Cycle Chemistry Optimization Experience Report

Mexican Power Plant: Combined Cycle HRSG with Air Cooled Condenser (ACC)

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ACCUG – Queretaro, Mexico

October 21-24, 2019

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Plant Information

- 2x1 triple-pressure HRSG (1700, 350, 50 psi)
  - 1950 psig HP with duct burners in service
  - 1040°F Superheat/Reheat
  - Stand-alone LP evaporator drum design
  - Rotor Air Coolers (RACs)
- Into service 2010
- Base load operation
- Air Cooled Condenser
- Makeup water is UF, 2-pass RO, CEDI

History - Cycle Chemistry Monitoring and Control

- 2010 - Plant commissioned with minimal sampling and analysis, no clear pH target
- 2014 - Improvements were made to sampling and analysis panels and a pH target of 9.8 was established using ammonia at the CPD
  - >50 ppb Fe in the condensate and boiler feedwater
  - Outage inspection conducted
  - DHACI (**D**ooley **H**owell **A**CC **C**orrosion **I**ndex) – 4C

History continued….Can a Filming Amine help us here?

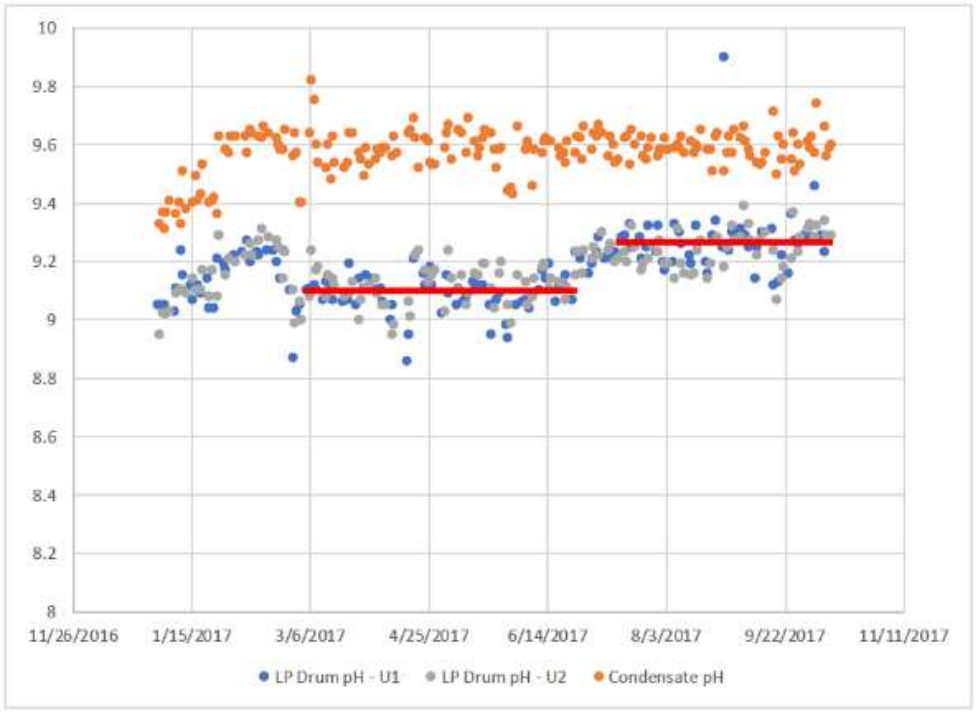
- After a year of unsatisfactory results with pH 9.8, filming amine treatment was tested
  - Attempted feeding a blended filming amine to a target residual but were unable to measure residual to verify
  - Limited the FA feed to minimize cation conductivity impact
  - Reduced pH target to 9.4 (still ammonia only)
  - With this treatment, iron transport still very high (>50 ppb), 80 µm condensate filter and BFP strainers plugged often

History continued…Optimize pH control with ETA?

