RECONNECT

SYMPOSIUM 2022

KNOWLEDGE • OPTIMIZATION • INNOVATION

Stamicarbon 75 YEARS

Importance of proper boiler feed water quality in Pool Condenser / Reactor plants

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Agenda

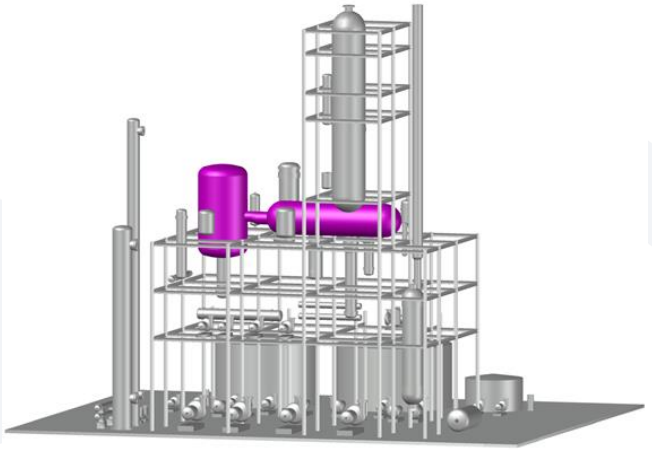
- Introduction
- Case history damaged Pool Condenser
- Repair
- Root Cause Analysis
- Mitigation Actions
- Status to Date
- Discussion and Conclusions

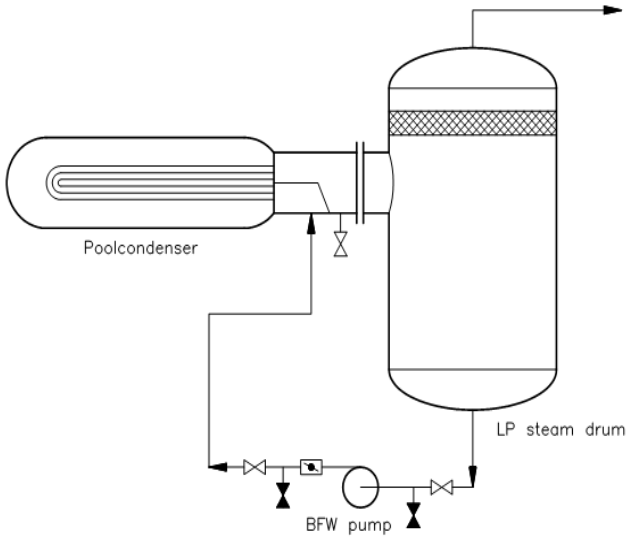
Introduction and background

- Unexpected damage occurred in a Pool Condenser in 2016:
  - 2700 mtpd CO2 stripping plant
  - Commissioned in 2003
  - Materials of Construction: X2CrNiMo25-22-2
- Integrity of the tube-sheet was affected at steam side
- Not related to corrosion at process side
- Complicated, expensive and time-consuming repair was needed
- Equipment replaced within two years

Case history

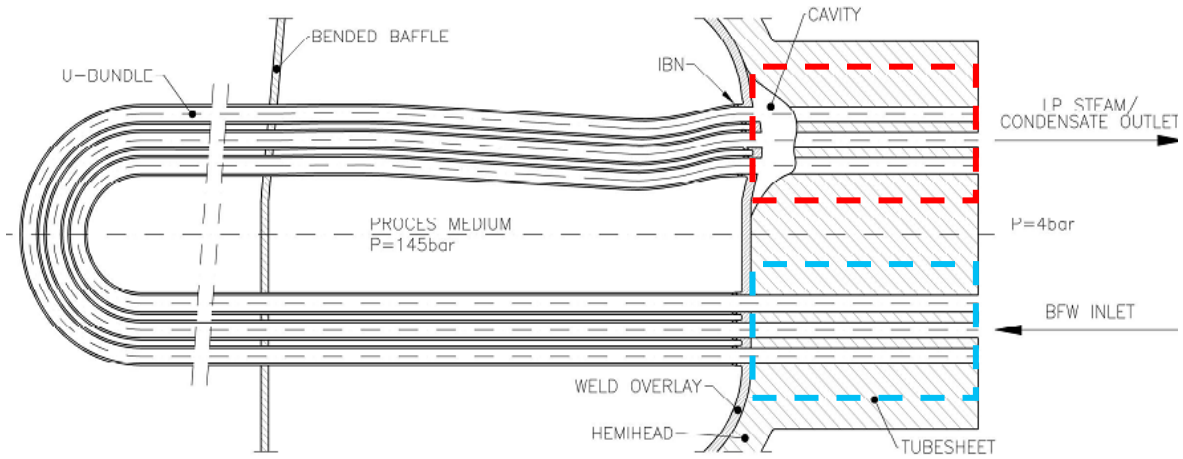
- Pool Condenser plant based on old Urea 2000plusTM Technology
- Low pressure steam drum connected to Pool Condenser
- Reaction heat removed by circulating BFW through U-bundle
- Corrosive carbamate at shell side
- Tube side: low pressure steam





