Operational and Design Issues Faced by Low NOx and Ultra Low NOx Burners

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AGENDA

- Statement of Intent
- The 3 W’s???
  - Corporate Overview
  - Market Sectors
- What is Delayed Coking
- Burner Design – Historical Requirement
- Burner Design – Current Requirement
- Factors for Consideration in Burner Design
- Burner Design – Advantages of Staging Principals
- Burner Design – Future Requirements
- Burner Design – Next Generation Technology
- Necessities for Meeting End User Future Objectives
- Questions???
Statement of Intent

Hamworthy Combustion informs that the contents contained within this presentation, including all information and statements made, are not specific to any manufacturer type or model but are intended only as topics for discussion with the intent to simply raise the criticality of certain information and data necessary to review the correct design, operation and function of Low NOx and Ultra Low NOx burners and how if not correctly interpreted this lack of clarity in information can lead to incorrectly designed equipment which in turn could lead to a loss in furnace efficiency and overall production of the furnace itself.

The information contained within this presentation is of a proprietary nature and shall not be released to third parties without the prior written consent of Hamworthy Combustion.
Hamworthy Combustion
Global Solutions, Local Delivery

WHO ARE HAMWORTHY COMBUSTION?

WHAT COMBUSTION EQUIPMENTS DO WE SUPPLY??

WHICH MARKET SECTORS DO WE SUPPORT??

THE 3 W’s ???
• History
   Established since 1911

• No. of Employees
   700 + worldwide

• Annual Turnover
   US$160 million

• Offices
  • Major European Economies
  • Japan
  • India
  • United States
  • China
  • Poland
  • Korea
  • Mexico
  • Brazil
  • Singapore
  • Dubai

Fully comprehensive Advanced Technology Centre incorporating 14 test furnaces
MARKET SECTORS – CUSTOMER CENTRIC

Dedicated teams of c 100 people focussed on each sector: specialists, 100% full time

We are a true customer solutions provider in the highly specialised markets we serve
What is Delayed Coking?

- I am still learning and hope to continue to learn, but!

- A process which incorporates a fired heater which is used to obtain thermal cracking temperatures of 905 – 940°F having horizontal tubes within which feed stock is processed at short residence times to ensure “delayed coking” occurs downstream of the heater in coking drums.

- A fired heater installation having up to 1,000 burners installed of low firing capacity.

- A large capital investment requiring optimum continual performance from all equipment installed to ensure maximum furnace efficiency is achieved with minimum maintenance requirements.
Delayed Coking – Burner Design Consideration
Historical Requirements....

- Burners firing gas & oil
- High excess air levels – oil firing 25-30% / gas firing 20-25%
- CO emissions of < 200 vppm
- Nox emissions of < 150 vppm for gas firing / < 350 vppm for oil firing
- UHC guarantees not required
- No defined noise guarantee
- Turndown limits of 3:1 oil firing / ≥ 5:1 gas firing
- Round Flame central burners / flat flame side burners

RESULTS????

Conventional burner design with good stability, low risk, low maintenance but high emissions and in some cases low furnace efficiency!
Delayed Coking – Historical Burner Design....
Burners predominantly firing gas (and oil depending on country)
- Low excess air levels – 10% (oil 20-25%)
- CO emissions of < 25 - 50 vppm
- Nox emissions of < 25 - 35 vppm for gas firing (150 – 200 vppm oil firing)
- UHC guarantees < 10 ppm
- Noise levels < 80-85 dB ‘A’
- Turndown limits of 5:1
- Round flame central burners / flat flame side burners
- Ability to fire various range of fuel gas cases from high H2 to heavies and double bonded characteristics
- Increasing tendency for burners having lower firing capacity but higher number in quantities
Detailed low NOx or ultra low NOx burner design requiring careful design considerations in order to achieve good stability, low maintenance requirements and tighter operational control.

The increasing need to review NOx reduction techniques vs burner operating envelope and flame configuration/shape.

