A Novel Revamp Technology to Maximize Fired Heater Capacity and Run-Length while Cutting CO_2 and NOx Emissions

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AN EMISSIONS CHALLENGE

Every year, fired heaters in refineries emit

400 – 600 million tons of CO_2

but also 0.25 – 0.35 million tons of NOx

AN EMISSIONS CHALLENGE

CO_2 can be reduced today by increasing efficiency.

- Most heaters operate at 80 – 90% efficiency
- Air preheat can increase efficiency > 95%

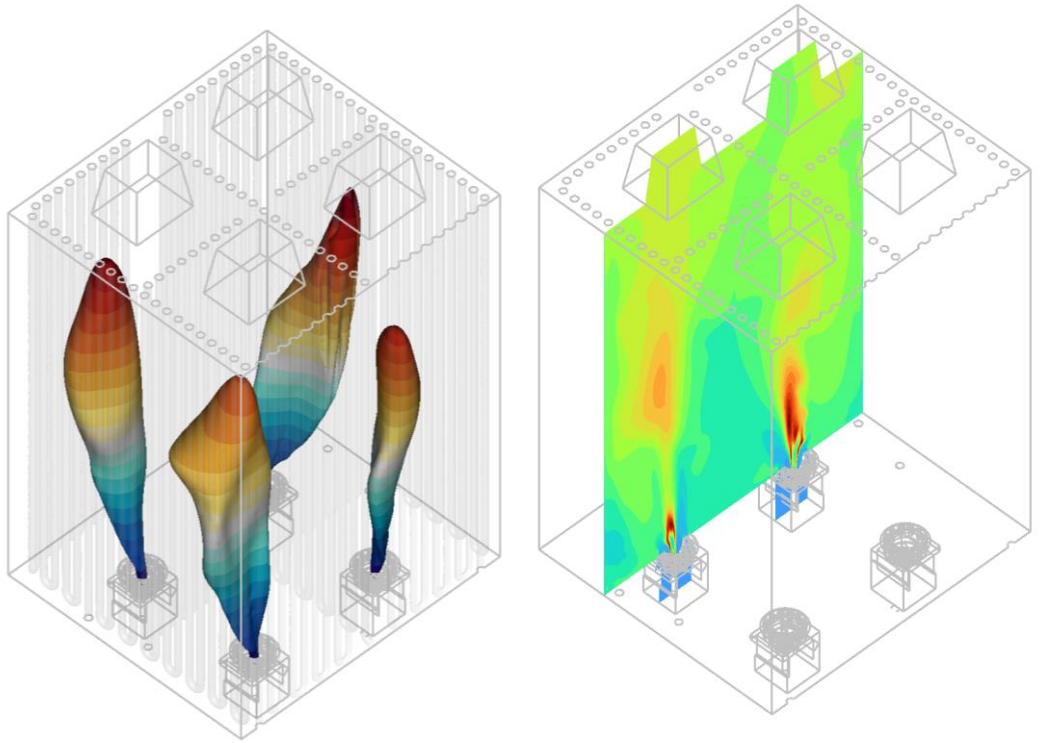
This may increase NOx by 50 – 200%.

AN EMISSIONS CHALLENGE

CO_2 can be reduced by changing fuel from hydrocarbons to hydrogen, or ammonia.

Needs study:

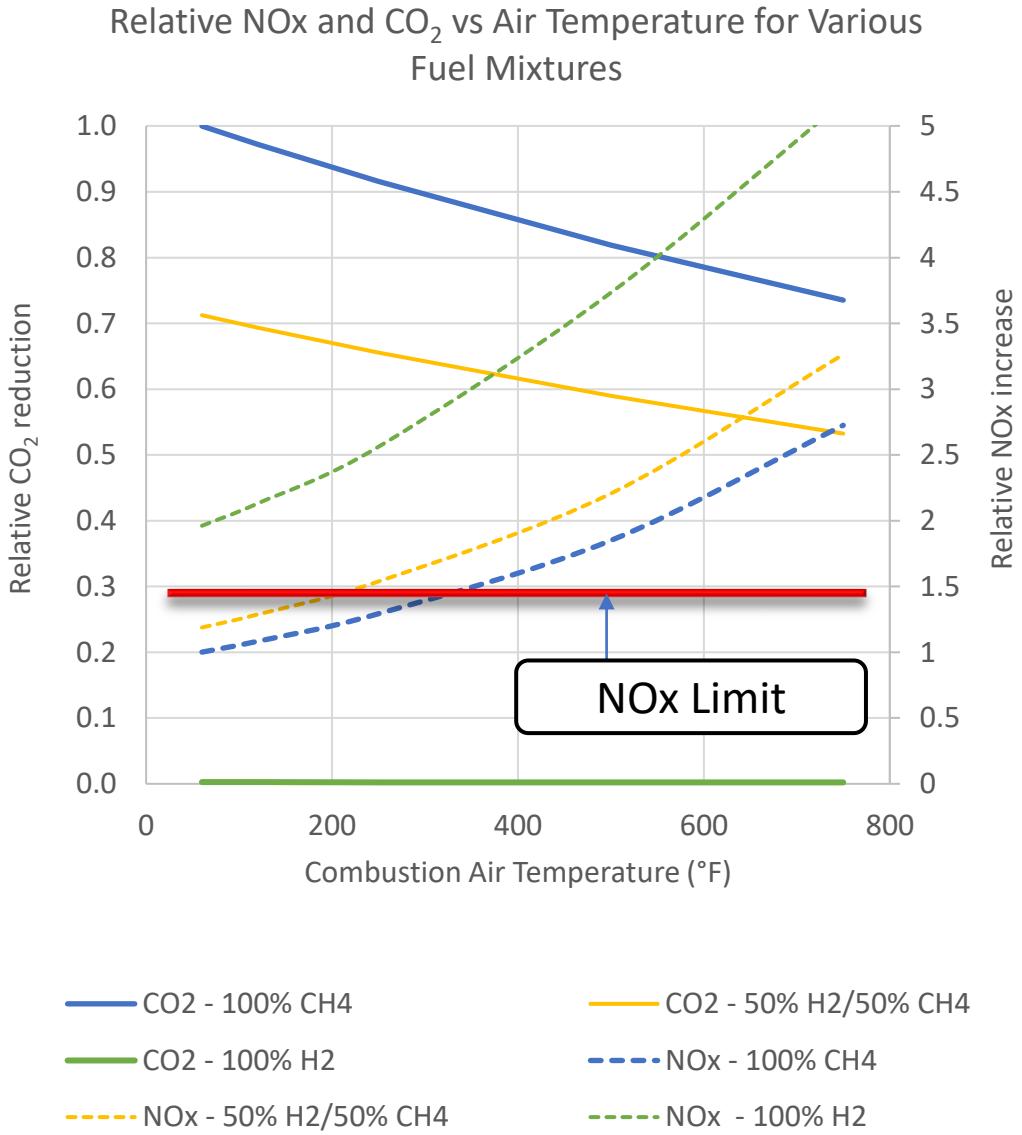
- Burner performance
- Heater performance
- Material compatibility
- NOx emissions



CHALLENGE MET? – INCREASE HYDROGEN FIRING

- The ideal solution; combine
  1. H_2 firing to minimize CO_2
  2. Air preheat to maximize efficiency and minimize H_2 consumption

- Problem: NOx limit is easily surpassed.



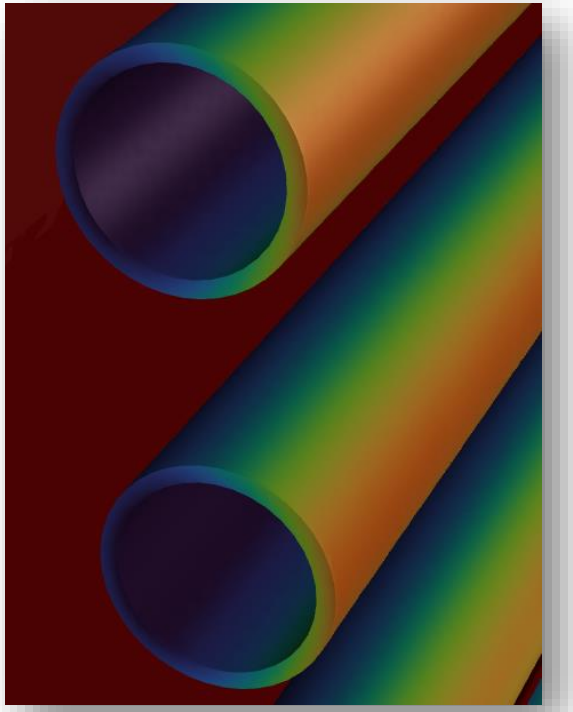
CHALLENGE MET?

- We need a technology that can
  - Improve performance of existing heaters
  - Increase firebox efficiency
  - Reduce or maintain tube metal temperatures
  - Reduce or maintain NOx
  - Function independent of the type of fuel
  - Increase heater capacity

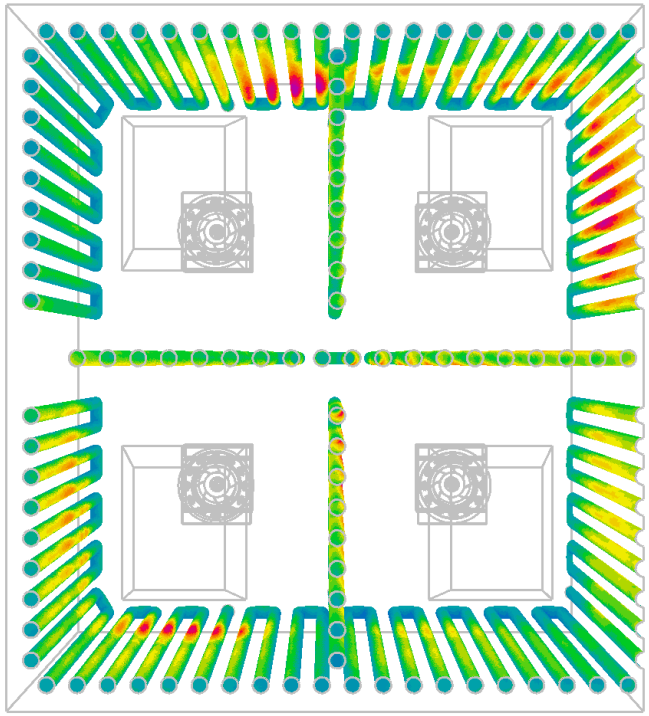
➢ Flameless combustion has been developed 20 – 30 years ago for these reasons.

