HYDROGEN REFORMER BURNER BASICS

JM H2 & SYNGAS TECHNICAL TRAINING SEMINAR

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PRODUCT LINE MANAGER - BURNERS

6 November 2024

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AGENDA

I. Fundamentals & Design Considerations

II. Installation, Operation & Maintenance

III. Technical Solutions for Revamps & Process Improvements

IV. Callidus Ultra Blue System Burners

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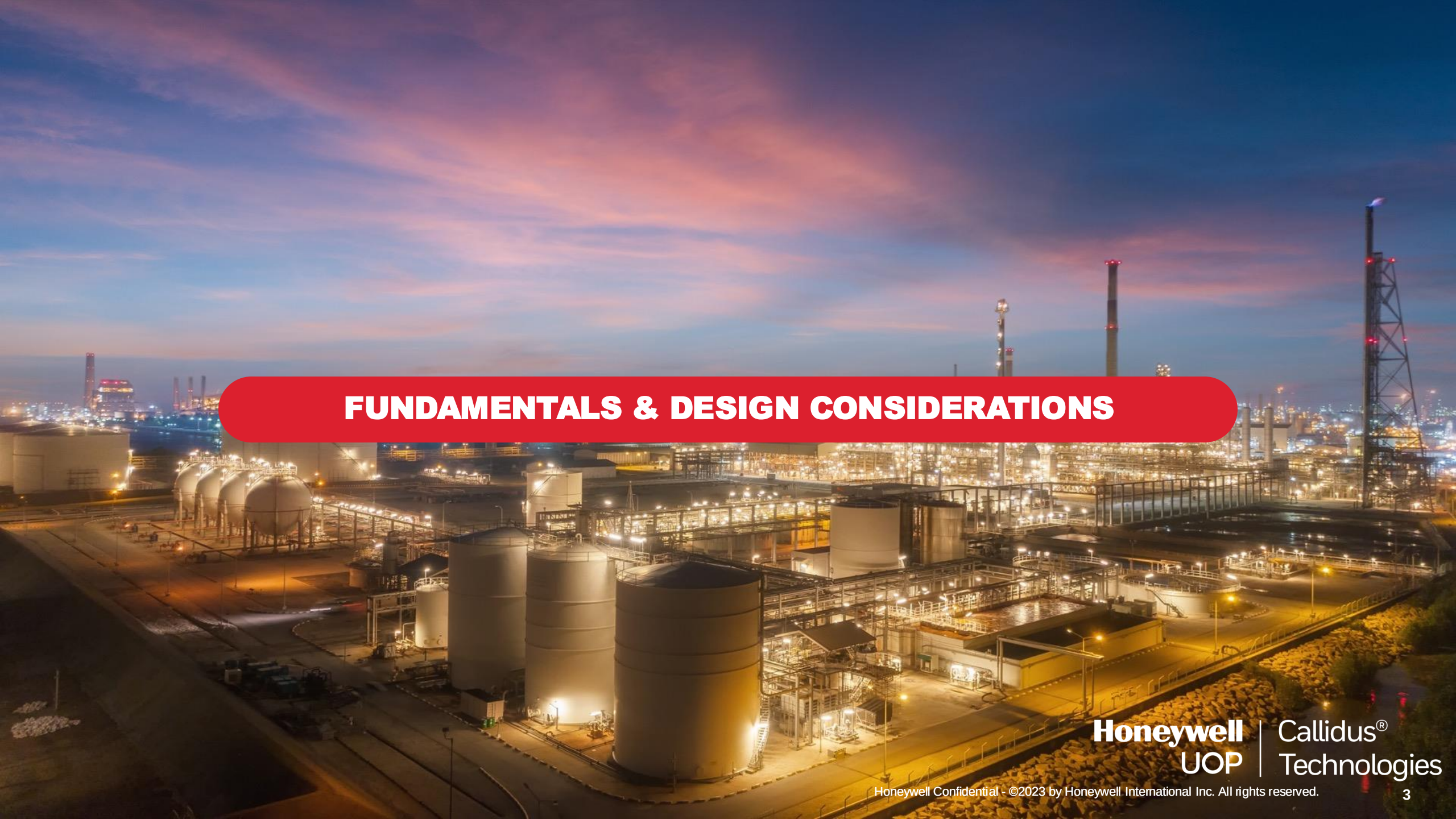