The increasing need to review fuel gas compositions and operating temperatures.

The need for closer integration of end user, EPC, heater contractor and burner vendor.

The need to ensure all correct design data and information is fully received and considered in the final burner design parameters.

The need for open honesty about what can and can not be achieved in order to avoid long term maintenance and operational issues.
Low NOx and Ultra Low NOx Burners – Factors for Consideration

- Receiving the correct and complete design data requirements, incl...
  - Altitude above sea level clearly stated.
  - Units of Liberation clearly stated.
  - Maximum pressure drop across burner correctly stated.
  - Design duty vs normal duty vs minimum duty fully reviewed
  - Fuel compositions and conditions clearly stated.
  - Emissions requirements stated with no additional safety factor added
### General Data
- ALTITUDE ABOVE SEA LEVEL ft
- VISCOSITY @ HEATING VALUE (LHV), (CST)
- PRESSURE, Psig
- ASH % WT
- FUEL TEMPERATURE @ BURNER, °F
- O ATOMISING MEDIUM: AIR / STEAM / MECHANICAL
- POTASSIUM, PPM
- FUEL TYPE
- VISCOSITY @ NORMAL FUEL PRESSURE REQUIRED @ BURNER, Psig
- NOISE SPECIFICATION
- FIXED NITROGEN PPM
- ASTOMA END POINT, °F
- SULFUR, % WT
- NICKEL, PPM
- LIQUIDS ASTM INITIAL BOILING POINT, °F
- TEMPERATURE, °F
- NOSE *
- FUEL GAS COMPOSITION, MOLE %
- SODIUM, PPM
- HEATING VALUE (LHV), MMBtu/hr MW (LHV)
- VANADIUM, PPM
- COMBUSTION PROCESS FOR THIS REASON WE DO NOT OFFER AS A GUARANTEE POINT
- DOCUMEN

### Emission Requirements
- EMISSION REQUIREMENTS
- FIREBOX TEMPERATURE (MIN / MAX / DESIGN)
- NOX * Vppm
- SOX *
- CO *
- UHC *
- PARTICULATE *
- 2) THE ABOVE EMISSION DATA IS BASED ON THE FOLLOWING CRITERIA:
- EXCESS AIR OF
- AIR TEMPERATURE OF
- H2 IN FUEL GAS OF
- TOTAL LIQUID FUEL CHARACTERISTICS
- H2O IN FUEL OIL OF
- O2 IN FUEL OIL OF
- H2O ACROSS PLENUM, . in.
- DRAFT TYPE: FORCED / NATURAL / INDUCED
- DRAFT AVAILABLE: ACROSS BURNER, . in.
- OPERATING RANGE OF NORMAL TO MAXIMUM LIBERATION.
- BURNER WALL SETTING THICKNESS, . in.
- HEATER CASING THICKNESS, in.
- FIREBOX HEIGHT, ft
- TUBE CIRCLE DIAMETER, in.
- MANUFACTURER
- MODEL / SIZE
- TYPE OF BURNER
- LOCATION (ROOF / FLOOR / SIDEWALL)
- NUMBER REQUIRED
- MODE OF OPERATION
- LEAKAGE, %
- BURNER TILE: COMPOSITION
- BURNER PLENUM: COMMON / INTEGRAL
- BURNER CIRCLE DIAMETER, . in.
- PILOTS:
  - NUMBER REQUIRED
  - TYPE
  - IGNITION METHOD
  - FUEL PRESSURE, Psig
  - CHAMBER SIZE
- OPERATING DATA
- FLAME LENGTH @ DESIGN HEAT RELEASE, ft
- FLAME SHAPE (ROUND, FLAT, ETC)
- INTERNAL INSULATION
- LEAKAGE, %
- BURNER TILE: COMPOSITION
- BURNER TUBE: COMPOSITION
- MATERIAL
- MAXIMUM SERVICE TEMP, °F
- NAME SPECIFICATION
- EXTRACTION METHOD
- FUEL PRESSURE REQUIRED @ BURNER, Psig
- BURNER LOCATION
- CONNECTION SIZE
- SAFETY INTERLOCK SYSTEM FOR BURNER NERVOUS OR
- PERFORMANCE TEST REQUIRED (YES OR NO)