THE PROBLEMS WITH FLAMES

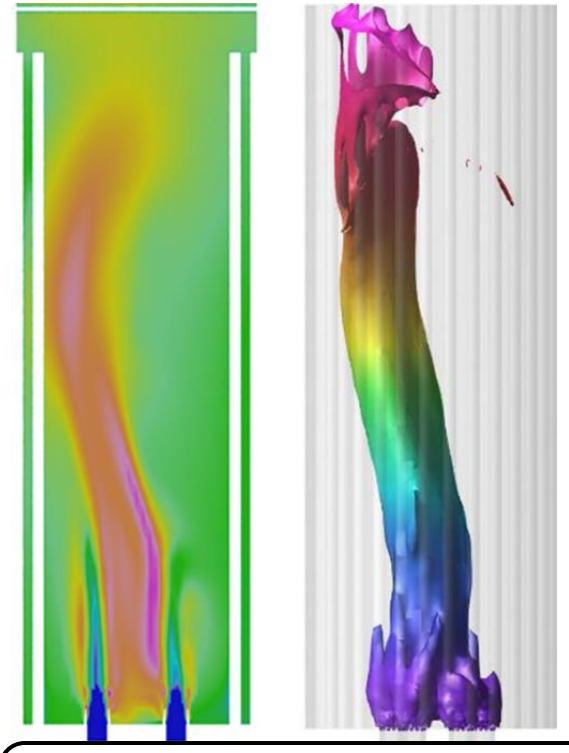
Flames cause problems. Flameless combustion solves them:



Uneven tube heating due to shadowing



Uneven heating due to bad flame shape / heat flux profile



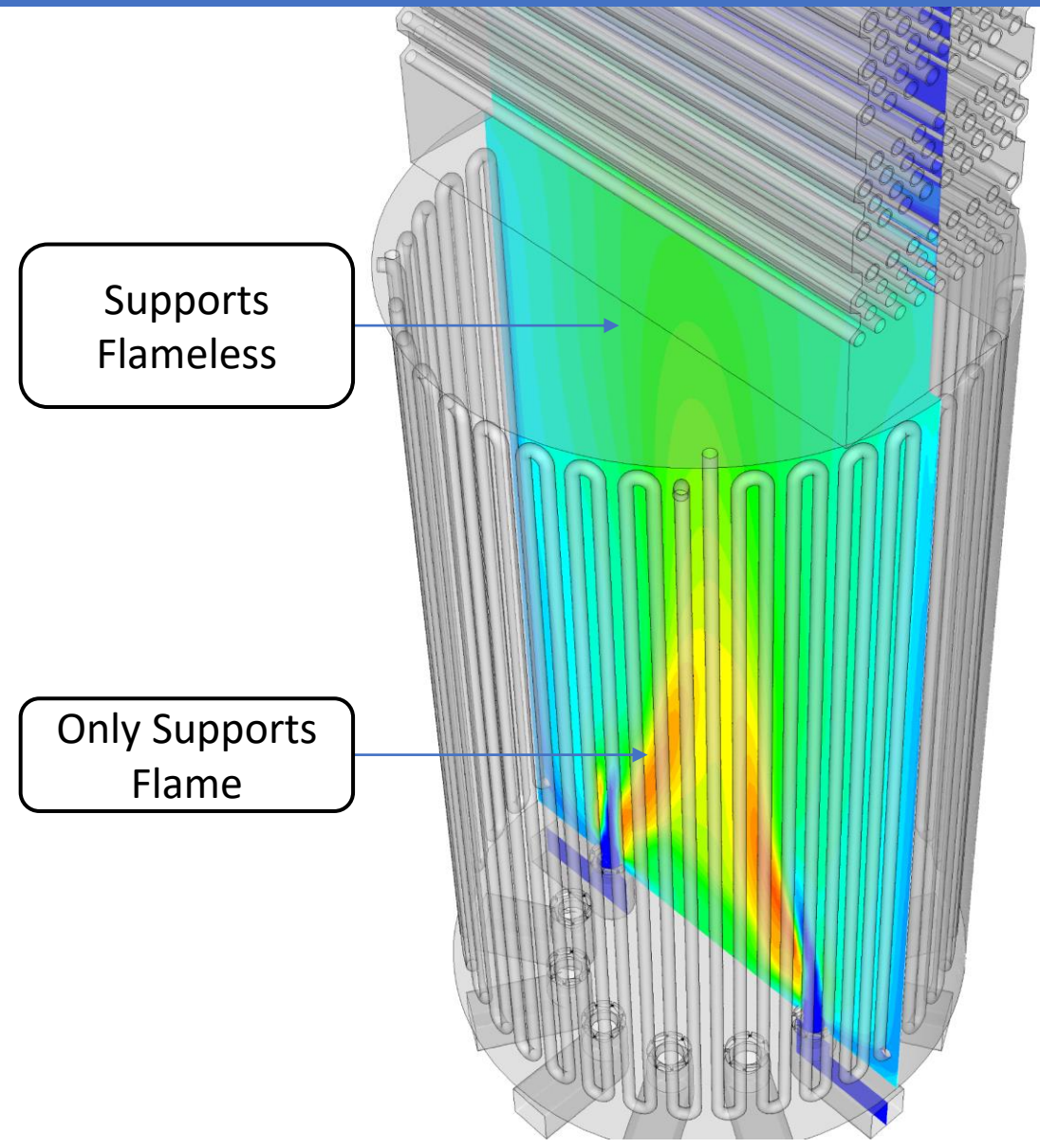
Afterburning, flame interactions, high emissions