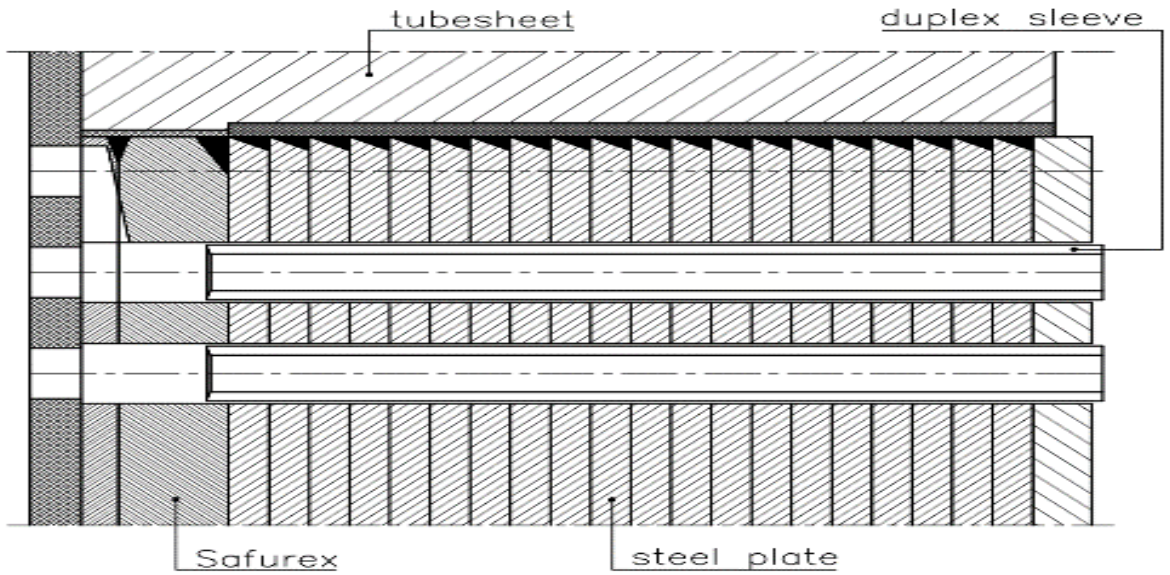
Case study

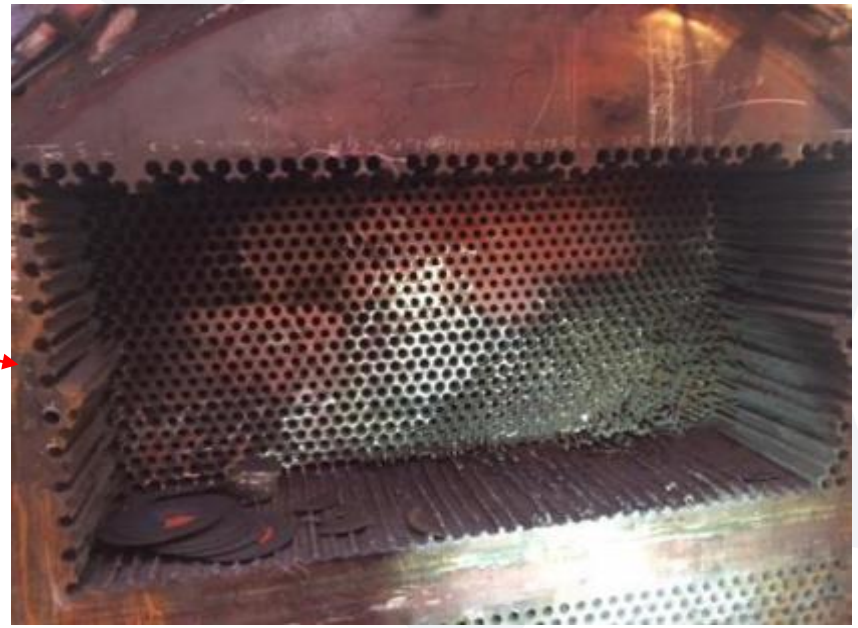
- Cavity in carbon-steel tube-sheet at steam condensate outlet
- No damages at BFW inlet side
- Severely bended U-bundle at process side, but no corrosion issues