FUNDAMENTALS & DESIGN CONSIDERATIONS

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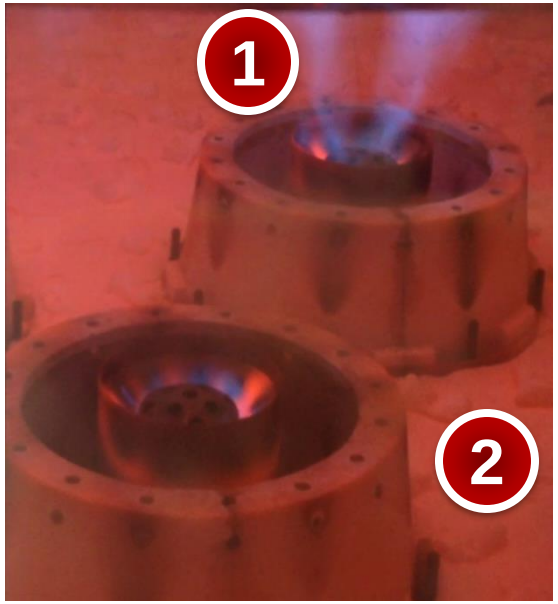
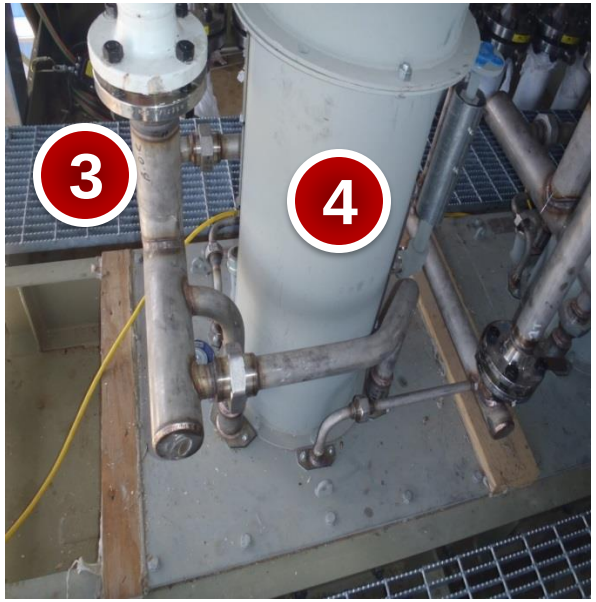
MECHANICAL COMPONENTS OF REFORMER BURNERS



Up-Fired Burner

1. NOx Technology
2. Burner Tile
3. Fuel Delivery Manifold(s)
4. Wind Box



Down-Fired Burner

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COMBUSTION BASICS

- A chemical reaction between fuel and oxygen producing heat
- Typical Fuel: Natural Gas (NG), Refinery Fuel Gas (RFG), PSA Tail Gas and Syn Gas
- Oxidant: Ambient Air, Preheated Air or Turbine Exhaust Gas (TEG)

$$C_xH_y + zO_2 + 3.71zN_2 \longrightarrow xCO_2 + \frac{y}{2}H_2O + 3.71zN_2$$

Undesirable Products of Combustion

1. Thermal NO_x – Formed as a result of "high" temperature combustion

N_2 + Heat → 2N
N + O_2 → NO + O

2. Fuel NO_x – Formed from the oxidation of a nitrogen bearing compound

$4NH_3 + 5O_2 \rightarrow 4NO + 6H_2O$

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NO_X FORMATION

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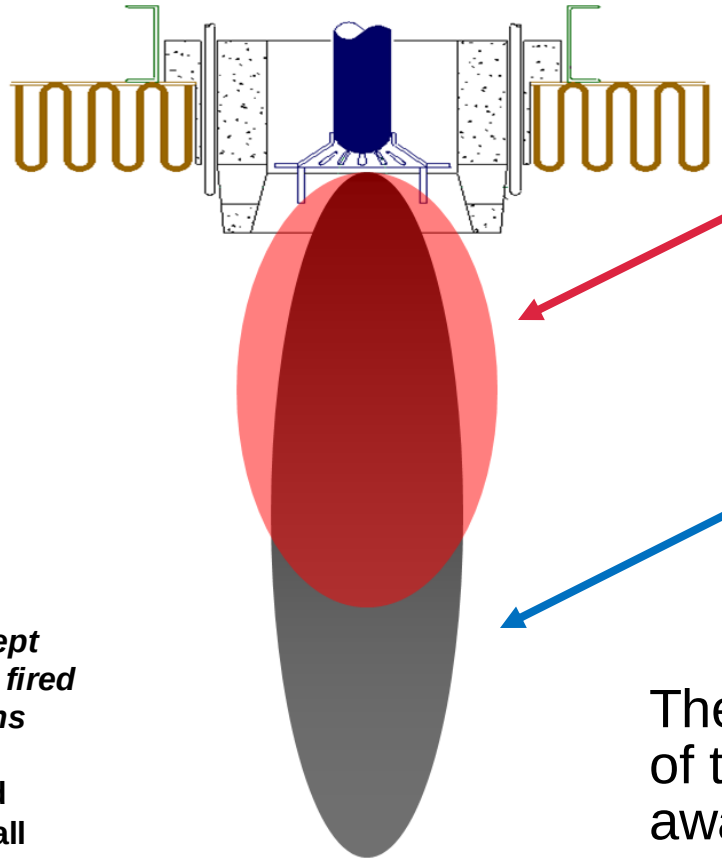
Factors that Affect Thermal NO_X Formation