A CHALLENGE - FLAMELESS FIRED HEATERS

- But: true flameless combustion requires high temperature and uniform oxygen/fuel mixing
- Fired heaters have large gradients of temperature, fuel and O_2

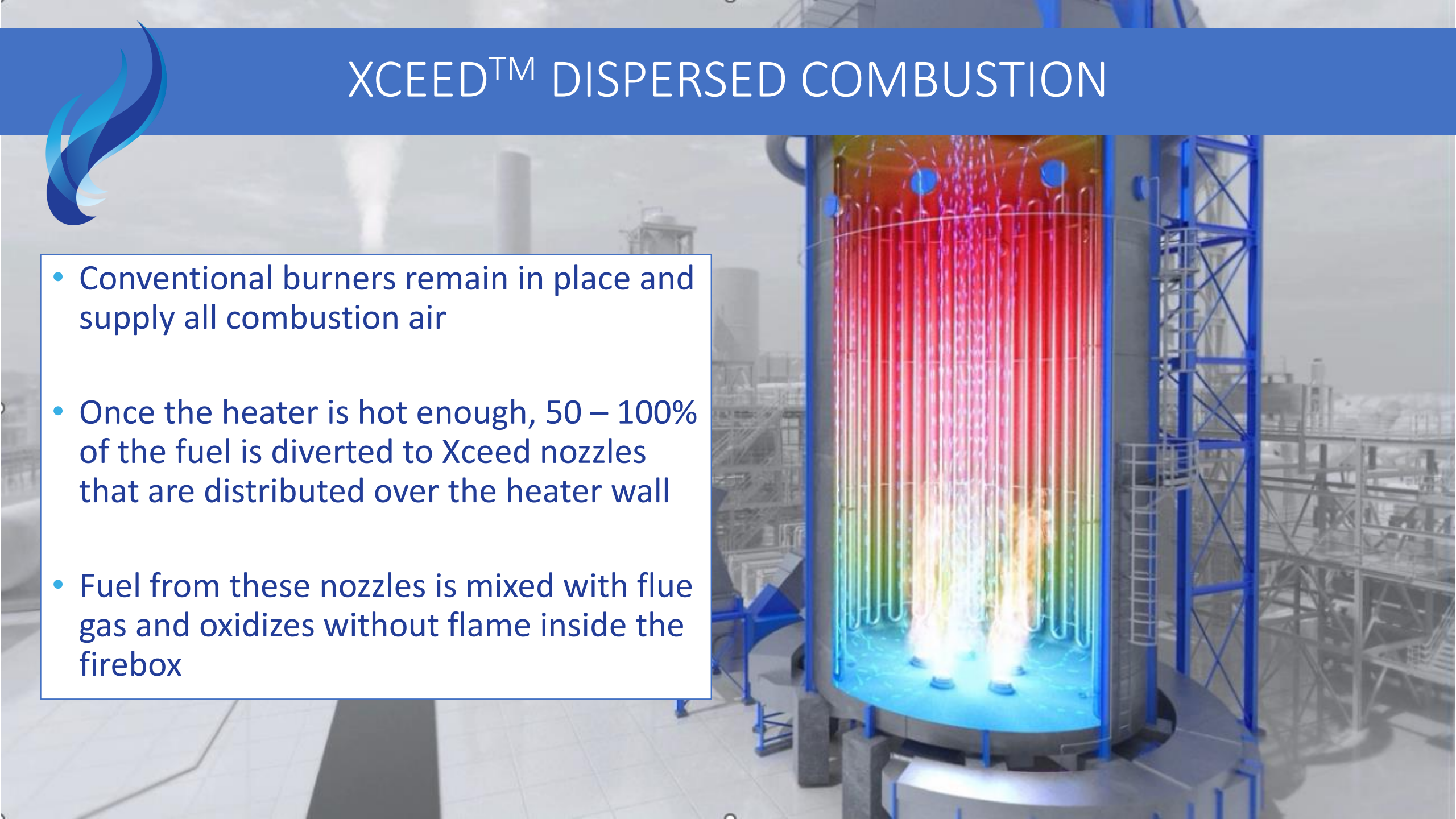
➢ True flameless is difficult;

➢ A hybrid approach is needed.



