

# 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?

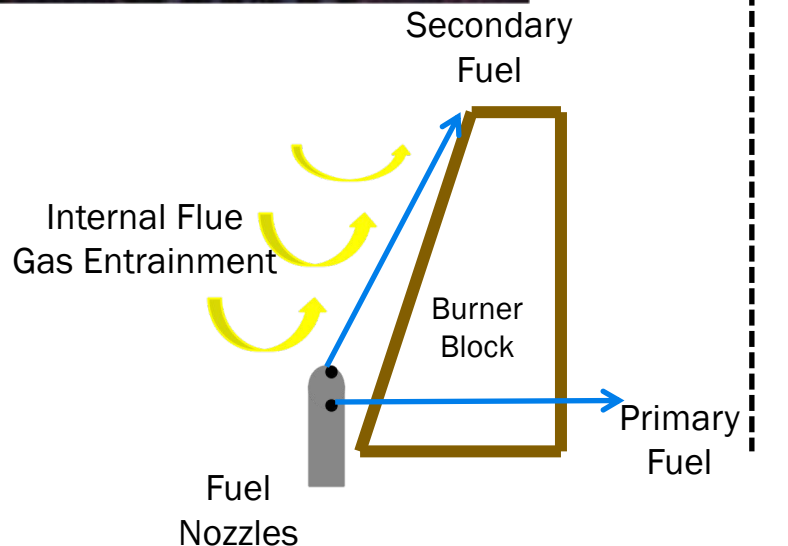
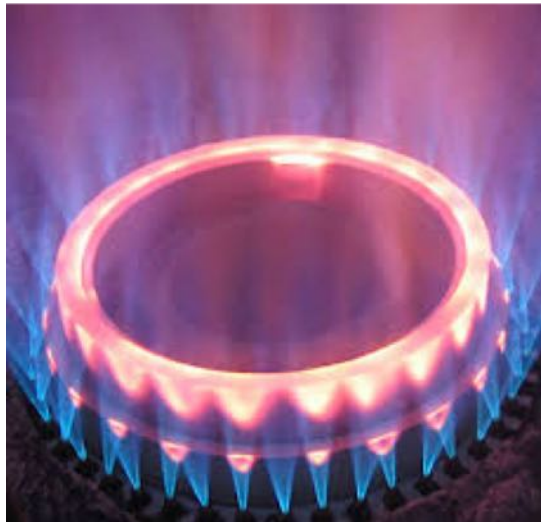
### ClearSign's Duplex™ technology

Is a commercialized and highly customizable combustion system that improves performance by:

- *Reducing emissions*
- *Eliminating capacity restraints*

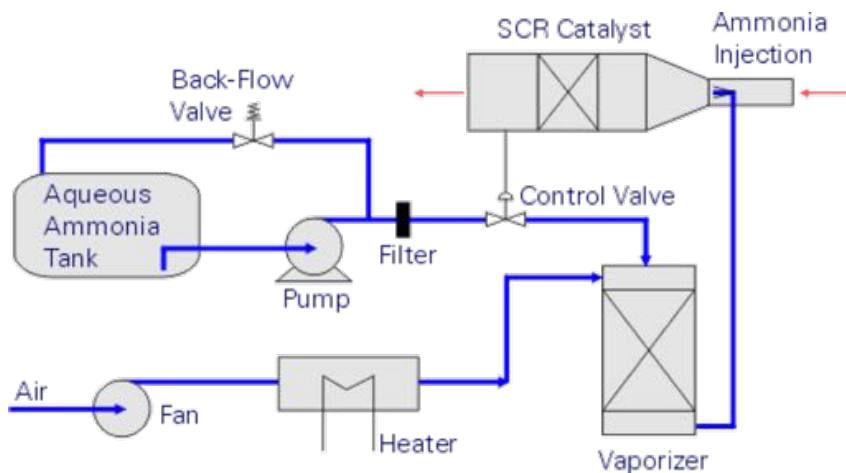
Duplex is not a clean up technology, rather it prevents NO<sub>x</sub> from being formed in the first place!