- Bridgewall Temperature → Typical Range of 1800 - 2000ºF
- Combustion Air Temperature → Ambient - ~800ºF
- Fuel Composition → 100% NG to 20% NG / 80% PSA Tail Gas
- Peak Flame Temperature → 2800 - 3900ºF

Combustion Excess Air Levels above stoichiometry impact NO_x
Typical Excess O_X Operating Levels Range from 1% - 3%

HOW TO REDUCE NO_x FORMATION



Old Technology Produces Short Compact Flame With HIGH Peak Flame Temperatures

New Technology Produces Longer Flames With Lower Peak Flame Temperatures

NOTE: Concept applies to all fired configurations

- **Up-fired**
- **Down-fired**
- **Radiant wall**

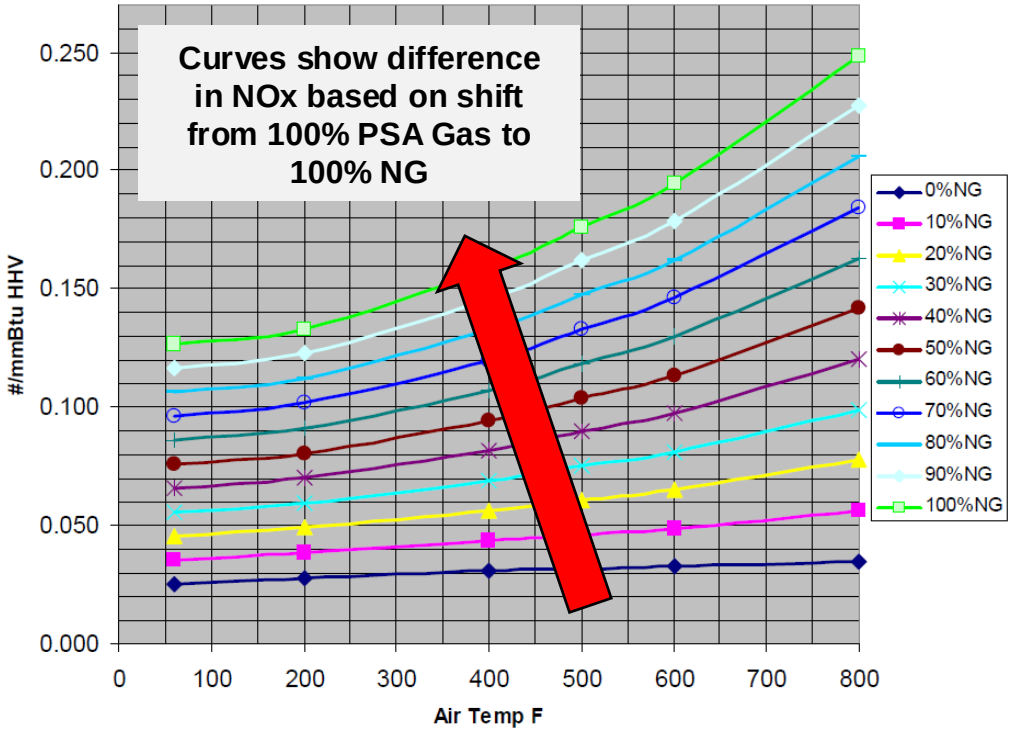
The *actual* flame temperature is the temperature of the combustion products with heat transfer away from the products.