Repair

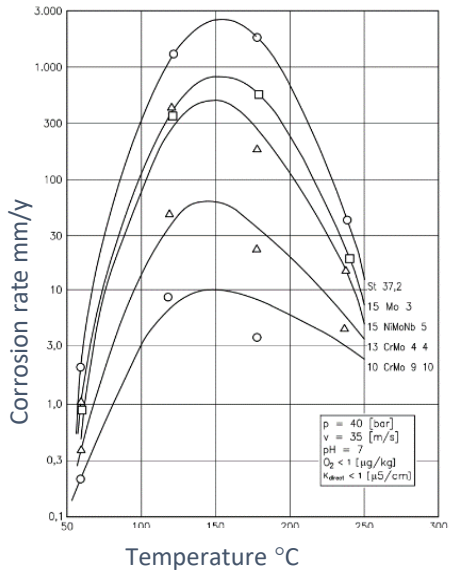
- Cavity complete excavated to repair bended weld-overlay
- Cavity closed with steel plates having pre-drilled holes
- Installation of sleeves in holes
- Temporarily repair; Pool Condenser replaced within 2 years

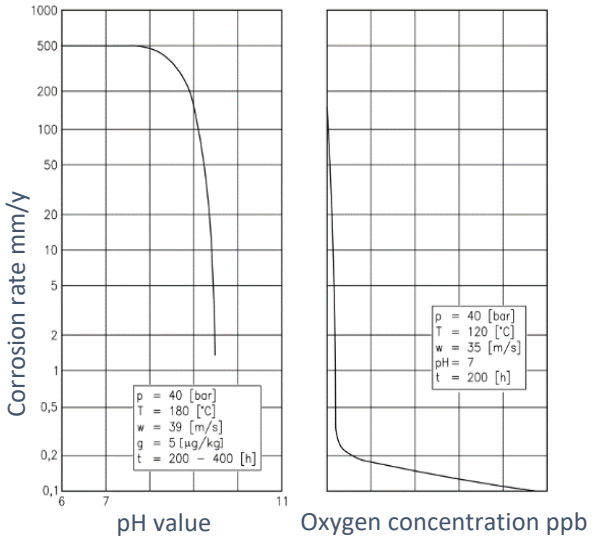




Root cause analysis

- Cavity in carbon-steel tube-sheet due to Flow Accelerated Corrosion (FAC)
  - Protective Hematite/magnetite layer dissolved by corrosion
  - Wall losses due to abrasive action of flow of steam-condensate (droplets)
- Depending on temperatures: high FAC at 150 °C
- Depending on too low pH and absence of oxygen