# THE PROBLEM – CURRENT BURNERS CAN'T MEET CLEAN AIR ACT REGS



- Traditional burner - NO<sub>x</sub> of 50-150 ppm
- Current ULNB reduce NO<sub>x</sub>
  - + NO<sub>x</sub> 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 SCRs

## THE PROBLEM – SELECTIVE CATALYTIC REDUCTION



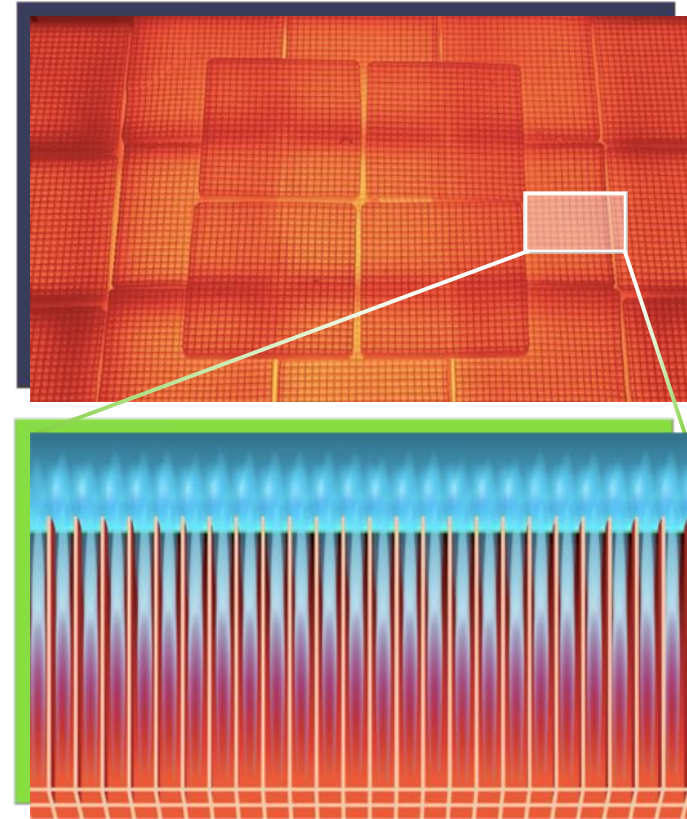
- SCRs require catalysts and an ammonia/urea reagent to convert NO<sub>x</sub> to Nitrogen
- SCRs only work within a limited temperature range, requiring addition in the middle of most convection sections
- FD and/or ID fans, ducting and structural reinforcement required
- Catalyst has to be replaced 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 NO<sub>x</sub> to below 5 PPM **while improving operational performance.**

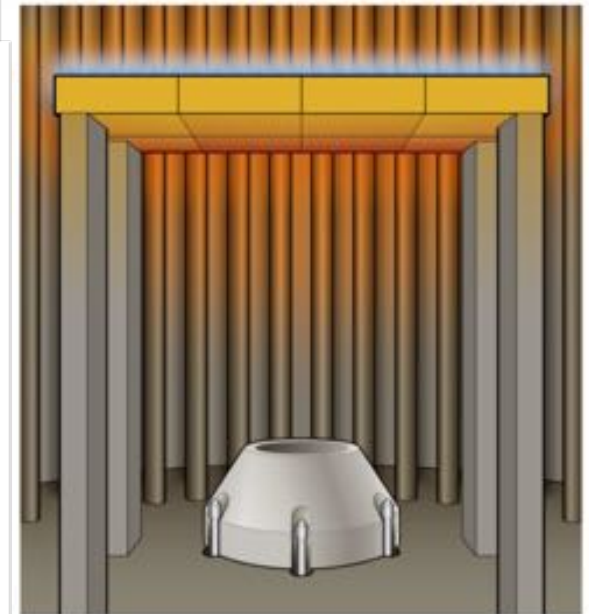
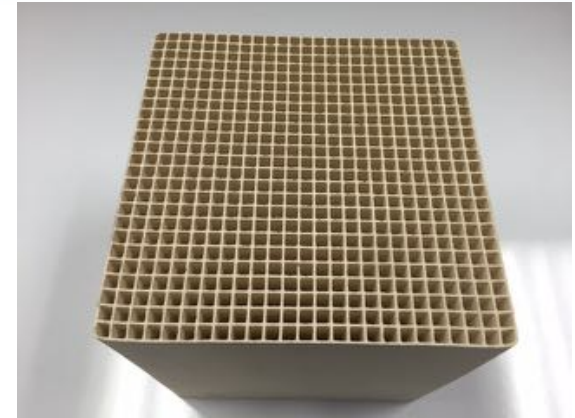
- Reduced emissions to SCR levels
- Elimination of flame shape issues
- Opportunity for increased fired duty
- Improved radiant heat transfer
- Low Capex and Opex
- Reduced downtime