Reduce Overall Emissions by Controlling the Combustion Process

TECHNICAL SOLUTIONS TO LOWER NO_X EMISSIONS

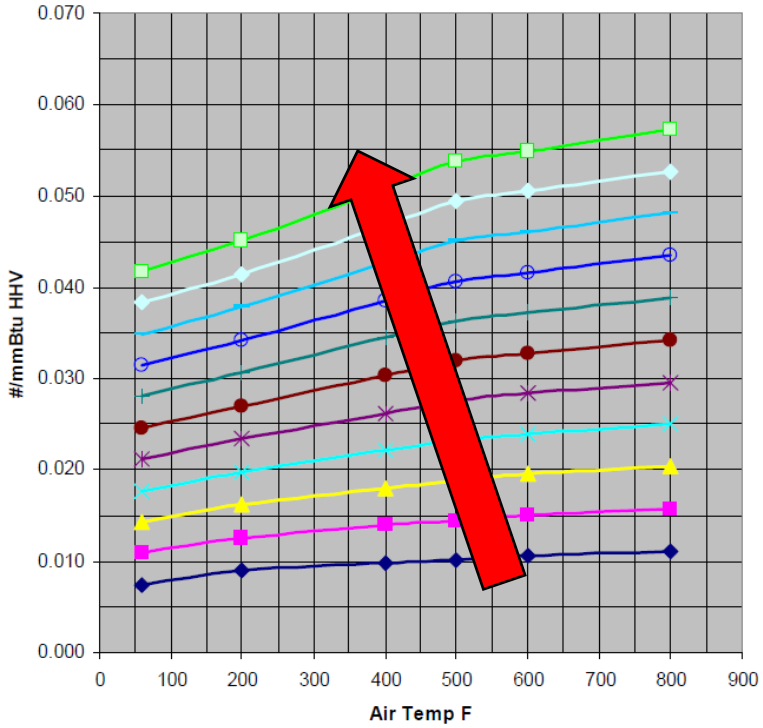
Conventional Burner

All Fuel
(Make-Up Fuel and PSA Gas) in
Throat of Burner



Ultra-Low NO_x Burner

Both Fuels
(Make-Up Fuel and PSA Gas)
are Staged (Small % in Throat)

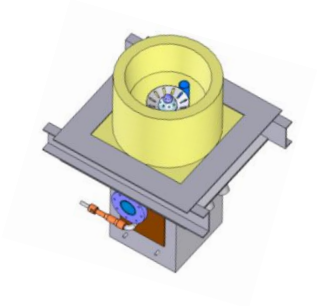


Advanced Burner Designs Reduce NO_X Emissions

FIRING ORIENTATION & DESIGN CONSIDERATIONS

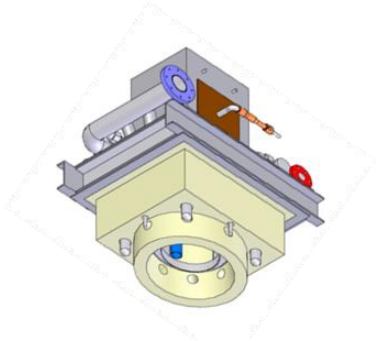
Up-Fired Reformer Burners

- Tile sits on furnace floor
- Induced or Forced Draft applications
- Typically installed in vertical cylindrical furnaces
- PSA tail gas and natural gas supplied via different manifolds
- Staged air, stage fuel, and ultra-low NO_x technology can be utilized



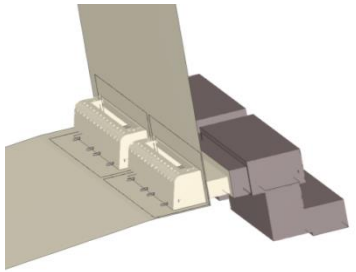
Down-Fired Reformer Burners

- Tile supported from furnace steel
- Air wind box supported on steel channels
- Induced or Forced Draft applications
- Installed in multiple lanes in down-fired furnaces
- PSA tail gas and natural gas supplied via different manifolds or mixed into a single manifold
- Staged air and ultra-low NOx technology can be utilized.



Terrace Wall Reformer Burners

- Tile supported by furnace ledge or unitized construction to wind box
- Air inlet typically horizontal entry
- Burner shape is a flat flame and fired up furnace wall
- Induced or Forced Draft applications
- Installed in multiple levels (vertically)
- PSA tail gas and natural gas supplied via different manifolds
- Staged fuel and ultra-low NOx technology can be utilized



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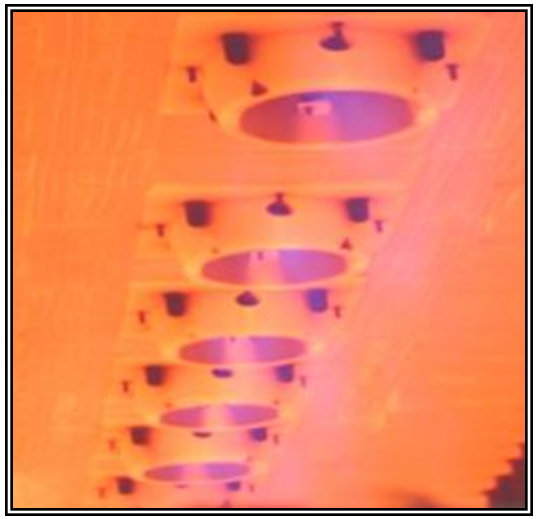
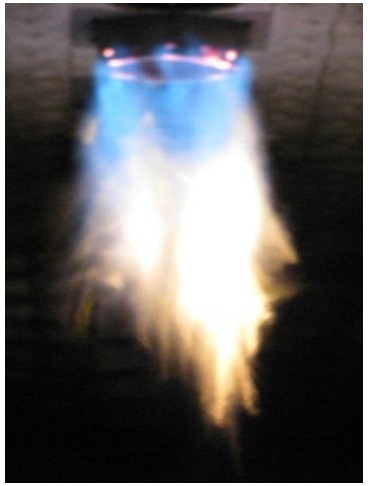
INSTALLATION