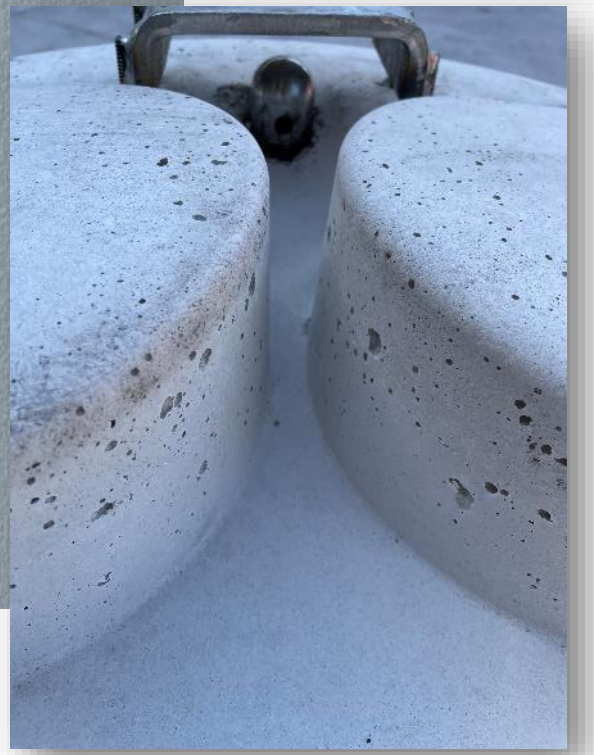
XCEED™ DISPERSED COMBUSTION

- Conventional burners remain in place and supply all combustion air
- Once the heater is hot enough, 50 – 100% of the fuel is diverted to Xceed nozzles that are distributed over the heater wall
- Fuel from these nozzles is mixed with flue gas and oxidizes without flame inside the firebox

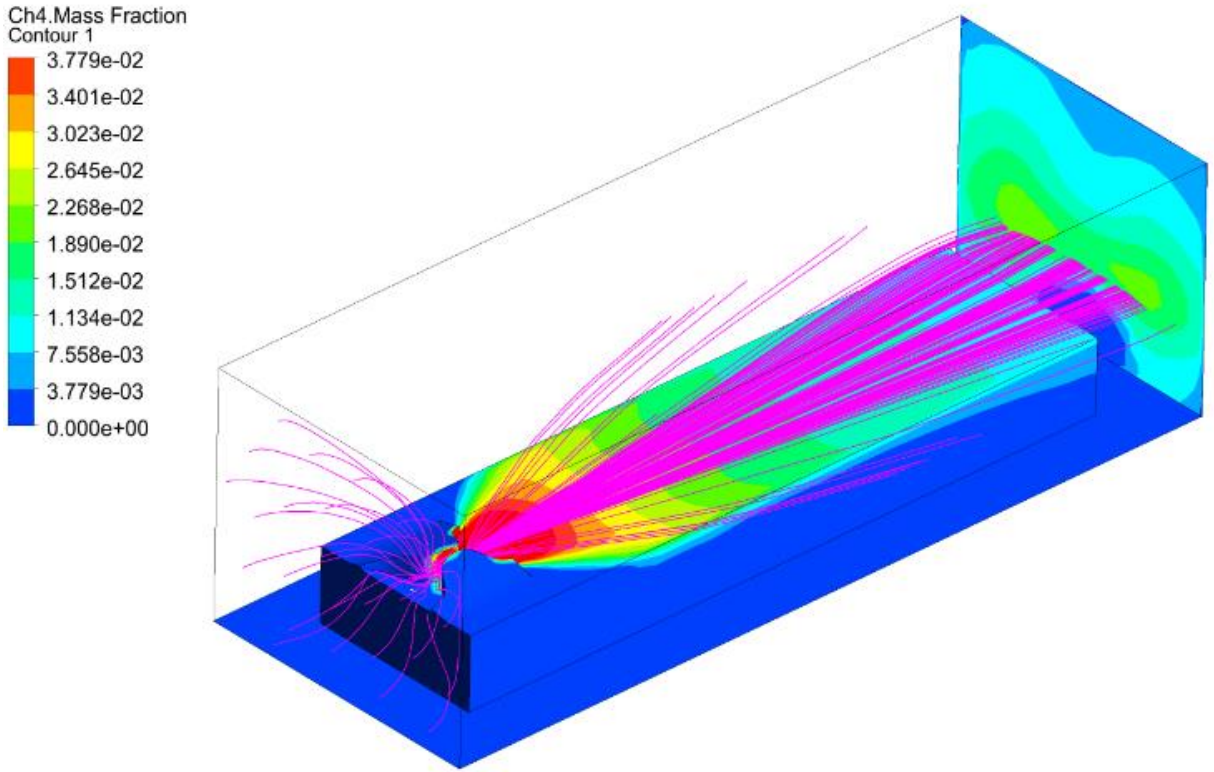


XCEED MODULES

- Xceed modules are installed in the heater wall
- 1 – 4 nozzles for each floor burner
- Refractory maintains casing temperature
- Can be turned off and left in place
- Thermal shock and fouling resistant fuel injector