*Duplex™ - a revolutionary porous ceramic matrix replaces an open flame.*

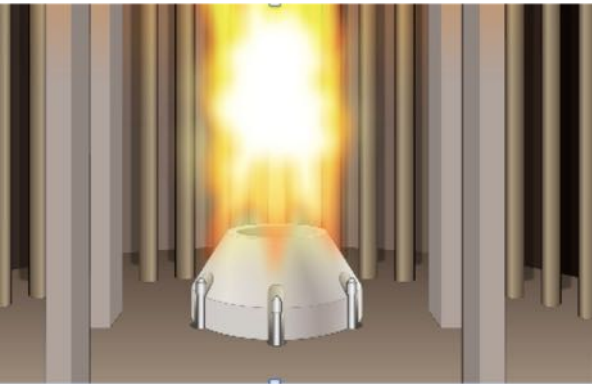
# DUPLEX CONFIGURATION

- 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

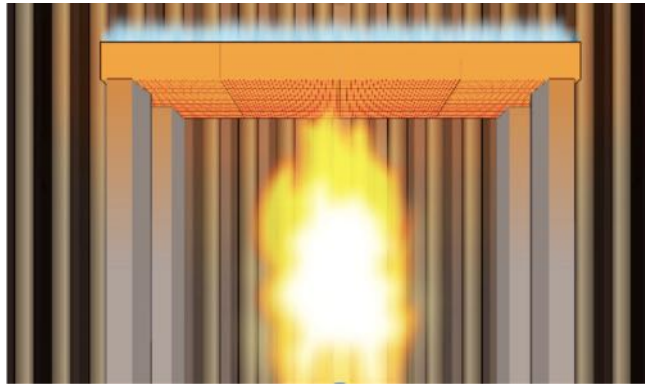




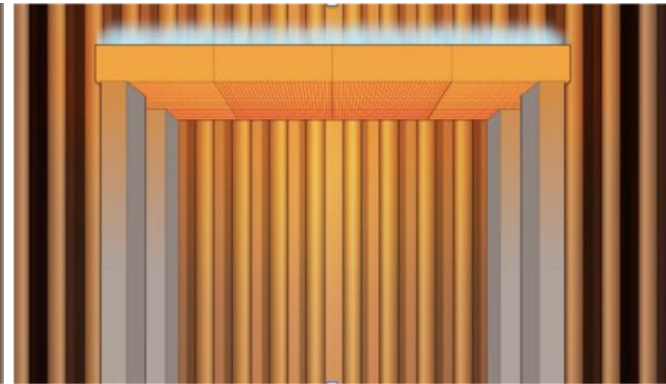
# DUPLEX MODES OF OPERATION



**Burner Mode  
(Warm Up)**

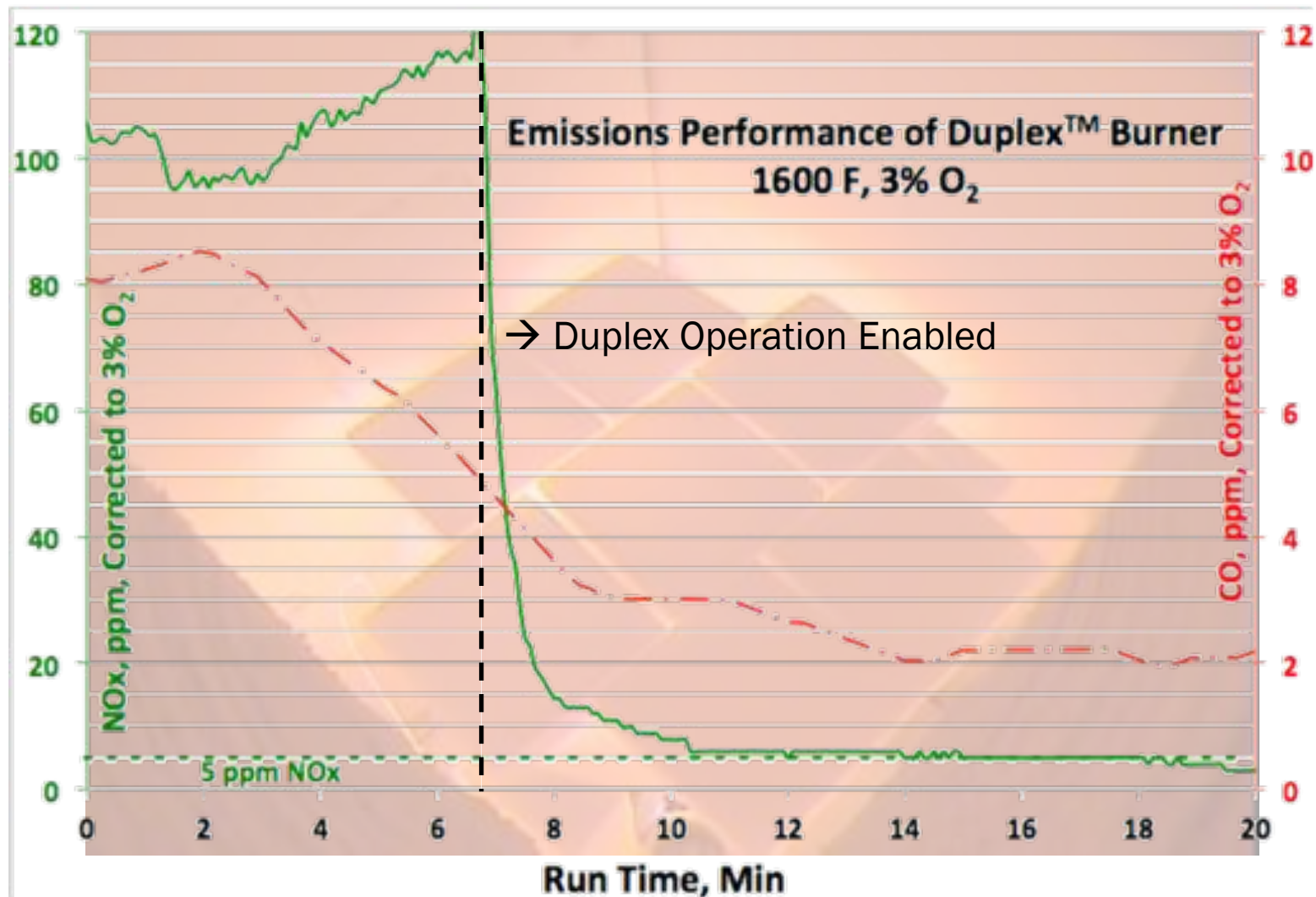


