout for the burners. Zeeco has developed the patented Ultra Low NO<sub>x</sub> GLSF Free-Jet burners for easy retrofitting into many types of equipment.



**Figure 5.** Typical side fired flat flame burner installation in an ethylene cracking furnace.

This burner series was designed with the specific purpose of maximising the amount of IFGR to reduce thermal NO<sub>x</sub> emissions without sacrificing burner performance with respect to flame length, turndown and stability. The GLSF burner achieves this by stabilising the burner flame with a highly inert fuel gas/flue gas mixture. This type of combustion is achieved when the flame is stabilised in a low pressure area created on a series of specially designed hot refractory ledges. Before combustion is initiated, a furnace is typically filled with normal air, which contains 21% oxygen. Once the burner is ignited, the oxygen content inside the furnace decreases until the burner achieves maximum duty. At this point, the oxygen content in the firebox is normally maintained at 2 – 3%. To keep the burner stable throughout the transition from start up with 21% oxygen to maximum duty with 2 – 3% oxygen, the burner has a series of stabilisation ledges (Figure 1). As combustion occurs, the refractory ledges retain heat and flame stability is enhanced.

Thus, to achieve improved stability and extreme thermal NO<sub>x</sub> reduction, the burners:

- Mix inert flue gas through free jet methods with all of the fuel gas before combustion occurs, lowering flame temperature.
- Stabilise the flame on a refractory ledge, improving flame characteristics.

**Table 1.** Design flare gas compositions, unit one

Stream composition (mol%)	1	2	3	4	5	6
Hydrogen	36.18	20.87	0.01			
Methane	62.96	29.11				
Acetylene		0.46				
Ethylene		27.88	77.82	99.95		
Ethane	0.13	7.85	22.02	0.05		
MAPD		0.22				0.12
Propylene		4.90	0.14		73.13	0.02
Propane		1.81	0.01		26.72	
Butadiene		0.97			0.02	46.70
Butenes		0.59			0.03	29.26
Butanes		0.47			0.10	23.82
C <sub>5</sub> S		0.42				0.08
C <sub>6</sub> – C <sub>8</sub> non-aromatics		0.07				
Benzene		0.72				
Toluene		0.13				
C <sub>8</sub> aromatics		0.11				
C <sub>9</sub> +		0.02				
Carbon monoxide	0.27	0.14				
Carbon dioxide		0.02				
Hydrogen sulfide		0.01				
Nitrogen	0.46					
Water		3.23				
Molecular weight	11.1	21.3	28.5	28.1	42.6	55.6
Temperature (°C)	0 – 20	40		10 – 20		

## Application one

This application centred on an alkylation unit isostripper reboiler at a refinery in the UK. The heater was a vertical cylindrical design with vertical tubes. The challenge was to reduce NO<sub>x</sub> emissions levels to a guaranteed level of less than 40 ppmv, with typical predicted emissions at below 15 ppmv.

Six floor mounted, vertically fired Zeeco ultra low NO<sub>x</sub> GLSF Free-Jet burners were installed: one GLSF-17 in the centre of the furnace and five GLSF-15 burners on a 87 31/32 in. diameter burner circle around the GLSF 17 (Figure 2). As a result, the burners are now operating within the guaranteed NO<sub>x</sub> emission limits.

## Application two

This application concerned a steam reformer in a refinery in the Middle East. The challenge was to meet stringent NO<sub>x</sub> emissions targets with burners that fitted existing cutouts for a raw gas burner.

The installed burners were 198 ultra low NO<sub>x</sub> GLSF-10 downfired Free-Jet burners for the inner row and 36 GLSF-7 downfired Free-Jet burners for the outer row. The customers had a number of design considerations:

- Ability to fit into the same cutout as a similar raw gas burner.