OPERATION

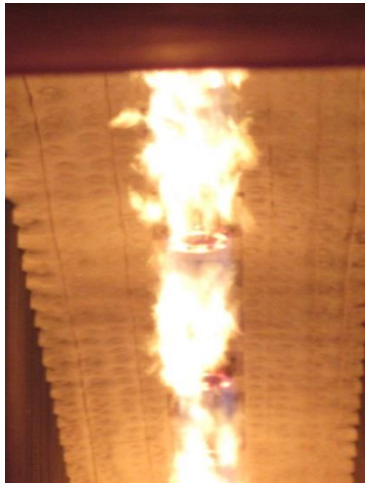
Start-Up

- Low firing rate
- Light off sequence staggered to keep heating uniform
- No PSA tail gas available



Introduction of Feed

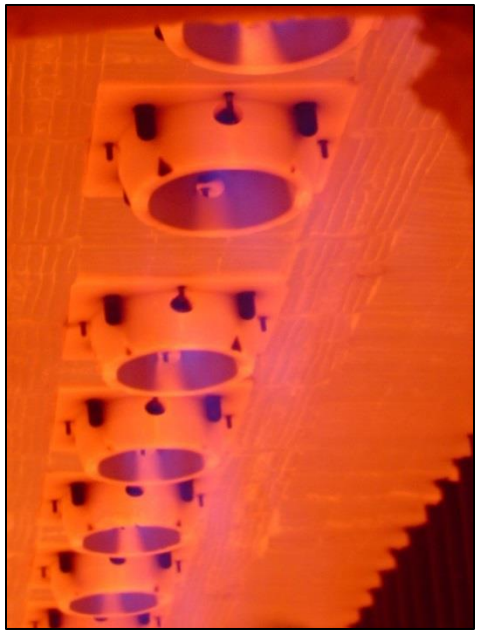
- More burners brought online
- Firing rate approaching 50% of furnace design firing rate
- No PSA tail gas available
- Steam and Feed introduced



Design Firing

- All burners on-line
- Firing rate at furnace design or normal firing rate
- PSA tail gas used as a burner fuel
- Natural gas fuel is reduced in firing rate
- Hydrogen production

OPERATIONAL ISSUES THAT IMPACT EFFICIENT REFORMER OPERATION



Avoid

- ☒ Unsealed tube penetrations
- ☒ Setting Air Registers Unevenly
- ☒ Throttling Fuel to Individual Burners
- ☒ Running Off Design Conditions

OPERATIONAL DO'S AND DON'TS

Do Contact Burner Supplier:

- Fuel Composition Change
- New NOx Emission Requirement

Do at the End of Each Shift:

- Visually Evaluate Flame Quality
- Shoot Tube Metal Temperatures
- Watch for Hot Spots on Tubes

- Don't Throttle Fuel Valves to Individual *Burners*
- Don't Distribute Air Unevenly to Burners
- Don't Ignore Poor Flame Quality

INSPECT CONDITIONS OF BURNERS

Points of Inspection

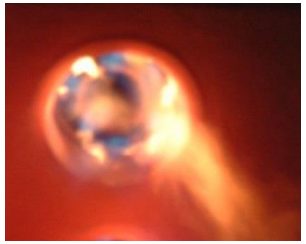
- Ensure burner tile and wind box assembly are aligned (concentric)
- Verify gas tips are in correct orientation & elevation
- Tips are not plugged or blocked with debris
- Pilot is in correct location & elevation
- Furnace insulation is compressed against tile (material will shrink when furnace is fired)

COMBUSTION ISSUES

Problem: High Gas Pressure

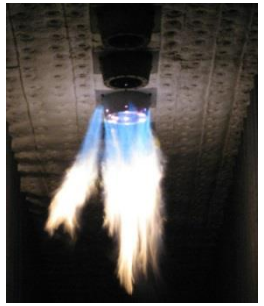
- **Indications**
  - Fuel gas pressure is higher than design
- **Effect**
  - Failure to get proper outlet temperature on process side
- **Long Term Implications**
  - Permanent plugging of gas tips
  - Poor flames
  - Loss of hydrogen production
  - Potential radiant tube damage and failure