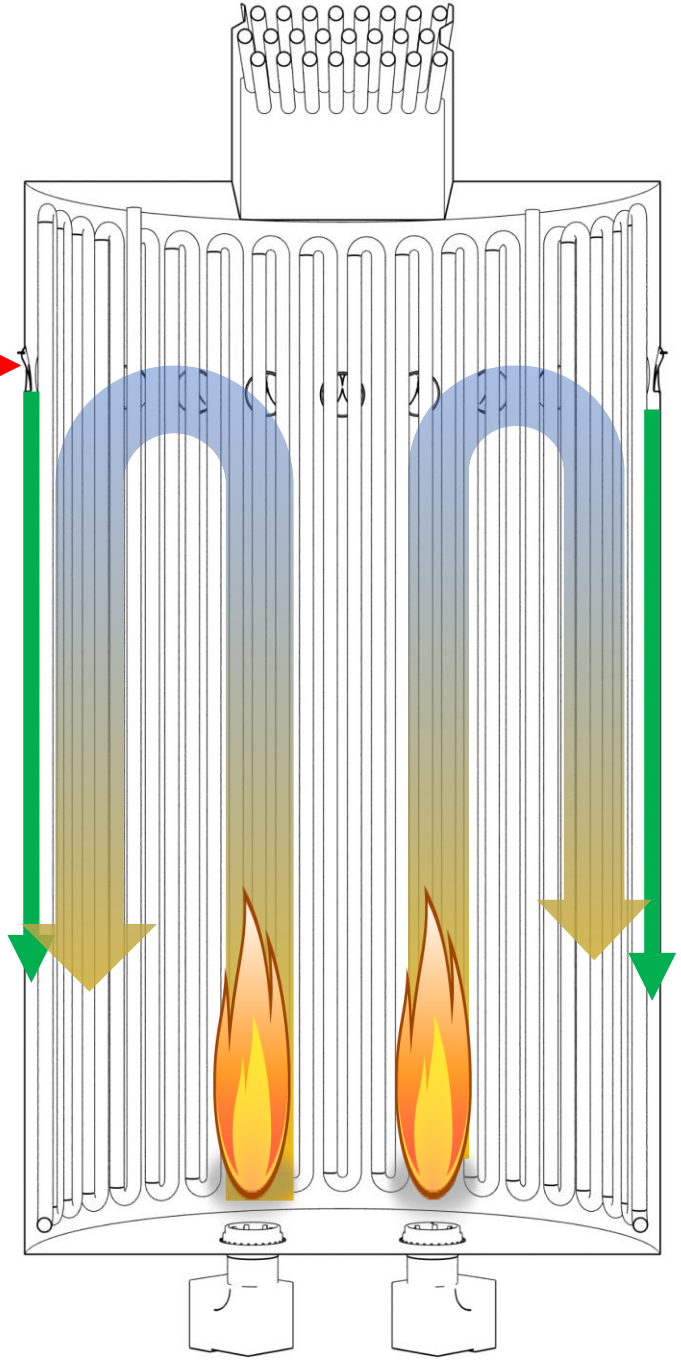


DISPERSED COMBUSTION



- The tile uses a combination of venturi and Coanda effects to maximize flue gas entrainment
- Fuel is diluted in a 40:1 ratio
- Creates a planar high-velocity jet
- The dilution and velocity make it impossible to establish a flame

XCEED SYSTEM



- Modules are placed behind radiant tubes
- Nozzles inject fuel downwards
- The fuel momentum creates a strong internal flue gas recirculation

XCEED OPERATION

- Once the firebox is heated above 700 – 750°C
  - Xceed nozzles are turned on
  - Floor burners operate at 20 – 50% duty but with 100 – 200% excess air → compact and cool flames
  - Xceed fuel oxidizes slowly, without flame, while heating the backside of the tubes → more uniform heat distribution
  - Any unreacted fuel will travel back into the main burner flame and complete the oxidation

TYPICAL XCEED RESULTS

- NOx reduction of 50 – 80%
- Firebox temperature drops 50 – 80°C
- Firebox radiant efficiency increase of ~6-8%
- Peak radiant tube wall temperatures drop 10 – 30°C
- Flame height reduction ~50%
- No CO emissions

XCEED CASE STUDY

CASE STUDY

VC Crude heater suffered from several issues:

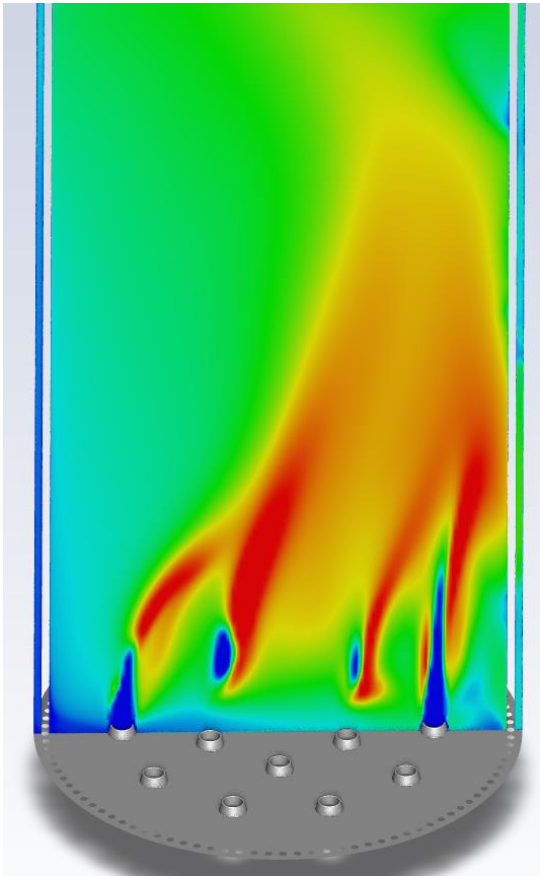
- Tube degradation caused by creep
- Short run-lengths between decokes
  - Due to high radiant tube metal temperatures the heater had to be shut down for cleaning every three to nine months
- Capacity constraints
  - Limitations on the heater firing rate was frequently the main refinery bottleneck
- Convection fouling/degradation

PROJECT GOALS

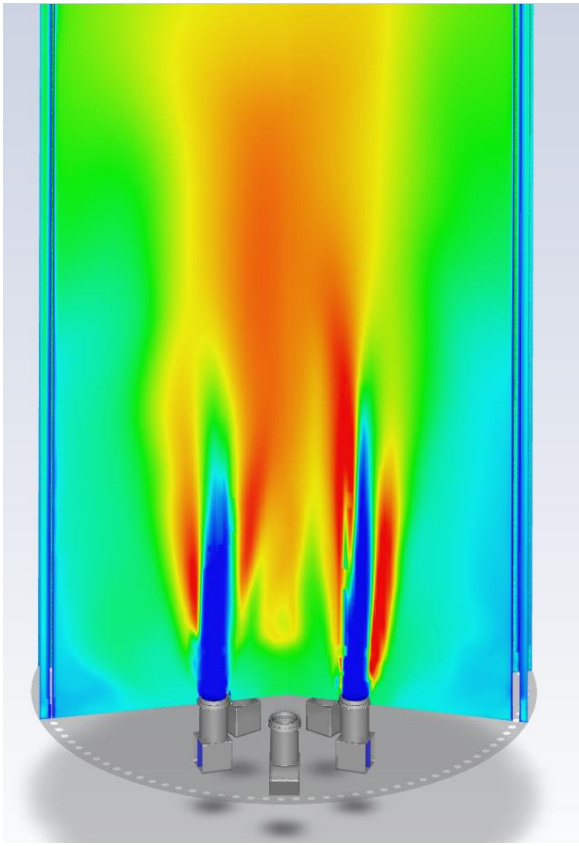
- Eliminate flame impingement / correct flame cloud issue
- Improve fuel efficiency from 78% to >90%
- Increase capacity by 20-30%
- Reduce coking
- Maintain NOx emissions

CASE STUDY

- Phase 1 Revamp:
  - Reduce burner quantity from 15 to 5
  - New ULN burners
  - Add a balanced draft, air preheat system
- Phase 2: Replace convection section
- Phase 3: Add Xceed
  - Long flames due to 100% butane firing