**Figure 6.** Flare before installation of FGRU.

<b>Table 2. Design flare gas compositions, unit two</b>						
Stream composition (mol%)	1	2	3	4	5	6
Hydrogen	34.5		0.02		0.03	
Methane	63.76		0.22	0.02	0.35	
Acetylene						
Ethylene	0.38		80.35	99.93	0.03	
Ethane			19.27	0.05	0.21	
MAPD						
Propylene			0.09		89.26	
Propane					9.77	
Butadiene						
Butenes						
Butanes					0.10	
C <sub>5</sub> s						
C <sub>6</sub> – C <sub>8</sub> non-aromatics					0.10	
Benzene						
Toluene						
C <sub>8</sub> aromatics						
C <sub>9</sub> +					0.03	
Carbon monoxide	0.35					
Carbon dioxide						
Hydrogen sulfide						
Nitrogen	1.01		0.05		0.12	
Water						
Molecular weight	11.4		28.4	28.1	42.2	
Temperature (°C)	0 – 20			10 – 20		

- Preference for burner tile that was approximately the same size and weight as a typical raw gas burner tile.
- Easy operation.
- Significantly lower NO<sub>x</sub> emissions than a raw gas burner.

The existing raw gas burners were removed from the furnace, and it was retrofitted with GLSF Free-Jet burners. The original combustion air plenums and air duct work were reused. The required NO<sub>x</sub> emissions level at the refinery is 43 ng/J. The previous burners installed in the reformer consistently had NO<sub>x</sub> emissions above 70 ng/J and occasionally exceeded 110 ng/J.

After the retrofit, the recorded NO<sub>x</sub> emissions were consistently below 43 ng/J. Figure 3 charts the emissions levels recorded both before and after the burner retrofit installation. Figure 4 shows GLSF downfired burners in operation burning mixed fuel.

### Application three

The third example is an ethylene cracking furnace in a northern European refinery. The challenge was to retrofit 40 burners to meet EN 746 NO<sub>x</sub> emissions standards. The burners used were ultra low NO<sub>x</sub> GLSF-10 flat flame enhanced jet burners (Figure 5).

The refinery in question needed to significantly reduce emissions levels through a retrofit project. Through CFD modelling, the furnace was predicted to achieve 24 ppmv of NO<sub>x</sub>. After the burner retrofit, the furnace now complies with EN 746 and has reliable remote ignition, correct air fuel ratio for combustion, increased efficiency/lower excess air, and lower NO<sub>x</sub> emissions.

### Flare gas recovery unit

This application was a European refinery in close proximity to a populated area. The challenge was to reduce or eliminate visible continuous flaring with visible black smoke, including flaring of gases rich in hydrogen sulfide (H<sub>2</sub>S). H<sub>2</sub>S content was in the 20 – 50+% range, creating a potentially dangerous situation for personnel and the surrounding population. The refinery had installed a flare gas recovery unit (FGRU) system in 1975 that was non-operable and had been idle for 40 years. The refinery was in danger of being shut down due to the continuous flaring. Figure 6 shows the flare before installation of FGRU.

The equipment utilised was two FGRUs designed to capture normal gases that were being flared, return them to the plant for utilisation to recover sulfur, and reuse the sweetened fuel gas in the facility to reduce the plant's overall fuel gas usage and carbon footprint.

At the start of the project, Zeeco performed a flow measurement and verification study at the jobsite to measure, record and analyse normal flowrates to the flares. This information was used to confirm the



preliminary design information provided by the refinery and ensure suitability for the plant. The following design parameters were followed:

- Single skid modular design for each system to allow easy installation and minimum plot space (Figure 7).
- 5 barg discharge pressure for recovered gas.
- Approximate capacity:
  - Unit one: 250 m<sup>3</sup>/hr.
  - Unit two: 1000 m<sup>3</sup>/hr.
- Liquid ring compressor technology.

As a result of the modifications, there was a significant decrease in visible flaring and a reduction in emissions due to the recovery of gases that were previously flared, thus allowing the refinery to continue to operate.

