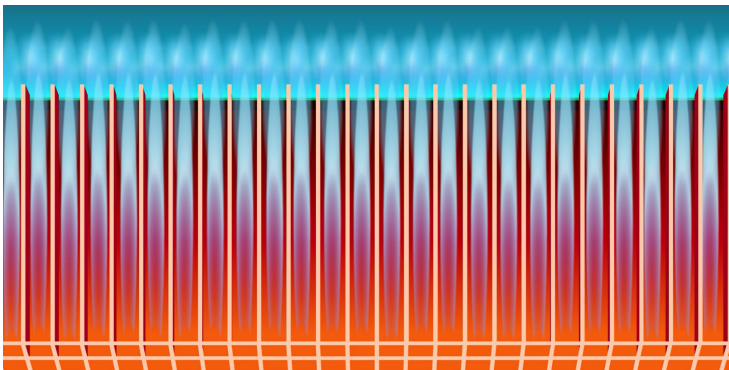


Process heaters probably suffer more wear and tear than any other item of equipment in a refinery.

Because they are at the front end of most processes in refineries and petrochemical processing facilities, optimal functioning of process heaters is essential to ensure adequate production.

However, environmental regulations for the refining industry are getting tighter and more difficult to achieve without compromising operations. The implementation of environmental controls, either at the combustion source or post-combustion, have many undesirable limitations that impose considerable economic costs, primarily related to the reduction in nominal furnace capacity. ClearSign has calculated that potential gains in refinery profitability could be \$12-28 million USD per year for an average 100,000 bpd refinery could be achieved by eliminating the bottlenecks caused by conventional NOx control technology in crude heaters alone.



By adding a ducted ceramic tile above a standard burner, Duplex essentially turns a single large and unruly flame into thousands of tiny, more easily controlled flames. Duplex burner architecture reduces flame length by more than 80%

Regulatory trends and proposed or pending regulations represent the greatest challenge facing the refinery industry today.

These regulatory trends negatively impact refinery operations in a variety of ways:

Reduction of stack emissions require expensive equipment upgrades, such as Low and Ultra-Low NOx burners (LNBs or ULNBs, respectively) and may require the installation of expensive post-combustion gas treatment technologies such as Selective Catalytic Reduction (SCR) and Selective Non-Catalytic Reduction (SNCR) systems.

These NOx reduction technologies reduce process throughput by diminishing burner capacity and stressing burner components, such as the process tubes (flame impingement).

Flame impingement and uneven heat distribution leads to increased maintenance costs associated with more frequent and longer maintenance cycles required to de-foul and de-coke process tubes.

There is an increased risk of unplanned shutdowns which can be costly to operations, while frequent thermal cycling of the heater can cause refractory damage of the furnace walls.

The reduction in burner capacity results in diminished separation performance in distillation towers, leading to less-than-desirable distillate ratios (a lower yield of premium products from crude).

Potentially hazardous after-treatment (SCR and NSCR) technologies produce other environmental challenges and associated costs.

LNBs and ULNBs pose an increased risk of catastrophic tube rupture (as a result flame impingement and uneven heat distribution to process tubes).

Clearsign's Duplex Technology can reverse this trend and significantly improve refinery profit while meeting or exceeding regulatory demands.

NOx Reduction Strategy

Ultra-Low NOx burners (ULNBs) are the technology of choice to meet ever more stringent regulations. For gas-fired applications, fuel staging and delayed mixing, combined with internal flue gas recirculation, ULNBs are the most common NOx control approach. NOx emission levels of 18-25 ppm at 3% O2 are typically guaranteed. (The range depends on fuel composition, furnace temperature and other parameters.)

Selective Catalytic Reduction (SCR) and Selective Non-Catalytic Reduction (SNCR) are post-combustion gas treatment technologies that may also be used for NOx control. However, their higher capital and operating costs, combined with a reluctance to store ammonia-based reagents at the refinery site and the large space requirements for these systems have limited their wide adoption.

Clearsign's Duplex Technology reduces NOx emissions to lower than 5PPM without the need of prohibitively expensive ULNBs or impractical SCR systems. While meeting or exceeding environmental regulations, Duplex Technology actually improves process throughput capacity and eliminates the cost associated with planned maintenance cycles and unplanned shutdowns resulting from the implementation of UNLBs and SCR systems.

