In The Name OF God

Primary Reformer

Hampa Energy Engineering &
Design Company

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Introduction

- Ammonia plants
- Methanol plants
- Hydrogen Plants
- Other plants

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A Brief historical Review

- Greater capacity
  - 3300 mtpd 20 rows with a total of 960 tube
- Improve efficiency

Reformer section of a 3,300 mtpd Uhde ammonia plant

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Reformer Types

- Top Fired
- Side Fired
- Terraced Wall

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Design Parameters

- Function
- Feed
- Fuels
- Type
- Pressure
- Exit Temperature
- Inlet Temperature
- Steam/Carbon Ratio
- Heat Flux
- Pressure Drop
- Catalyst
- Tubes
- Burners
- Flow distribution
- Heat Recovery

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Function

\[ C_nH_m (g) + nH_2O + \text{heat} = nCO (g) + (m/2+n) H_2 (g) \]  \hspace{1cm} (1)

\[ CO (g) + H_2O (g) = CO_2 (g) + H_2 (g) + \text{heat} \]  \hspace{1cm} (2)
Feed

- Natural gas
- Propane
- LPG
- Butane
- Naphtha

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Fuels

- Natural gas
- Distillate fuels
Type : Top Fired

- The highest flue gas temperature when the intube process gas temperature is lowest
- The lowest flue gas temperature when the intube process gas temperature is highest
- Uniform tubewall temperature over the length of the tube
- Inherently stable furnace operation
Pressure

- The reforming reaction equilibrium is favored by low pressure
- The shift reaction equilibrium is independent of pressure
- Product hydrogen pressure requirement (down stream)

\[
C_nH_m (g) + nH_2O + heat = nCO (g) + (m/2+n) H_2 (g) \quad (1)
\]
\[
CO (g) + H_2O (g) = CO_2 (g) + H_2 (g) + heat \quad (2)
\]
Exit Temperature

- Lower temperatures give insufficient conversion
- Higher temperature increase metallurgical requirements
- Gas exit temperature typically runs between 800 to 900 °C
Inlet Temperature

- The reforming reaction rate becomes significant at about 540 °C
- Higher reformer inlet temperature decrease the number of tubes, the size of the furnace and fuel
- Higher reformer inlet temperature decrease the steam generation from WHR
- Metallurgical limits
- Optimum reformer inlet temperature 560 °C
Steam/Carbon Ratio

- Sufficient steam to eliminate carbon formation
- If proper catalyst is chosen, 3 steam to carbon ratio is applicable
Heat Flux

- A low heat flux provides extra catalyst volume and lower tubewall temperature.
- A high heat flux has the advantage of reducing the number of tubes.
- 20000 to 28000 Btu/hr-ft²
Pressure Drop

- Length of tubes
- Tube diameter
- Catalyst selection
- Approximately 3 Bar

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Catalyst

- Reaction conversion
  - Nickel-alkali
  - shape
- Catalyst pressure drop
  - Shape

Key aspect of catalyst: formulation & shape
Tubes

- Temperature condition: 850 to 920°C
- Inside tube diameter: 4 to 5 in
  - Better heat transfer and cooler walls for lower ID
  - Higher pressure drop for lower ID
  - More required tubes for lower ID
- Tube length: 12 to 13 m
  - Longer tube reduces the flue gas exit temperature
  - Longer tube increases pressure drop
  - Longer tube decreases required tube
- Tube pitch: 2 to 3 tube diameter
- Lane spacing: 1.8 to 2.4 m

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Burners

- Uniform heat release
- One burner for every 2.5 to 3.5 tubes is a good design practice
Flow distribution

- Symmetrical piping design
- Detailed pressure drop calculation
- Properly designed flue gas tunnel
- Properly fan design
Heat Recovery

- Inlet temperature of flue gas approximately 900°C
- Reformer mixed feed preheater, steam superheater, steam generation, boiler feedwater heater, feed heater, combustion air preheater
- Exit temperature of flue gas approximately 200 °C
Overall view
Forced fan
Air Preheater

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Air ducts
Fuel
Radiant box
Convection box

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Heat recovery
Induced fan and stack
Feed
Catalyst tubes
Tube supports

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Radiant Section

- Considerations
  - Variation of heat demand from inlet to outlet
  - Uniformity of heat distribution along the length of the furnace
  - Uniformity of circumferential heat flux
  - Flow distribution in reactors for lowest turn down
  - Average and critical heat flux in the reformer firebox
- CFD modeling
Casing Design

- Design Temp 80 °C
- Designed for deflection to minimize refractory damage
- Needs to be an air tight construction
- Resistant to wind loads and other imposed loads
Reformer Tubes

- Creep
- Bending stress
- Thermal cycles
- Elongation

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Reformer Tubes

- Tube material

- Tube Strength

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Catalyst Development

- Control tube wall temperature
- Achieved the required conversion
- Have a low and stable pressure drop
- Avoid carbon formation
- Operation over a larger feed composition
Catalyst shape

- Activity
- Heat Transfer Coefficient
- Pressure Drop
Refractory

- Ceramic fiber
  - Module
  - Blanket
- Cast
- Brick
Transfer line

- Design Conditions
- Problems
  - Erosion
  - Pipe failure
  - Condensation
- Refractory
  - Design
  - Anchoring

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Sample Reformer

Process Requirements:

(2050 TPD AMMONIA PRIMARY REFORMER)
• Process Gas
  • 174 ton/h
  • 520 °C
  • 39 Bar
• Super Heated Steam
  • 353 ton/h
  • 510 °C
  • 117 Bar
• Process Air Heater
  • 105 ton/h
  • 540 °C
  • 37 Bar

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HEDCO
Specifications For:
2050 TPD AMMONIA PRIMARY REFORMER
• Catalyst Tubes
  • 48 tube @ 7 row
  • ID = 114.3
  • Effective Tube Length : 12.5 m
  • Inlet Temperature : 520
  • Outlet Temperature : 800
  • Design Temperature : 920
  • Max Wall Thickness : 890
  • Thickness : 12 mm
  • Design Pressure : 41 Bar
  • Max Pressure Drop : 3 Bar
  • Row Spacing : 2.1 m
## Catalyst Tubes

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<tr>
<th></th>
<th>capacity</th>
<th>total tubes</th>
<th>row</th>
<th>tubes in row</th>
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## Tube Wall Temperature

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<td>920</td>
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• Burners
  • Arch Burners
    • Inner burners Number : 12 @ 7 row = 84
    • Inner burners Duty = 2 MV
    • Outer Burners Number: 12 @ 2 row = 24
    • Outer Burners Duty = 1.73
  • Tunnel Burners
    • Tunnel Burners Number = 8 @ 1 row
    • Tunnel Burners Duty = 0.53 MW
  • Auxiliary Burners
    • Auxiliary Burners Number : 10 @ 5 row
    • Auxiliary Burners Duty = 4.26 MW
## Burners

<table>
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Thank You