## Refinery flare

The application concerned a European refinery in a populated area. Flares are a necessary safety device in refineries and other petrochemical processing plants. When a flaring event occurs at a refinery, the facility's flare system should operate with a stable flame, with little or no smoke during routine flaring events and achieve a high destruction removal efficiency (DRE). It is critical that a refinery meets stringent DRE requirements of 98% or better to stay in compliance and assure the flare is ready to serve its intended purpose should the need arise.

The flare needed to efficiently destroy anything from butadiene to cracked gas with very little available pressure and do so with no

visible light or noise. Tables 1 and 2 show the gas composition from two process units served by the flare. The flare would have to limit light and noise emissions for normal day to day flaring and during controlled start up and shut down. The flare had to meet the established industry standard of 98% DRE during operation.

The equipment utilised in this case was a 75 metric t/hr enclosed ground flare (Figure 8). The installed ground flare now destroys up to 75 metric t/hr of normal gases to be flared before the refinery must switch to using an elevated flare in a non-routine flaring event. Routine visible flaring and noise associated with routine flaring have both been significantly reduced.

## Ultra low NO<sub>x</sub> thermal oxidiser


This case centres on a SRU at a North American refinery. A sulfur recovery plant is important to a refinery as it converts H<sub>2</sub>S gas that has been separated from refinery gas streams into elemental sulfur. SRU thermal oxidisers are typically used to destroy the 'tail gases' produced during this process. The objective is to limit the residual hazardous sulfur to emissions levels permitted by national and local air quality requirements.

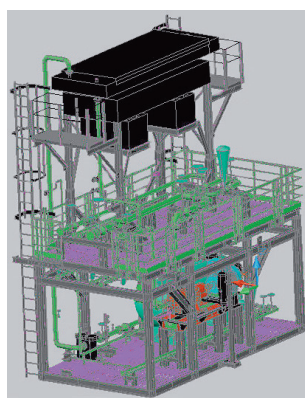
The challenge here was to destroy the tail gas waste stream with ammonia levels averaging in excess of 400 ppmv while lowering emissions levels. If the high ammonia stream burned in a high temperature, high oxygen environment, the amount of bound nitrogen could be

converted to NO<sub>x</sub> at a rate of 30% or greater.

The equipment used was a thermal oxidiser fired with ultra low NO<sub>x</sub> burners, a specialised waste gas injection method and controlled amounts of excess air. The test results in Table 3 show that the combined thermal NO<sub>x</sub> plus fuel bound NO<sub>x</sub> is 18.5 ppmv at 3% oxygen.

## Conclusion

No two refineries have the same set of operating parameters, but every refinery and petrochemical plant must be concerned about increasing efficiency, reducing emissions and protecting the environment. Fired equipment tailored to the needs of the refinery and designed for maximum efficiency helps facilities balance emissions reduction with profitable operation. Ultra low NO<sub>x</sub> technologies are being successfully applied to process heaters, thermal oxidisers and boiler burners. More efficient and reliable flaring with little to no visible smoke and reduced noise helps refineries coexist more peacefully and safely with their environment. Greater use of flare gas recovery units can reduce the need for routine flaring and further improve efficiency and emissions control. Fired equipment innovation and carbon footprint reduction often go hand in hand and many refineries are already benefitting from the latest technologies. 



**Figure 7.** Modular skid design for FGRU system to recover refinery gases previously being continuously flared.



**Figure 8.** Refinery ground flare installed to limit light and noise pollution during routine flaring.

**Table 3.** SRU tail gas thermal oxidiser test results

	SRU tail gas to thermal oxidiser	Flue gas from thermal oxidiser
Temperature (°C)	132	871
Oxygen, wet (mol%)	0.00	2.51
NH <sub>3</sub> , wet (ppmv) at 3% O <sub>2</sub>	470	<0.1
NO <sub>x</sub> , wet (ppmv) at 3% O <sub>2</sub>	Not measured	18.5