Maintenance Cost

While satisfying regulatory requirements, ULNBs have several disadvantages (aside from decreased throughput) which result in increased maintenance cost. Process tube damage and decreased lifespan resulting from flame impingement and uneven heat distribution is the most common and noteworthy.

There is an emerging trend to extend the period between turnarounds with some refineries extending their operating cycles to five, six or even seven years where practical and safe to do so. If applied to process heaters, this trend applies even more impetus to ensure optimum operation and avoid premature deterioration.

Flame impingement and uneven heat distribution caused by ULNBs can result in catastrophic tube failure resulting in very costly repairs and personal injury or death.

Flame impingement can occur as a result of the increased flame length associated with ULNBs. Over time, this leads to the formation of an insulating layer of coke on the inside of the process tube reducing the inside diameter of the tube. If unchecked, coke formation will eventually lead to tube bowing (typically rectified by shutting off adjacent burners and restricting capacity) or can result in a pin-hole leak (requiring unplanned shutdown and tube replacement) and may lead to catastrophic tube rupture, which can cause collateral damage from the resulting fire and possible firebox explosion.

Fouling can also occur on the firebox side due to soot and ash deposits. These deposits create an insulating barrier to heat transfer and lower heater efficiency. Cleaning of the convection tubes can be achieved by soot blowing (if fitted), or by mechanical cleaning or grit blasting of the radiant tubes requiring a shutdown of the heater and entry to the firebox.

Refractory damage can occur as a result of frequent thermal cycling of the heater (frequent ups and downs) and firebox explosions (caused by events such as burner flame-outs, inadequate purging at light-off and ineffective securing of fuels during a process upset or outage). Cracks in the refractory may also form, allowing hot flue gases to migrate into the space between the refractory and the steel shell of the heater.

Clearsign's Duplex Technology eliminates the risk flame impingement, allowing for more even heat distribution to process tubes. This prolongs the life of the process tubes and reduces the frequency and occurrence of costly de-coking cycles and unscheduled shutdowns which cause thermal stress on burner components.

Performance

Ultra-Low NOx burners lower potential process throughput as result of increased temperatures and uneven heat distribution within the firebox which can stress burner components. These systems not only require significant up-front capital cost but also add to the frequency of planned maintenance cycles and unplanned shutdowns due to flame impingement and fouling. These systems also suffer reduced fuel economy, further impacting plant profitability.

ClearSign's Duplex Technology shortens burner flames by up to 80% while reducing NOx to 5PPM or less and keeping O2 at 3% of volume or less. Our analysis shows that thermal efficiency gains on the order of 2-4% can be accomplished through lower levels of excess oxygen in the stack and enhanced radiant heat transfer, while offering fuel savings of 1 to 2%. **Duplex Technology is the only NOx reduction strategy on the market which can also offer the potential for increased process throughput and fuel savings.** The improved radiant heat transfer of the Duplex tile reduces stress on furnace components giving operators more flexibility in determining burner performance to increase process throughput and improve the production of more high value distillates. The advantages brought about by ClearSign's Duplex Technology also allow refinery operators to explore additional revenue options, such as the possibility of running more difficult, lower cost crudes with improved yields, or participating in emissions trading schemes.

Summary

Clearsign's Duplex Technology completely revolutionizes the way process tubes are heated. With more stringent regulatory demands being placed on the refinery operators, Clearsign offers the world's only emissions reduction solution which can:

Meet or exceed current and foreseeable regulatory requirements

Offer a return on investment through:

Improved fuel economy

Improved radiant heat transfer to process tubes

Increased process throughput

Improved distillate ratios and desirable product yield

Reduce the capital cost of NOx mitigation

Offer a simple retrofit strategy as opposed to ULNBs or SCR systems

Eliminate flame impingement

Reduce stress on burner parts

Reduce planned maintenance frequency and duration

Reduce the occurrence of unplanned shutdowns

Contact Clearsign now to find out more about how Duplex Technology can benefit your operation.



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