Duplex™ Advanced Combustion Technology

RefComm
May 2018
AGENDA

- Duplex Technology
- Why Duplex works
- Case Studies:
  - VC Reboiler
  - Plug and Play Device
- Research and Development
Duplex Technology
WHAT IS DUPLEX TECHNOLOGY?

ClearSign’s Duplex™ technology
Is a commercialized and highly customizable combustion system that improves performance by:

- Reducing emissions
- Eliminating capacity restraints

Duplex is not a clean up technology, rather it prevents NOx from being formed in the first place!
THE PROBLEM – CURRENT BURNERS CAN’T MEET CLEAN AIR ACT REGS

- Traditional burner - NOx of 50-150 ppm
- Current ULNB reduce NOx
  - NOx guarantee of 15-25 ppm
  - Fuel Staging or dilution
  - Control peak flame temperatures
  - Disadvantages: Long lazy flames cause impingement or coalescing requiring reduced firing
- Additionally some local regulations are down to 5-10 ppm
  - Or lower in some regions
  - ULNB cannot meet most stringent regulations, requiring SCR
THE PROBLEM – SELECTIVE CATALYTIC REDUCTION

- SCRs require catalysts and an ammonia/urea reagent to convert NOx to Nitrogen
- SCRs only work within a limited temperature range, requiring addition in the middle of most convection sections
- FD and/or ID fans, ducting and structural reinforcement required
- Catalyst has to be replaced every 3 - 5 years
- Injected reagent must be stored and refilled regularly
- Very high capex, opex and downtime to install and maintain
THE SOLUTION –
DUPLEX, A TRANSFORMATIONAL TECHNOLOGY

Duplex can reduce NOx to below 5 PPM **while improving operational performance.**

- Reduced emissions to SCR levels
- Elimination of flame shape issues
- Opportunity for increased fired duty
- Improved radiant heat transfer
- Low Capex and Opex
- Reduced downtime
DUPLEX CONFIGURATION

- High Temperature Porous Ceramic Matrix
  + Flame confined within Duplex
  + Bluff body stabilizes flame shape and temperature
  + Surface radiation vs. gas radiation

- Fuel Delivery System
  + Uniquely designed aerodynamic fuel delivery tips
  + Entrainment length in feet rather than inches with ULNB
  + Enhanced fuel/air mixing
  + Improved internal FGR
DUPLEX MODES OF OPERATION

Burner Mode (Warm Up)  Transition  Duplex Mode
DUPLEX EMISSIONS

→ Duplex Operation Enabled
DUPLEX BENEFITS

- Capable of sub-5 ppm NOx emissions
- Improved radiant heat transfer
- Noise reduction of 10-15dB
- Wide range of fuel flexibility
- Adaptable to different fired equipment
- New or revamp
- Potential for increased fired duty
- Does not require
  + External flue gas recirculation (FGR)
  + Additional excess air
  + Catalysts or chemicals
  + Electrical consumption
  + Large amounts of capital
Why Duplex Works
WHY DUPLEX WORKS

Duplex reduces formation of thermal NOx by lowering the adiabatic flame temperature via three mechanisms:

1. Improved fuel/air mixing improves flame temperature uniformity
2. Enhanced internal flue gas recirculation cools flame through dilution
3. Radiative cooling effect of tile surface
Case Study-
Vertical Cylindrical Reboiler
DUPLEX INSTALLATION VARIETIES

OTSG

VC HEATERS

ENCLOSED FLARES

PLUG-AND-PLAY

FIRETUBE & WATERTUBE BOILERS
VERTICAL CYLINDRICAL HEATERS

- ClearSign’s first commercial refinery project
- 2 units in service
- 3rd unit ready for install
- Original unit in operation more than 1 year, second unit 9 months
- Conducted site visit 10/17 and recorded 2.8 ppm NOx
REFORMER SPLITTER REBOILER

- Vertical Cylindrical Heater
- Three ULN Burners
- Maximum Capacity = 11.25 MMBtu/hr
- Dimensions:
  - Shell OD 9’ 6 1/2”
  - Height 17’ 8 1/2”
- Refinery Fuel Gas

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<th>CH4 (vol. % @ STP)</th>
<th>LHV (Btu/scf)</th>
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<td>Average</td>
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DUPLEX IN A REFINERY HEATER

Duplex Surface
Ceramic structure
Support (welded to furnace shell)
DUPLEX IN A REFINERY HEATER

NOx as a function of Reformer Unit Charge Rate

Reformer Unit Charge Rate (bpd)

NOx (ppm - corr. @ 3% O2)
Case Study-
Duplex Plug and Play
DUPLEX PLUG-AND-PLAY

- Second generation Duplex product
- One piece integrated fuel/air supply and Duplex surface product
- Designed for:
  + Easy installation like a traditional up-fired burner
  + Furnace geometries not supported by Duplex tile wall design
- Provides opportunity for increased fired duty from existing burner opening
DUPLICATE PLUG-AND-PLAY INSTALLATION

- Initial installation of Plug-and-Play device at a Texas refinery
- Service is a FCC Feed heater
- Cabin style, 6 floor mounted burners
- Customer had impingement issues and caused unwanted downtime
- In operation for more than 4 months
- Plan is ultimately to replace all 6 burners and to consider another heater (DCU)
Thank You!