**Transition**



**Duplex Mode**

# DUPLEX EMISSIONS

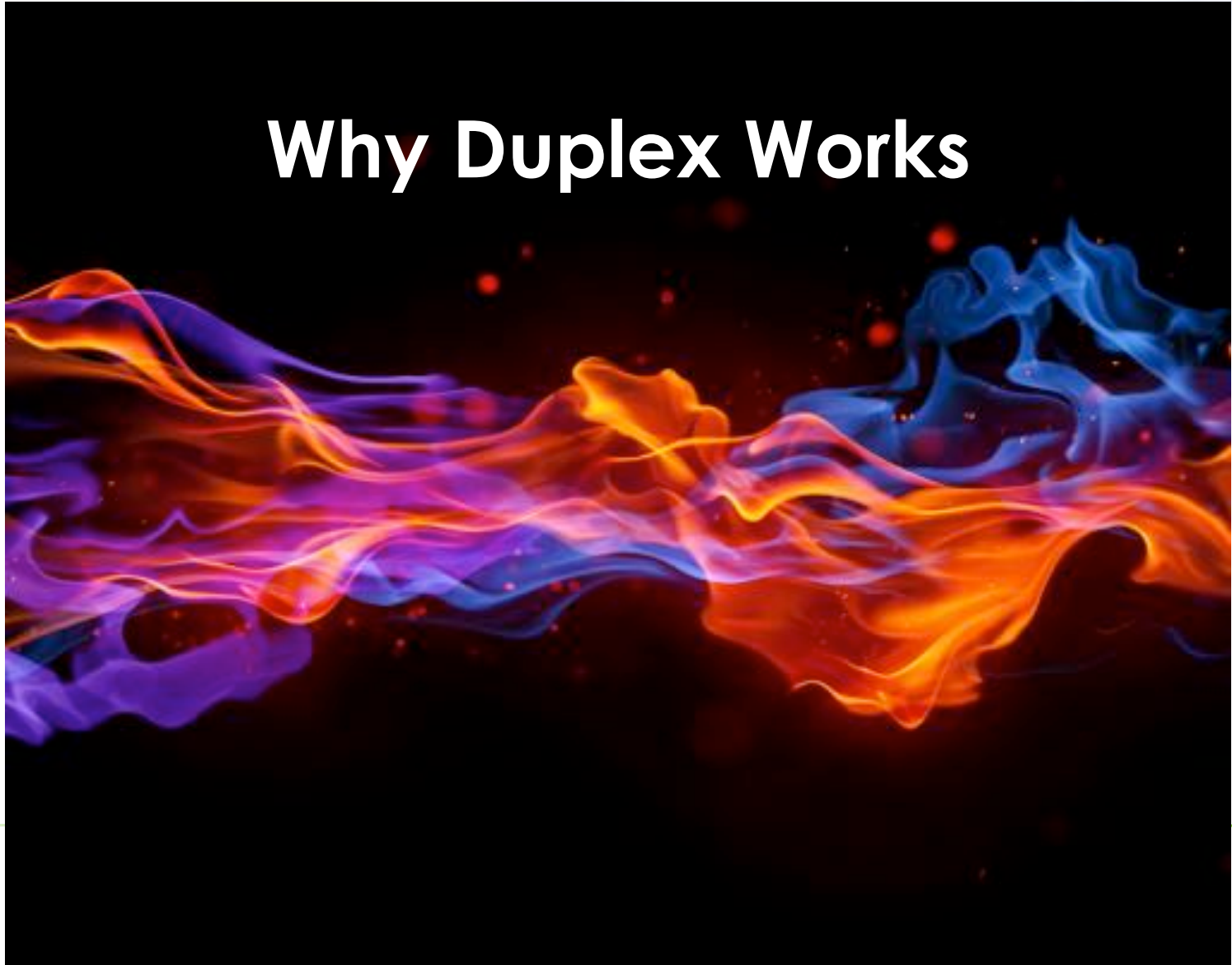


## DUPLEX BENEFITS

- Capable of sub-5 ppm NO<sub>x</sub> 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



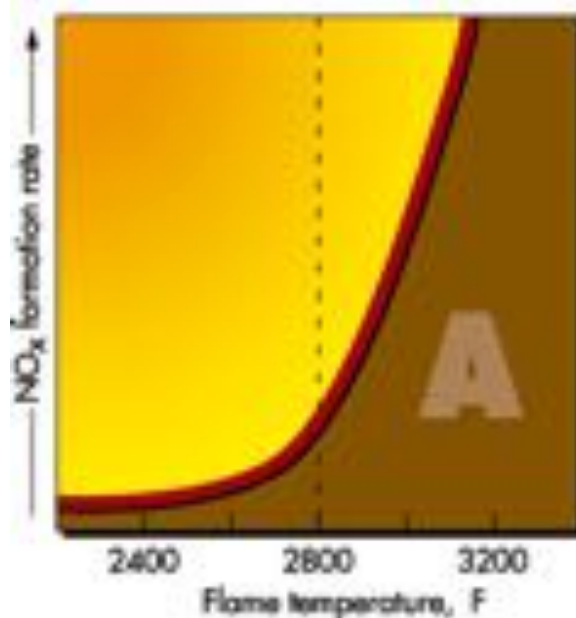
# Why Duplex Works



## WHY DUPLEX WORKS

Duplex reduces formation of thermal  $\text{NO}_x$  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