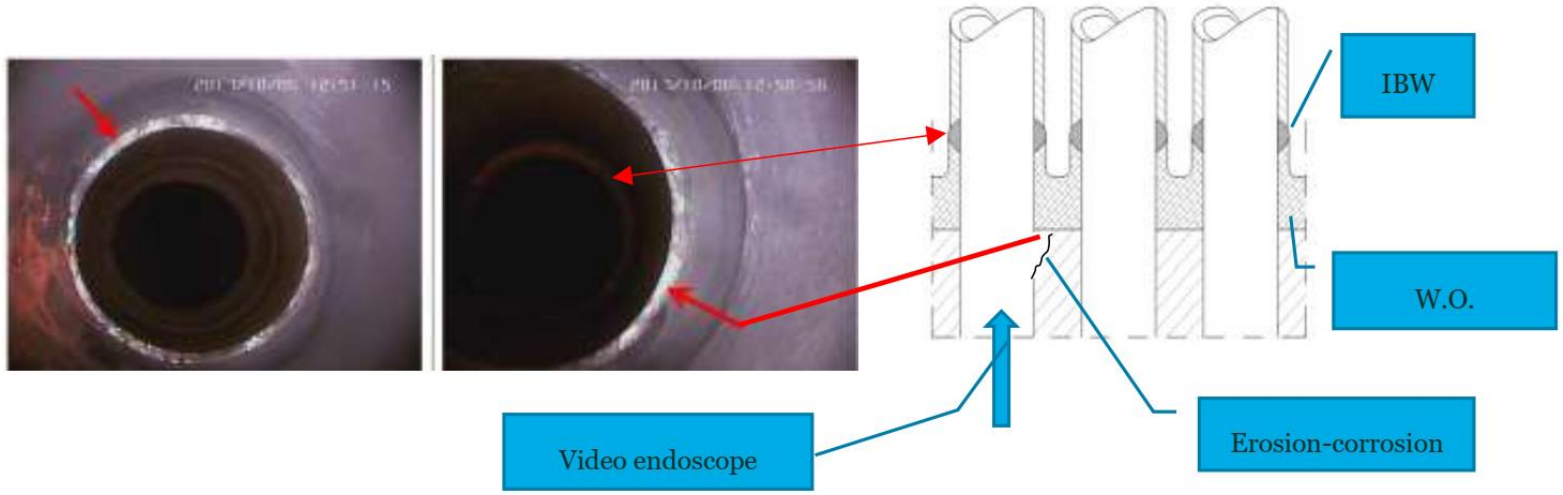


pH > 9.5

Oxygen approx. 10 ppb

Mitigation Actions

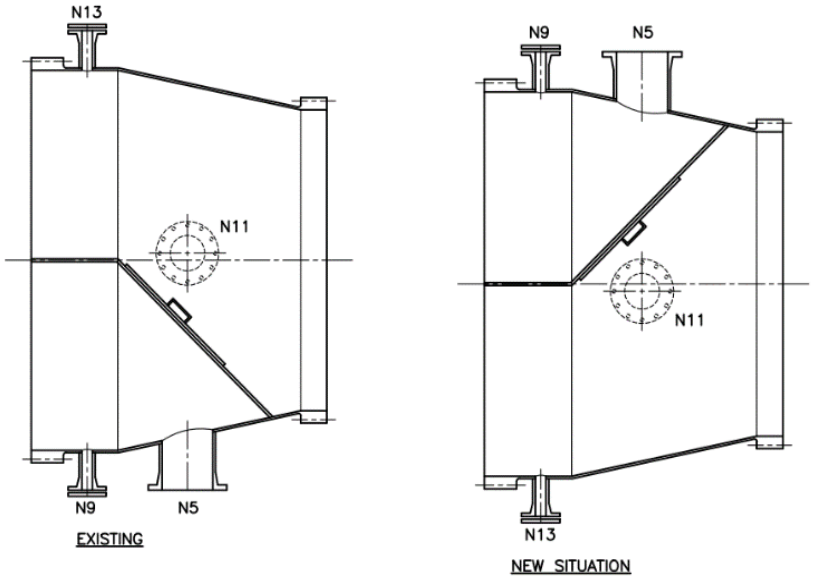
- All licensees were informed about potential damages
- Advised to monitor the BFW chemistry (guideline)
- Advised to inspect tube-sheets in Pool Condensers / Pool Reactors
- Improved inspection program: video endoscopy and eddy current testing



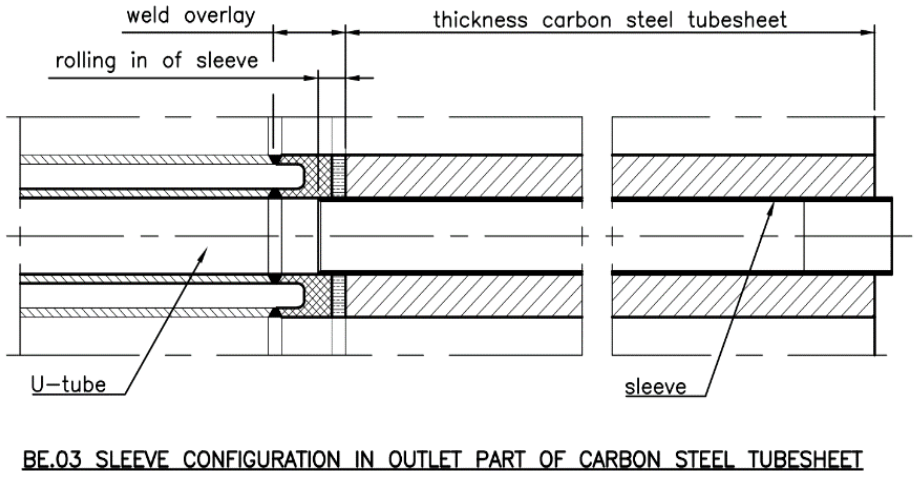
Mitigation Actions

- Repair strategies based on inspection findings
- Scenario 1: FAC damages (hole size increase) still within design criteria
  - Improve chemistry BFW
  - Inspection planning
- Scenario 2: FAC damages not within design criteria
  - Perform Fitness For Service Assessment (FEA analysis)
  - Changing in and outlet
  - Preventively install sleeves later on

