MANAGING CORROSION CHALLENGES ASSOCIATED WITH HEAT EXCHANGERS

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Outline

- Objective
- Operational Criticality
- Functionality of Heat Exchangers
- Corrosion Challenges
- Root Causes
- Corrosion Management Strategies
- Integrity Management Program
- Conclusions
Objective

Process Overview

C2+ to Yanbu & Ju'aymah

C2+ sphere

Associated Gas

Slug Catchers

Cond to Crude Inj

Khuff Gas Conditioning

Khuff Gas

Hp Dga

Fuel Gas Comp.

Sales Gas Comp.

SEC Power Generation

To Sales Gas Grid

In-Plant Fuel Usage

Sweet Gas

Childown

LP Fuel

Filp Fuel

In-Plant Fuel Usage

Acid Gas

Sulfur Recovery

Sulfur to Truck Loading

Acid Gas Sulfur to Truck Loading

Sulfur Recovery
Heat exchangers (HE) are crucial for plant Operations. HE help to achieve:

- Heat transfer between two process streams
- Phase transformation
Types of Heat Exchangers

HE are of different types and the design depends on Process requirements.

- Air Cooled
- Shell & Tube
- Double Pipe
- Plate & Frame

Based on the application, HE are categorized as:

- Condenser, Reboiler,
- Cooler, Chiller, Evaporator/Vaporizer,
- Steam Generator, Heater, Waste Heat Boiler
Shell and Tube Heat Exchanger

- Shell side
  - Flow In
  - Flow Out
- Tube side
  - Flow In
  - Flow Out
- Tube Bundle
Plate and Frame Heat Exchanger

A

- Separating Sheet
- Corrugated Sheet
- Side Bar
- Distributor

B

- B_in
- A_out
- Nozzle
- Header
- C_in
- Effective Length
- Effective Width
- Heat Transfer Section
- Distribution Section
- A_in
- B_out
- C_out
Corrosion Challenges: Critical HE

Hydrocarbon Service
- Propane Condensers
- Stripper Overhead Condenser

Amine Service
- Lean Solution Coolers

Cooling Water Service
- Cooling Water Heat Exchangers
- Cooling Tower

Steam/BFW Service
- Sulfur Condensers
- Boiler Feed Water Heat Exchangers
- Condensate Reboilers
- Regen Steam Condensers
Propane Condenser

**HE Type:** Air Cooled

**Service:** Propane

**Material:** Carbon Steel (with Al Fin on the external)

**Number of Tubes:** 220 per bank

**Total No of Tubes:** $220 \times 48$ banks $= 10,560$ tubes

**Mode of Attack:** Internal Pitting
Internal Corrosion - Pitting
Internal Pit Penetration
# Propane Condenser Tube Inspection

<table>
<thead>
<tr>
<th>Metal Loss</th>
<th>&lt;20%</th>
<th>20-40%</th>
<th>40-60%</th>
<th>&gt;60%</th>
<th>Inspected</th>
<th>Restricted</th>
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<tbody>
<tr>
<td>E-161A</td>
<td>2,559</td>
<td>2,270</td>
<td>378</td>
<td>66</td>
<td>5273</td>
<td>7</td>
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<tr>
<td>E-161B</td>
<td>1,247</td>
<td>2,144</td>
<td>458</td>
<td>109</td>
<td>3958</td>
<td>2</td>
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<tr>
<td>Total # of Tubes</td>
<td>3,806</td>
<td>4,414</td>
<td>836</td>
<td>175</td>
<td>9231</td>
<td>9</td>
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</tbody>
</table>
Propane Condenser Tube Assessment

% Metal Loss (Corrosion)

- <20%
- 40-60%
- Restricted

# of Tubes

E-161A  E-161B

E-161A

E-161B
Prop Condenser Tube Corrosion Review

• Internal Corrosion
• Process Contaminants: H2S & Moisture

Source of Contaminants:
  ➢ From Condensate Stripper
  ➢ Propane Make-up stream From Depropanizer

Resolution:
Source of contaminants eliminated by Rerouting
Lean Amine Cooler

**HE Type:** Air Cooled

**Service:** Lean DGA

**Material:** Carbon Steel (with Al Fin on the external)

**Number of Tubes:** 258 per bank

**Total No of Tubes:** $258 \times 40 \text{ banks} = 10,240 \text{ tubes}$

**Mode of Attack:** Tube-end Erosion (1st Row)

- Fouling
Figure 1: The cooler tube as received. Notice that the erosion is limited to the first four inches of the tube in the vicinity of the inlet nozzle.
Lean Amine Cooler Tube-end Restoration
Lean Amine Cooler Corrosion Review

Internal Corrosion: Tube-end Erosion

- Increased Velocity
- Suspended Solids

Fouling due to:

- Corrosion Products
- Heat Amine Stable Salts
**Sulfur Condenser**

**HE Type:** Shell & Tube

**Service:** Shell side: Boiler Feed Water

  Tube side: Acid gas/Sulfur

**Material:** Carbon Steel

**Number of Tubes:** 3159

**Mode of Attack:** Pitting
Sulfur Condenser Tube – External Pitting
Sulfur Condenser Corrosion Review

Shell side (Tube External) Corrosion
- Dissolved Oxygen
- Lack of Adequate Treatment

Internal Corrosion:
- Under deposit
Closed Recirculating Cooling System

Heat Exchanger

To Cooling Tower

From Cooling Tower

Surge Tank

Pumping Station

Batch Chemicals

Make-up Water
A Typical Cooling Water System
**Cooling Water Heat Exchanger**

**HE Type:** Shell & Tube  
**Service:** Shell side: Cooling Water  
Tube side: Cooling Tower Water  
**Shell/Tube sheet Material:** Carbon Steel  
**Bundle Material:** Aluminum Bronze  
**Number of Tubes:**  
**Mode of Attack:** Localized Tube sheet Deterioration
CW Heat Exchanger Tube sheet
CW Heat Exchangers – Tube sheet
CW HE Tube sheet – After Restoration
Heat Exchanger Restoration
Cooling Tower

Type: Cross flow Cooling Tower

Service: Cooling Water

Tube side: Cooling Tower Water

Material: Redwood

Number of Tubes: 1595

Mode of Attack: Chemical & biological
Cooling Tower Structure & Basin
Cooling Tower Wood Deterioration
Treated Wood - Susceptibility to MIC
Boiler Feed Water Heat Exchanger

HE Type: Shell & Tube
Service:
Shell side: Steam Condensate Return Stream
Tube side: Boiler Feed Water
Shell Material: Carbon Steel
Tube Material: Aluminum Bronze
Number of Tubes: 2294/Unit
Mode of Attack: Dealloying
Boiler Feed Water Heat Exchanger

DGA Steam Condensate (Shell-Side)

DGA Steam Condensate (Shell-Side)

Dearator Feed Water (Tube-Side)

To Dearators D-103 A/B/C

Steam Condensate Tanks D-102 A/B
**Condensate Stripper Reboiler**

**Type:** Shell & Tube

**Service:**
- Shell side: Sour Wet HC
- Tube side: Steam

**Shell Material:** Carbon Steel

**Tube Material:** Carbon Steel

**Mode of Attack:** External Pitting/Fouling
Tube Bundle: External Fouling
Regen. Steam Condenser

Type: Air Cooled
Service: Steam
Material: Carbon Steel
Number of Tubes: 273/unit
Mode of Attack: ?
Regen. Steam Cond. - Closed Header Box
Root Causes

- Mode of Operation
- Contaminants
- Metallurgical
- Design
- Corrosion
- Fouling

Need For Corrosion Management program with Predictive & Preventive Strategies
**Corrosion Management Strategies**

- **Enhance Monitoring:**
  - Video Borescoping
  - Magnetic Flux Leakage (MFL)
  - Internal Rotary Inspection System (IRIS)
  - Laser Optic Tube Inspection System (LOTIS)
  - Remote Field Eddy Current (RFEC)

- **Explore suitable corrosion protection options:**
  - New Clad Fabrication Vs Strip lining of existing equipment,
  - Use of tube inserts than retubing
  - Thermal Sprayed Coatings, Coatings
  - Corrosion Inhibition, VCI
Corrosion Management Strategies

• Monitor Process chemistry

• Establish Best Practice, Corrosion Control Manual

• Partner with CSD in Amine JIP
  - Develop database
  - Parametric evaluation of Temp, CO2/H2S ratio, HSAS, Organic Acids
  - Develop software corrosion prediction tool (Predict-Amine)
  - Expand R&D For Better Understanding of the New problems

• Partner with CSD/BPC in CAST Validation
  - Prediction of corrosion and scaling tendencies in BFW
  - Diagnose process stream chemistry variations
Integrity Management Programs

- Process Stream Monitoring Program
- Timely Evaluation of Monitoring Data
- Predictive and Preventive Corrosion Management
- Involvement in Design Phase
- Explore suitable Corrosion Protection Options
- Enhance Corrosion Monitoring Program
- System Upgrade
- Conduct Risk Based Assessment
- Conduct Fitness-For-Service
- MOC Implementation
Asset Integrity Management (AIM) Contributing Factors

- Operational Integrity
  - Operating envelopes
  - Contaminants

- Design Integrity
  - Design
  - Verification/Review
  - Technical function

- Technical Integrity
  - Inspection
  - Process
  - Maintenance
  - MOC
Conclusions

• HE are critical Process Equipment and require periodic comprehensive integrity assessment.

• Identify Damage Mechanisms. Corrosion trend can be generic but can also be plant specific, which requires careful evaluation.

• Conventional NDE techniques have Limitations. Advanced NDE is crucial.

• Establish comprehensive process stream monitoring program

• Enhance Corrosion Monitoring Program

• Evaluate the Monitoring Data in coordination with other disciplines

• Ensure an Active On-Stream Inspection Program

• Partner with Other Organizations or JIP

• Implement the Integrity Management Program
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