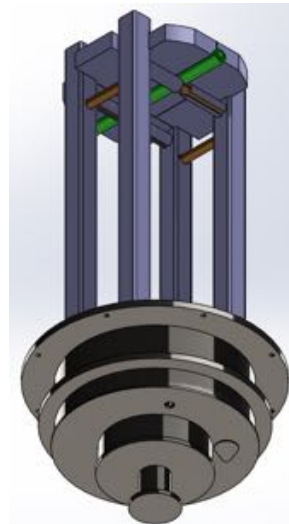
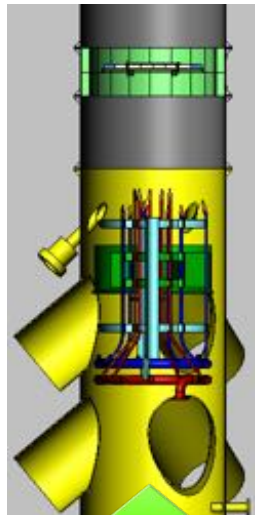
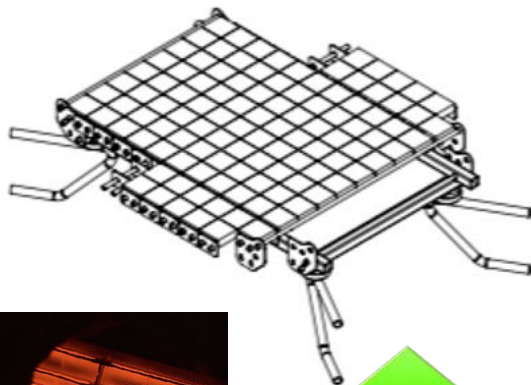