Before



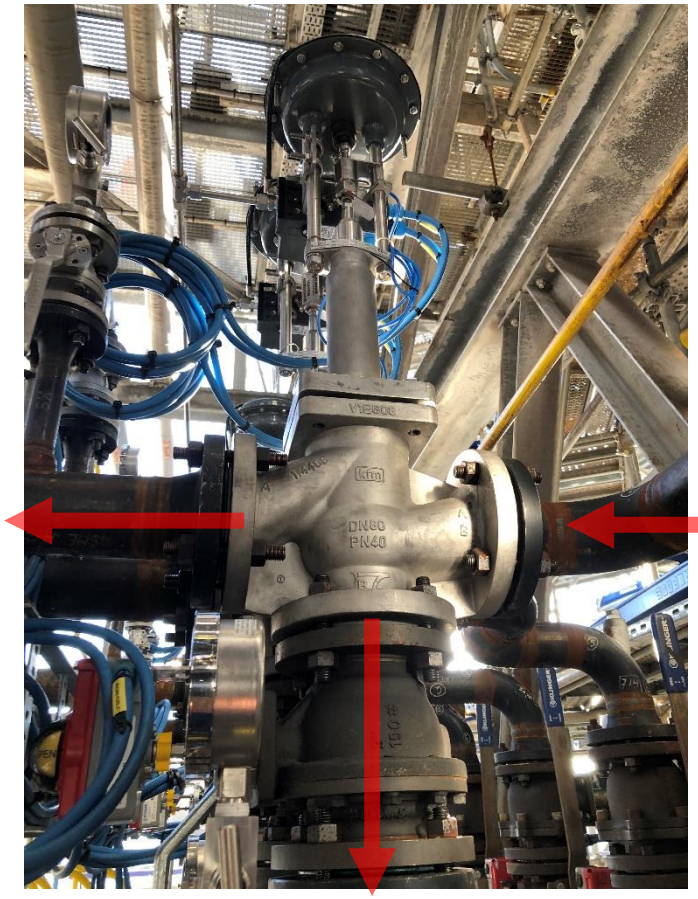
After

XCEED REVAMP

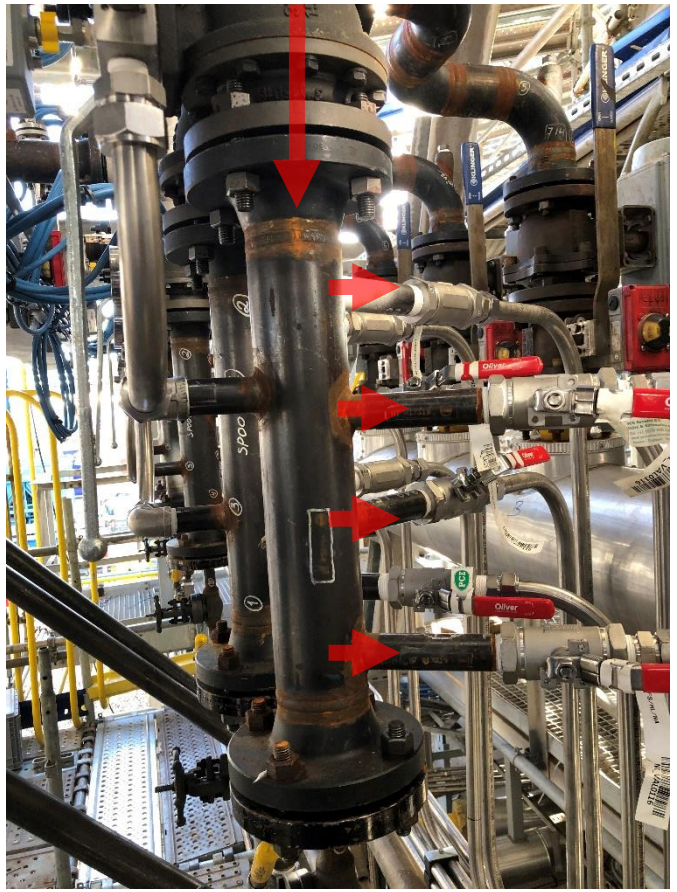
- Twenty Xceed nozzles installed on two elevations
- Four modules per floor burner, 2.2 MW duty / nozzle
- No changes to the heater control and safety system
- Passed EN 746-2 conformity check

XCEED REVAMP

Three-way valve between each burner and Xceed header



Manifold feeds four Xceed fuel lines



FIELD RESULTS

Floor burner flame

Xceed front plate temperature (96°F = 35°C)

Stack sample: 18.6 ppm NOx
0 ppm CO

RESULTS

	Natural Draft Base case	Post APH Revamp	Xceed
Firing rate (MW)	68	76	79
Absorbed duty (MW)	55	69	73 (+33%)
Combustion air temperature (°C)	15	298	290
NOx (ppm)	< 25 ppm	36	18 (-50%)
Peak radiant skin temperature (°C)	461*	562	530
Arch temperature (°C)	801	945	902
Stack temperature (°C)	400	155	153
Fuel efficiency (%)	81	91	92 (+11%)

*Prior TMT location not at real peak

FIELD RESULTS

- In operation since October 2022
- Arch temperature reduced 43°C
- Peak wall temperature decreased by 32°C
- Saved 22,500 tpy CO_2
- Saved 26 tpy NOx
- Flame height reduced from 18 to 8 m on 92% butane fuel
- Zero (0) ppm CO
- Eliminated radiant fouling almost completely

CONCLUSIONS

- Xceed Dispersed Combustion can be used to
  - Minimize CO_2 emissions,
  - *And* minimize fuel consumption,
  - *And* minimize NOx emissions, all at the same time
- It requires minimal changes to the existing heater control and safety system
- It improves heater reliability by reducing fouling
  - Additional fuel savings
  - Less downtime for maintenance

CONCLUSIONS

- Dispersed combustion can be retrofitted to many existing heaters; cylindrical, box or cabin type
- Integrates seamlessly with *any* burner technology
- Can be used to fire *any* gas fuel: hydrocarbons, hydrogen, ammonia
- Can be used in combination with electric elements to further reduce carbon footprint :
- *e*-Xceed is in development for the next phase!

THANK YOU