Problem: Irregular Flame Patterns



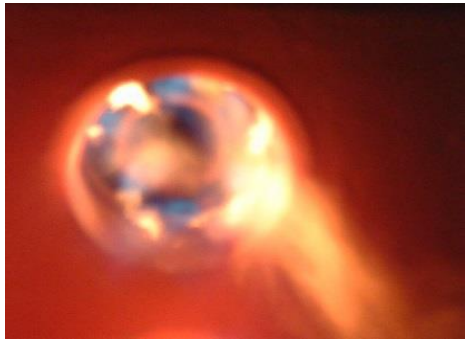
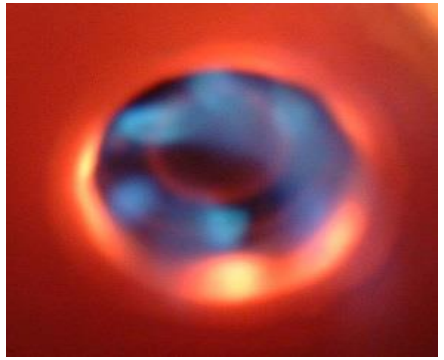
- **Indications**
  - One side of flame pattern is long, the other side is short
  - Flames lean toward the tubes
- **Effect**
  - High Tube Metal Temperatures (TMT's)
  - Increased Rate of Tube Coking or Failure
  - Decreased heater capacity
  - Increased fuel usage
- **Long Term Implications**
  - Loss of hydrogen production
  - Potential radiant tube damage and failure

Misaligned TIP: Start-Up Condition or After Maintenance



- **Burner Has Natual Gas Tip That is Installed in Wrong Orientation**
  - Orientation Must be Corrected!
  - Left Uncorrected:
    - Flame can impinge on radiant tube
    - Create hot spot or tube rupture
    - Increase NOx or CO emissions

POTENTIAL SOLUTIONS TO COMMON COMBUSTION ISSUES

Issue	*Solution*
Fouled Gas Tips	Clean or Replace Gas Tips
Improper Air Register Settings	Adjust All Burner Air Registers to Uniform Settings
Replacement Gas Tips Installed in Wrong Orientation	Correct Gas Tip Alignment
	

SUPPORT FOR REVAMPS OR PROCESS IMPROVEMENTS

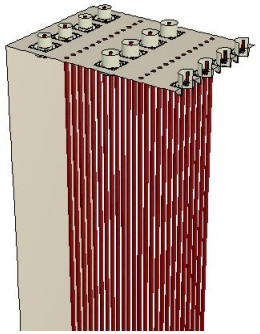
Changes that can impact burner performance:

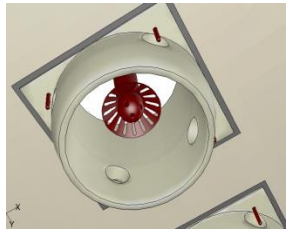
- **Change in Feedstock Results in a Change in the PSA Tail Gas which is Fuel Supplied to Burners**
- **Changing Make-Up Fuel From Natural Gas to Refinery Fuel Gas**
- **New NO_x Requirements**
- **Requiring Increase / Decreased Capacity Operation**

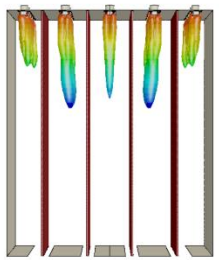
Combustion Specialists Provide Value for Reformer Modifications

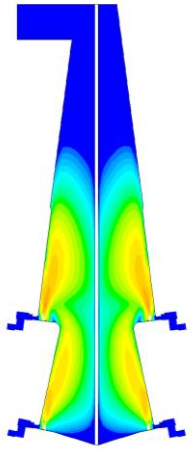
SUPPORT FOR REVAMPS OR PROCESS IMPROVEMENTS

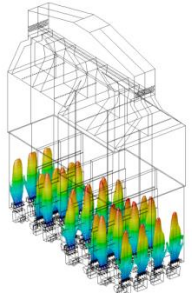
CFD Analysis for Retrofits and Revamps









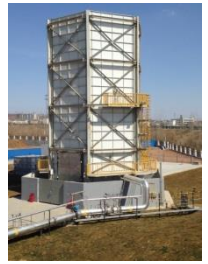


Burner Testing and R&D, Beggs, OK

- **Seven (7) Test Furnaces**
  - Vertical Up Fired
  - Down-Fired Fired
  - Radiant Wall
  - Horizontally Fired
- **Flare Facility**
  - Multipoint Flare
  - Totally Enclosed Ground Flare
  - Elevated Flares
- **Thermal Oxidizer**
  - Burners
  - UHC & NOx Testing

Burner Testing and R&D, Louyang, China

- **Three (3) Fired Furnaces**
  - Vertical Up Fired
  - Down-Fired Fired
  - Radiant Wall
  - Horizontally Fired
- **Flare Facility**
  - Multipoint Flare
  - Totally Enclosed Ground Flare
  - Elevated Flares