# Case Study- Vertical Cylindrical Reboiler

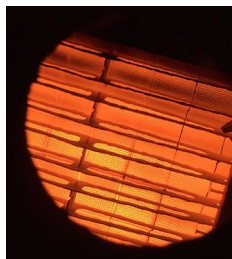




# DUPLEX INSTALLATION VARIETIES



PLUG-AND-PLAY



VC HEATERS



ENCLOSED FLARES



FIRETUBE &  
WATERTUBE  
BOILERS



OTSG

## 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 NO<sub>x</sub>

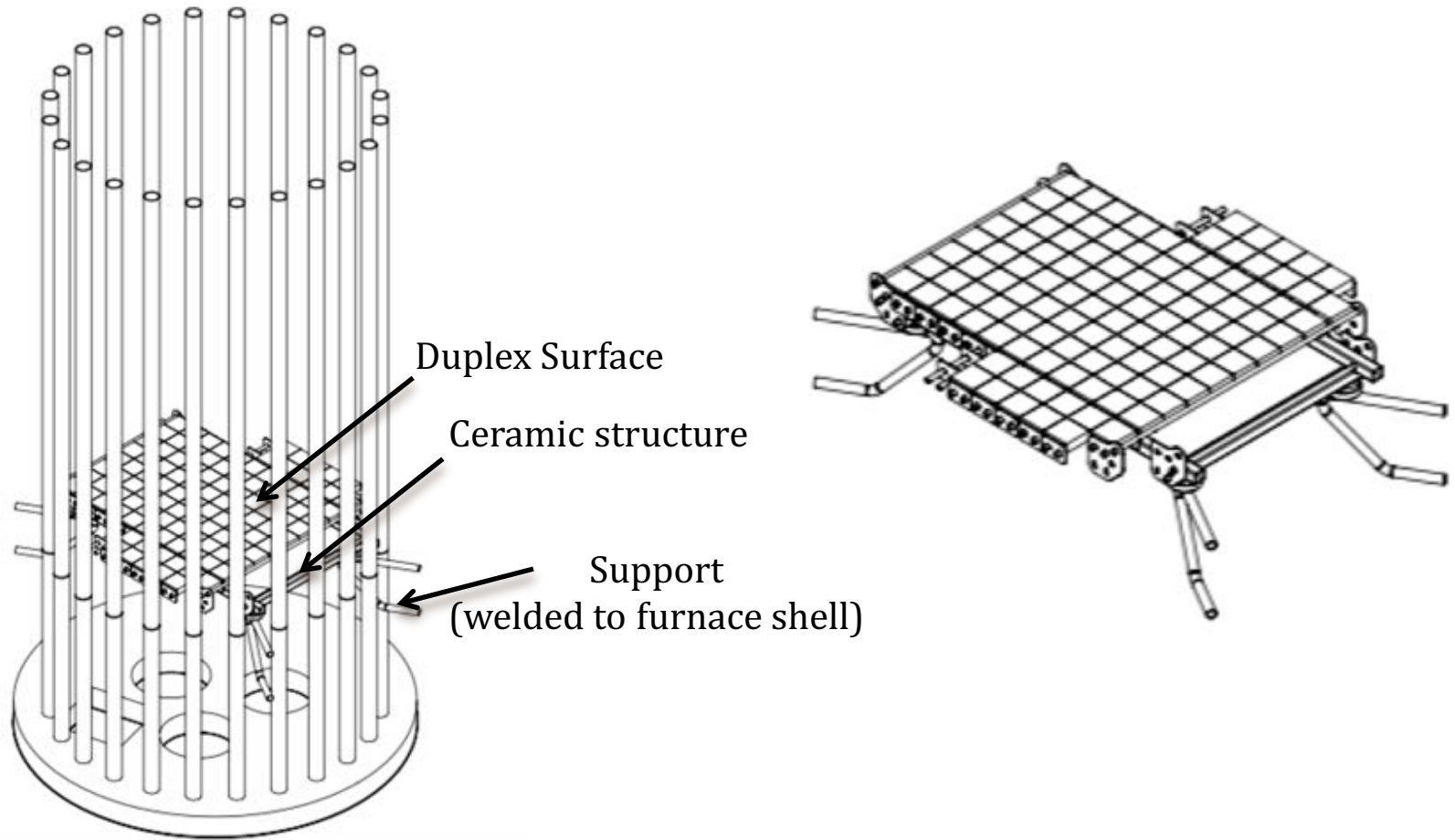