### Mishellanous
- BURNER DATA SHEET
  - API STANDARD 560
  - PROJECT No. DOCUMENT No. SHEET
  - BURNER DATA SHEET
  - API STANDARD 560
  - PROJECT No. DOCUMENT No. SHEET
  - BURNER DATA SHEET
  - API STANDARD 560
  - PROJECT No. DOCUMENT No. SHEET
Low NOx and Ultra Low NOx Burners – Factors for Consideration

Comparison of Operating and Design Envelopes

Heater Load Range

Natural Draught Burner dP. in H2O

Design

Normal

Minimum

Burner Operating Envelope

Burner Design Envelope
Low NOx and Ultra Low NOx Burners – Factors for Consideration

- Reviewing completely the fuel gas compositions, temperatures and operating pressures
  - Single fuel gas firing
  - Requirement to fire high H2 gases to LPG, Butanes, etc...
  - Climatic / ambient temperatures and effect on fuel gas conditions.
  - Increased tendency for coke formation through variation of fuels.
  - Possibility of increased maintenance as a result of burner design choice vs fuel gas composition.
Low NOx and Ultra Low NOx Burners – Factors for Consideration

Single gas only =
- good pressure
- good velocity
- good fuel to air mixing
- good combustion
- low maintenance
Low NOx and Ultra Low NOx Burners – Factors for Consideration

Multi gas cases =
- lower pressure for high MW gases
- lower velocity for higher MW gases
- Poorer fuel to air mixing for higher MW gases
- higher design review to achieve good combustion
- possible increase in maintenance
Low NOx and Ultra Low NOx Burners – Factors for Consideration

- Reviewing NOx reduction techniques in terms of staged fuel vs staged air vs staged combustion
Staged Air Burner
Flat Flame Burner Dynamics
Staged Fuel Burner
Round Flame Burner Dynamics

Secondary Fuel Stages

‘Pre Burn’ Zone

Hearth Flue Gas Entrainment

Primary Fuel Stages

Air Pressure Drop Plans

Gas Inlet

Air
Staged Combustion
Low NOx and Ultra LOw NOx Burners – Advantages Staged Air vs Staged Fuel

<table>
<thead>
<tr>
<th>Staged Air</th>
<th>Staged Fuel</th>
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</thead>
<tbody>
<tr>
<td>Less Potential for coking</td>
<td>Greater NOx reduction</td>
</tr>
<tr>
<td>Wider turndown</td>
<td>Easier set up</td>
</tr>
<tr>
<td>Less maintenance</td>
<td></td>
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<tr>
<td>Increased flexibility</td>
<td></td>
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<tr>
<td>Adjustable for changing gas cases</td>
<td></td>
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<tr>
<td>Tighter flame dimensions</td>
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Why?????
## Low NOx and Ultra LOw NOx Burners – Advantages Staged Air vs Staged Fuel

<table>
<thead>
<tr>
<th>Reasons</th>
<th>Staged Air</th>
<th>Staged Fuel</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single nozzle – larger orifices</td>
<td>Possible to adapt more severe staging</td>
<td></td>
</tr>
<tr>
<td>Air staging means as you decrease fuel burner becomes in ratio</td>
<td>Staging principle is fixed</td>
<td></td>
</tr>
<tr>
<td>Larger orifices / drillings</td>
<td></td>
<td></td>
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<tr>
<td>Possibility to change staging principle</td>
<td></td>
<td></td>
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<tr>
<td>Secondary air can be adjusted via separate damper</td>
<td></td>
<td></td>
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<tr>
<td>Tile is smaller as no risers outside of tile</td>
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<td></td>
</tr>
</tbody>
</table>
Low NOx and Ultra LOw NOx Burners – Staged Air vs Staged Fuel – Nozzle Design

