REPAIR OF A HP SCRUBBER DAMAGED BY CORROSION

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1. Leak in HP Scrubber
2. Why is ammonium carbamate highly corrosive?
3. How to protect pressure vessel?
4. Case history
5. Which damage mechanisms occurred?
6. How to repair?
7. How to avoid this mishap?
February 2018: leak to atmosphere observed in HP Scrubber sphere

LEAK IN HP SCRUBBER
Why is ammonium carbamate highly corrosive?
• Strong Brønsted Acid solution (pH <0 !!).
  • Proton donor is the Ammonium ion

\[
\text{NH}_2\text{COONH}_4 \rightarrow \text{NH}_4^+ + \text{NH}_2\text{COO}^-
\]

\[
2 \text{Me} + 2 \text{NH}_4^+ \rightarrow 2 \text{Me}^+ + \text{H}_2 + 2 \text{NH}_3
\]

• Corrosion C-steel in Ammonium Carbamate: > 500 mm/y
How to protect steel pressure vessel for corrosion?
HOW TO PROTECT C-STEEL PRESSURE VESSEL

- Stainless Steel barrier
  - Weld overlay
  - Loose liner (leak detection system)
  - Austenitic SS-steel (316L UG and X2CrNiMo25-22-2): passivation air needed
    - Passive corrosion rates: 0.05 ~ 0.1 mm/y (active: > 30 mm/y)
  - Take care of weld quality

- Catastrophic failure urea reactor (100 mtpd)
- Unnoticed leakage through stainless steel barrier
- Affected the carbon-steel pressure shell
- Break-Before-Leak Scenario
1. Loss of containment
2. Corrosion of stainless steel barrier unnoticed by leak detection system
3. Unnoticed corrosion of pressure shell
4. 20MnMoNi45 carbon-steel: 53 mm
5. Near miss: Leak-Before-Break Scenario

Present Leak detection system
Severe corrosion of stainless steel liner: 316L UG nominal 9 mm thickness
CASE HISTORY

➢ Liner severely cracked
➢ Many cracks through wall
➢ Ammonium-carbamate leaking behind liner
CASE HISTORY

➢ Carbon-steel pressure shell
➢ Severely corroded by ammonium-carbamate
➢ Local wall thinning and Stress corrosion cracks
What are the corrosion mechanisms?

- Liner?
- Carbon Steel?
Liner damage:
• Strain Induced Intergranular Cracking
• Condensation of NH$_3$/CO$_2$/H$_2$O gas
  • Hot off gas reactor
  • Insufficient insulation - tracing
• Plastic deformation of liner
  • Bending of plate
  • Temperature – pressure cycles
  • Poor fit
  • Large grain size (ASTM 2.5-3)
• Contaminants such as Sulphur
• Slowly propagating cracks
Carbon-steel pressure shell:

- Wall thinning carbamate corrosion
- Hydrogen Induced Stress Corrosion Cracking (HIC)
- Hydrogen developed by cathodic corrosion reaction
- Steel metallurgy (too high Carbon Equivalence)
- Sulphur enhances hydrogen uptake
- Slowly propagation of cracks
How to repair?

- Liner?

- Carbon Steel?
Phase 1: Remove old liner plates:
Phase 2: Carbon steel shell repair by welding
Phase 3: Metal Epoxy Component (Belzona application)
Phase 4: Install new liner plates; improve metallurgy into X2CrNiMo25-22-2
Phase 5: Hydrostatic pressure test and ammonia leak test

Repair is considered temporarily

HP Scrubber will be replaced
Phase 1: removing old liners (16 segments)
Phase 2: Carbon steel shell repair by welding

How to take care of hydrogen in C-steel?
Phase 2: Carbon steel shell repair

❖ Care taken to outgas hydrogen (soaking)
  • Before welding
  • After welding
  • Take care to minimize welding as much as possible

❖ Remove all cracks by careful grinding

❖ Determine minimum required wall thickness (Fitness For Service assessment)
  Minimum required wall thickness: 37 – 45 mm

❖ Repair welding until meeting minimum required thickness

❖ Subsequent filling with metal epoxy compound
REPAIR

Pre-heating during repair welding: 120 °C
Soaking to outgas hydrogen before and after welding: 300 °C
PWHT after welding: 540 °C
REPAIR

Grinding out cracks and repair welding

Clean & repair leak detection system

The time needed to remove all cracks approx. 11 days
Phase 3: Metal Epoxy Component (Belzona application)
Phase 4: Installation new liners: 6mm X2CrNiMo25-22-2

- Welding process GTAW
- Root passes were checked by DPT, Ferrite content and soap leak test
- The time needed approx. 11 days
Phase 5: Hydrostatic pressure test and ammonia leak test

Stepwise increase in pressure to allow the liner to yield onto the pressure shell; test pressure: operation pressure.
How to avoid this mishap?
Mitigation actions to avoid such mishap

• Reliable and robust leak detection system
  • Stamicarbon offers State-of –the Art systems
• Act immediately upon leak in the stainless steel barrier
• Apply Safurex® as protective barrier:
  • Not susceptible for SIIC:
THANK YOU