# REFORMER SPLITTER REBOILER

- 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

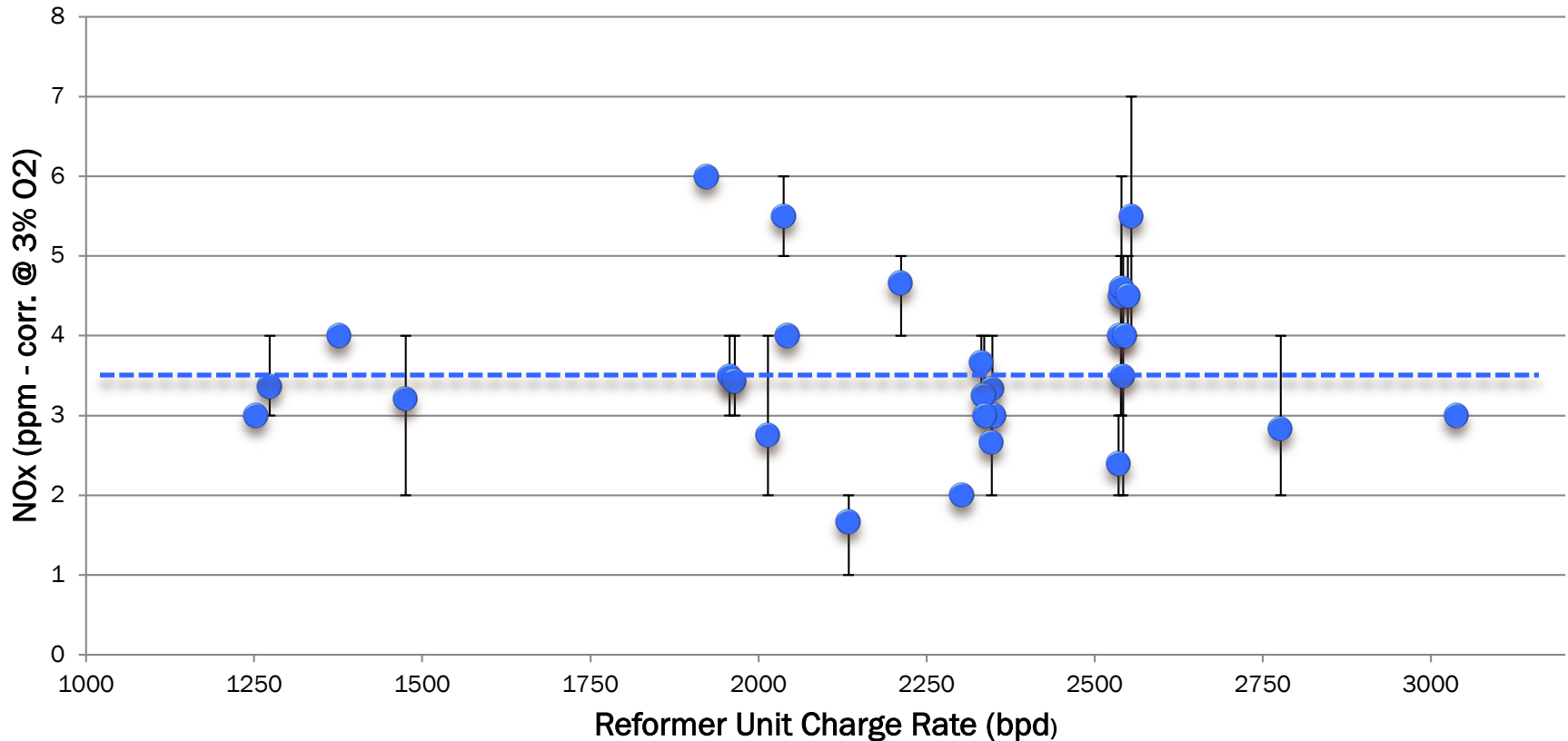
	H2 (vol. % @ STP)	CH4 (vol. % @ STP)	LHV (Btu/scf)
Maximum	68.7	55.6	1462
Minimum	22.8	12.3	636
Average	43.8	31.7	892