Staged Air Nozzle

Staged Fuel Nozzle
Low NOx and Ultra LOw NOx Burners – Staged Air/Staged Fuel – possible flame condition
Low NOx and Ultra Low NOx Burners – Factors for Consideration

- The need for closer integration of end user, EPC, heater contractor and burner vendor

- The need for open honesty about what can and can not be achieved in order to avoid long term maintenance and operational issues.
Delayed Coking – Burner Design Considerations
Future Requirements…..

- Burners predominantly firing gas
- Low excess air levels – 5 to 10% (oil 20%)
- CO emissions of < 15 to 20 vppm
- Nox emissions of < 20 vppm for gas firing (150 vppm oil firing)
- UHC guarantees < 10 ppm
- Noise levels < 80-85 dB ‘A’
- Turndown limits of 5:1
- Ability to meet emissions across all operating conditions
- Higher and more even heat flux (tighter flame shape)
- Possibly larger burners in restricted burner spacing to meet flux profile but keep capital cost low.
- **Ultimately, Lower Capital cost, improved reliability, lower maintenance, lower emissions & higher efficiency.**
Delayed Coking – Burner Design Considerations

Future Requirements.....

How to Achieve???

- Draw and expand on existing successful designs
- New Concepts
- Resolve Conflicts e.g
  - High furnace temperature vs NOx
  - Low flame temperature vs CO
  - Low Emissions vs Stability
  - Development using CFD and physical flow modelling
- Burner Test Firing
- Site Trials
Delayed Coking – Burner Design Considerations
Next Generation Burner Design Evaluation.....

Typical NOx Reduction Technology:

- Fuel Staging
- Air Staging
- Flue Gas Recirculation (FGR)

- Staged fuel or staged air is used to delay combustion, minimise peak flame temperature
- Effect of FGR – adds heat but increases inerts and changes flame temperature / flammability range
Staged Combustion / Flue Gas Re-Circulation Burner Dynamics

- Internal Flue Gas Recirculation
- Creates Superheated diluted fuel gas (analogous to a low CV gas)
- Rapid ignition on contact with combustion air – excellent stability
- Suitable for high hydrogen and heavy hydrocarbon gaseous fuels

Patent Pending
Advantages of Staged Combustion technology

- Simple burner design
- No complex low NOx gas nozzles
- Avoid pre-mix
- Stable operation / good burn-out
- Large turn-down range
- Even flame profile
- Suitable for wide range of fuel gas from hydrogen to heavy hydrocarbons
- Ultra Low NOx (10-15 v ppm?)
- Size range 1 – 20 MMBtu/hr
Advantages of Staged Combustion technology

Cont’d....

Staged Combustion

1/4” orifice

3/8” orifice

Staged Air
Advantages of Staged Combustion technology

Cont’d....

100% Natural Gas

20% Natural Gas / 80% H2
Necessities for Meeting End User Future Objectives

- Review of burner technology vs operating data and conditions.
- Increased openness within the industry regarding technology pro’s and con’s.
- Larger understanding of end user issues, equipment operability, maintenance requirements. (closer integration)
- Clarity in terms of end user emission guarantee requirements – avoid adding safety margin on safety margin
- Realisation that a price driven market may not always offer the way forward in terms of achieving optimum furnace operation.
Questions???

- Is Ultra Low NOx the best solution if the operating and maintenance cost of equipment outweigh the cost associated with additional SCR catalyst?

- Is it possible moving forward with furnace designs that flame flame burners can be accepted as round flame design?

- Are local EPA requirements clearly visible between end user, EPC, heater vendors & equipment suppliers during conceptual design stages of a project?

- Do we all know of or have been involved with a furnace where operation could have been improved from an alternative review of burner selection?