SUMMARY

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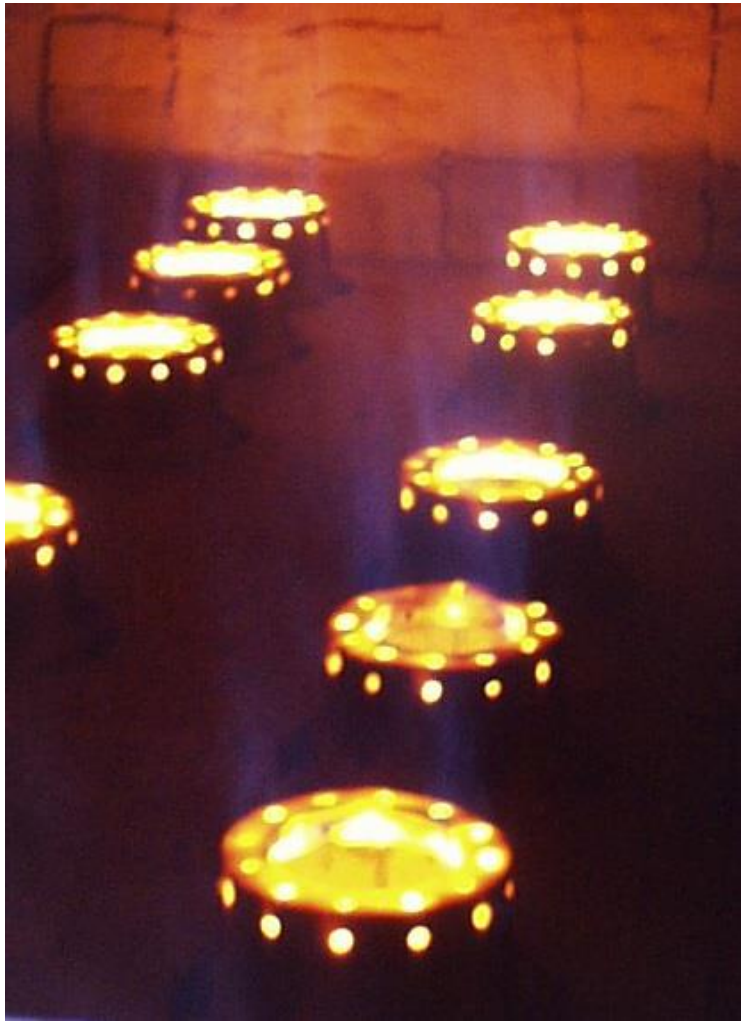
- **Fundamentals & Design (NOx)**
  - Select the Right Burner for the Application & Emissions Requirement
- **Installation, Operation & Maintenance Considerations**
  - Operate Burners Uniformly
  - Monitor Flames and Tubes
  - Inspect Burners and Tube Seals during T/A's
- **Technical Solutions for Revamp / Process Improvement**
  - Collaboration Yields Highest Results
  - Right Approach Yields Best Solution / Minimum Risk



CALLIDUS ULTRA BLUE SYSTEM BURNERS

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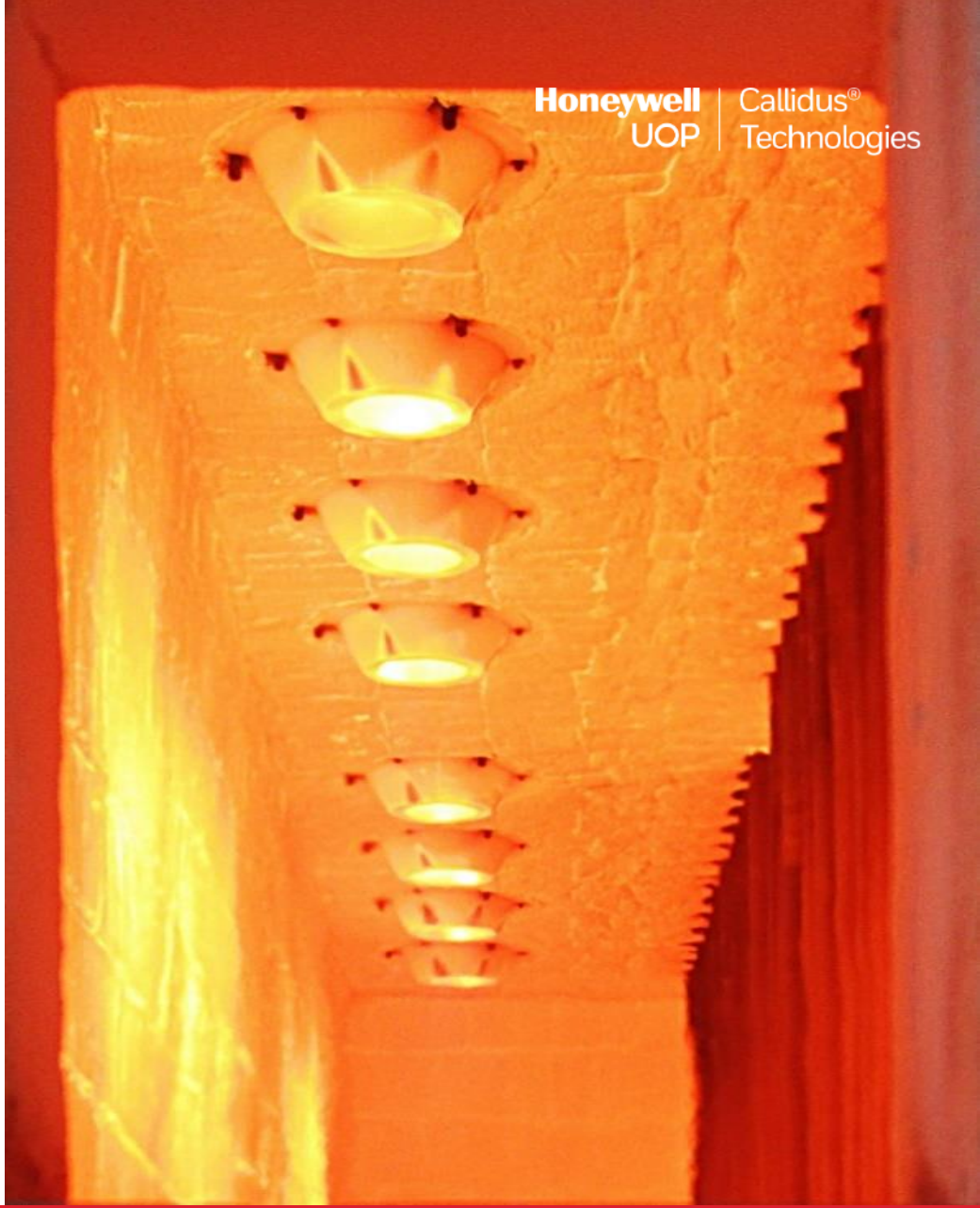
THE ULTRA BLUE SYSTEM WITH CALLIDUS® ULTRA BLUE HYDROGEN - CUBH LOW NO_x BURNERS