# DUPLEX IN A REFINERY HEATER



# DUPLEX IN A REFINERY HEATER

NOx as a function of Reformer Unit Charge Rate





# Case Study- Duplex Plug and Play





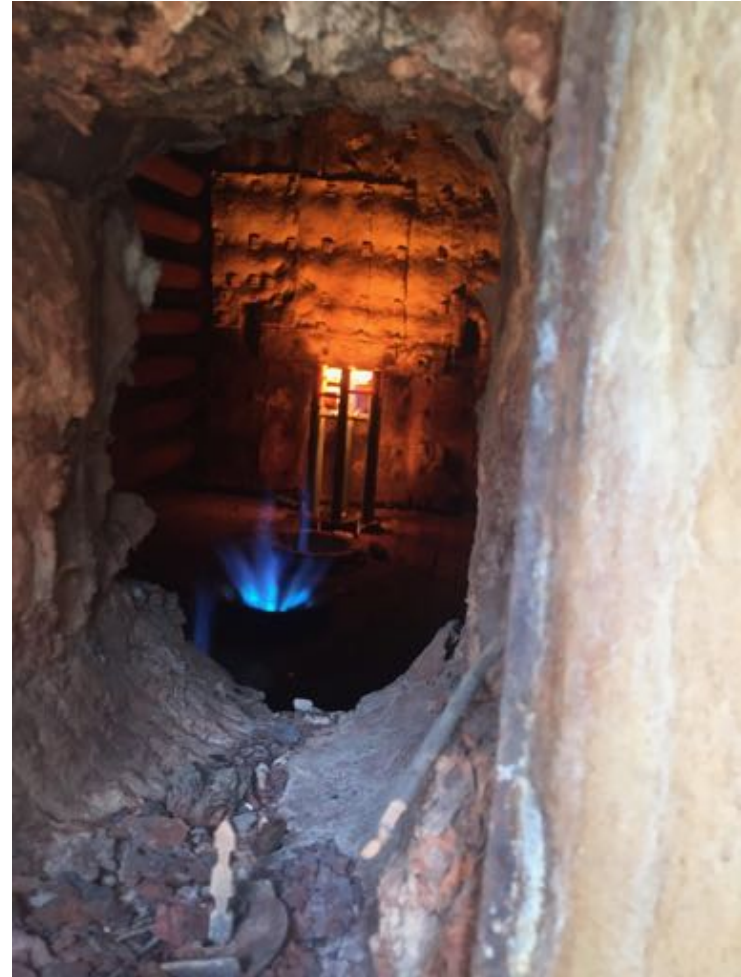
## DUPLEX PLUG-AND-PLAY

- 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



# DUPLEX 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!