Mitigation Actions: Repair scenario 2



Changing in and outlet



Preventively install sleeves later on

Mitigation Actions

- Repair strategies based on inspection findings

- Scenario 1: FAC damages (hole size increase) still within design criteria
  - Improve chemistry BFW
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- Scenario 2: FAC damages not within design criteria
  - Perform Fitness For Service Assessment (FEA analysis)
  - Changing in and outlet
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- Scenario 3: Not anymore Fit For Service
  - Repair or reinforce the tube-sheet
  - Replace the vessel

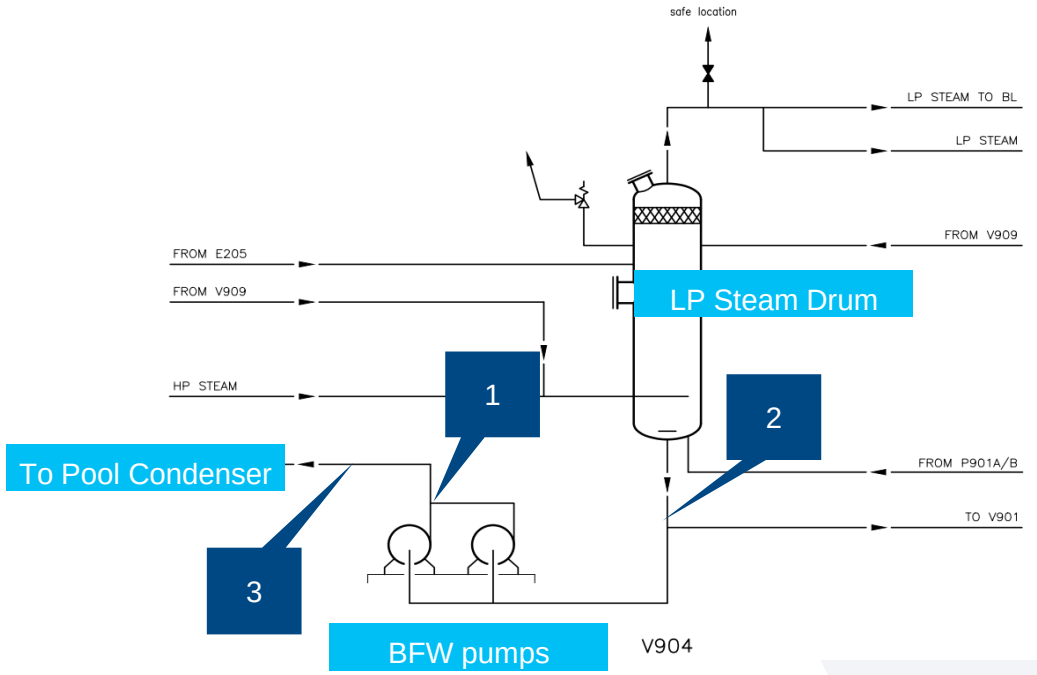
Mitigation Actions: new design

- Grass Root projects and replacements
- Change material of construction tube-sheet
- Installation of duplex sleeves in outlet holes

Mitigation Actions

Process design changes:

- Reduction of steam to condensate exit ratio from 2 to 1 kg/kg
- Introduction of flow control in BFW circuit [1]
- Introduction of on-line pH monitor in BFW circuit [2]
- Dosing point for ammonia or another volatile agent [3]



Status to date

- In total 37 Pool Condenser and Pool Reactor are in operation

- Risk assessment: likelihood for FAC damages to occur
  - Based on process and mechanical design data
    - Plant capacity
    - Design flow BFW
    - Expected velocities Steam condensate at outlet

  - BFW condition program in place
  - Inspection results
  - On-stream time

- High, medium and low risk equipment identified

Discussions and conclusions

- FAC damage occurred was unexpected
- FAC damage in Pool Condenser / Pool Reactor independent from type stainless steel
- With proper BFW chemistry: no FAC damages

- Mitigation actions are effective:
  - Existing plants:
    - Inform all licensees to monitor and condition BFW chemistry and perform inspections
    - Repair strategies developed
  - New plants / equipment
    - Changes in process and mechanical design

- In conclusion:
  - Risk for severe damages of Pool Condensers / Pool Reactors is under control in existing plants
  - Risk is non-existing in new designed plants

Thank you!

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