Rapidly Switch From/To Any Fuel

- 100% Hydrogen Fuel Gas
- 100% Natural Gas Fuel
- CO_2 Rich and CO_2 Lean Purge Gas
- 0% to 100% Purge Gas Fuel
- High or Low Design Pressure
- Premixed or Separate Fuel & Purge Gas
- High 2 Barg or Low 0.2 Barg Design Fuel Pressure

Consistent Low NOx Emissions Across All Fuels[3]
No Special Operator Intervention on Fuel Change
Normal Furnace Excess Air and Draft Control



1 Based on the results of Callidus' June 2022 Test Report for CUBH and CUBP Process Heater Burners available at:
https://uop.honeywell.com/en/equipment-and-aftermarket-services/callidus-environmental-combustion-technology/callidus-burners/callidus-ultra-blue-petrochemical-cubp-burners

Ready for Energy Transition and Even More Stringent Emissions Regulations

THE ULTRA BLUE SYSTEM
CALLIDUS® CUBP Burners with Targeted De-NO_x Gas injection TDGi™

Energy transition – 100% Hydrogen firing

- Flexibly transition between high-hydrogen firing and conventional plant fuels[1]
- Rapid, on-demand fuel switching

Breakthrough lower NO_X emissions

- Over 50% reduction in NO_X[1]
- Compared to conventional ultra-low NO_X burners
- Eliminate or reduce CAPX/OPEX for SCRs

Efficient Energy Transition & Lower Emissions

- Breakthrough low NO_X on virtually any fuel gas
- Can deliver the lowest NO_X emissions when 100% hydrogen firing[1]
- Enables Carbon Capture Technologies

1 Based on the results of Callidus' June 2022 Test Report for CUBH and CUBP Process Heater Burners available at:
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Ready for Energy Transition and Even More Stringent Emissions Regulations

THE PROVEN CALLIDUS® ULTRA BLUE® FAMILY OF LOW NO_X BURNERS

	CUBL	CUBH	CUBP
Ultra-Low NO_X Performance Sub-10ppm NO_X for many refinery cases[1]	✓	✓	
Breakthrough Low NO_X Performance Single Digit ppm NO_X for many refinery cases[1]			✓
Flexible Fuels: 100% H2 to 100% Hydrocarbons and Virtually Any Synthesized or Refinery Fuel Gas[1]	✓	✓	✓
Optimized for 100% Hydrogen Service[1]		✓	✓
Bolt-On Retrofittable / Upgradable	✓	✓	✓
Conventional Burner Operation	✓	✓	✓
with The Ultra Blue System			✓

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CUBL

Callidus® Ultra-Blue Low NO_X Burner

The Industry Standard Low NO_X Workhorse

CUBH

Callidus® Ultra-Blue Hydrogen Burner

Optimized for Hydrogen Fuel Service Proprietary Flame Stabilization Technology

CUBP

Callidus® Ultra-Blue System Burner

Optimized for Hydrogen Fuel Service Proprietary Flame Stabilization Technology
Breakthrough Low NO_X Performance Proprietary Targeted De-NO_X Gas Injection, TDGi™

THANK YOU
FOR YOUR PARTICIPATION

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