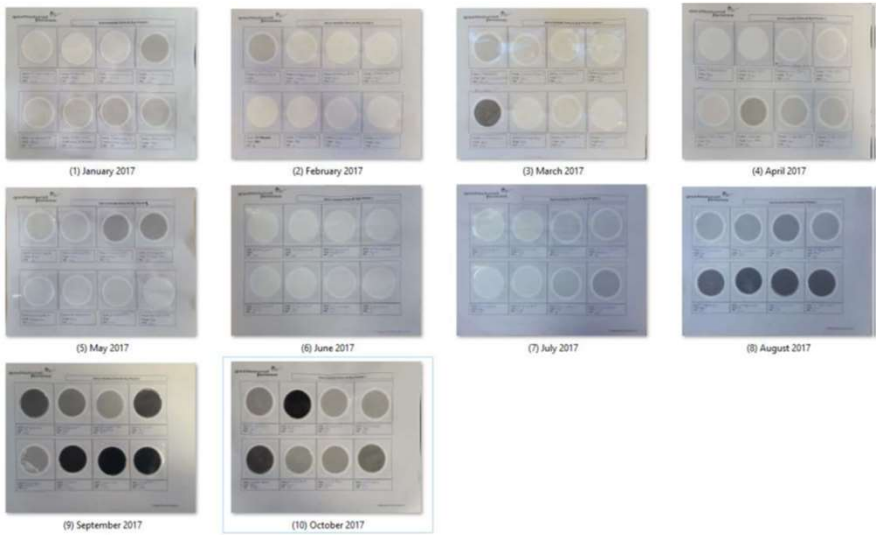
- January 2017 – Changed from Ammonia only to a 2:1 Ammonia/ETA blend and increased pH target from 9.4 to 9.6
  - Cation conductivity across the cycle increased to 1 – 1.5 µS/cm
- After several months the Ammonia/ETA was changed to 5:1
  - Cation conductivity decreased to 0.5 µS/cm
  - Measured $pH_{25°C}$ of 9.1-9.2 in the LP drums, RAC's, and IP drums
- After several months the Ammonia/ETA was changed again to 4:1
  - Cation conductivity unaffected (remained 0.5 µS/cm)
  - Measured $pH_{25°C}$ in LP drums, RAC's, and IP drums increased to 9.2-9.3
- This treatment continued up to the 2017 outage.

During this time period, the FA treatment continued unchanged.

Results of Ammonia/ETA Blend Ratio Change



Plant successfully increased LP drum $pH_{25°C}$ without affecting cation conductivity



LP Drum Millipore Results

Iron ranged 10 – 50 ppb but worsened to >100 ppb in July

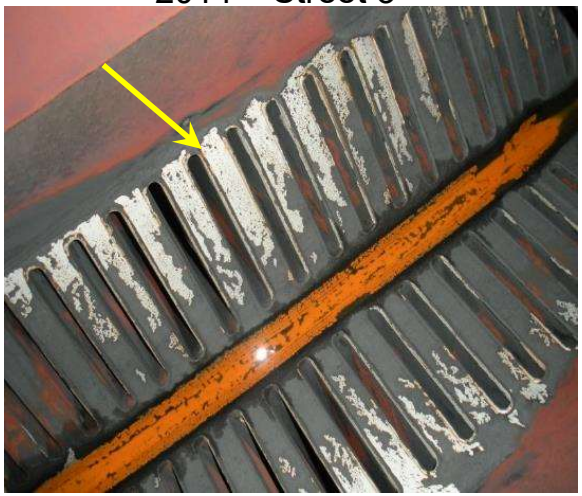
Change in operation resulting in increased duct firing began in July

No measurable improvement in iron transport resulted from use of ETA compared to baseline ammonia-only

Air-Cooled Condenser 2017 Outage Inspection Results

- ACC lower header, hotbox, and upper horizontal duct tube inlets showed little to no improvement in corrosion compared to the 2014 inspection.
- DHACI remained 4C

2014 – Street 3



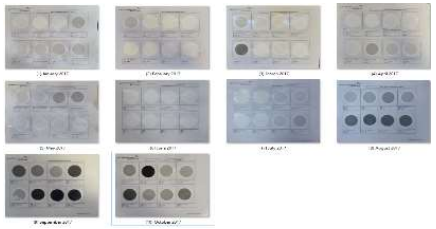
2017 – Street 3

- Filming Amine (FA) residual too low to form protective barrier. Ethanolamine (ETA) and Cyclohexylamine (CHA) decompose in the high temperatures of the HRSG and not helping ACC. Decomposition products lower the liquid phase pH_T.

LP Drum Inspection Results

- LP Drums show significant Flow Accelerated Corrosion (FAC) and very high iron (magnetite) particulate. LP Drums operate at peak FAC temperature (150°C). Black color indicates oxygen is being consumed in this area by large amounts of iron even though DO_2 at BFP is >15 ppb.

Loose magnetite particulate; also seen on Millipores

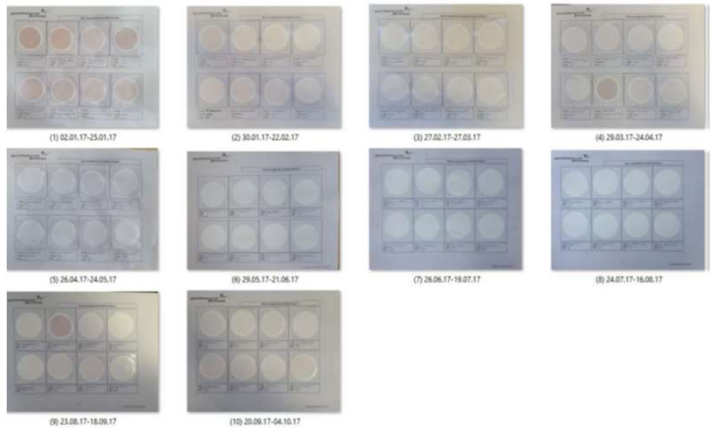


FAC in belly plate (through-wall)

- Measured $pH_{25°C}$ ~9.2 but actual pH_T will be much lower due to ETA decomposition products concentrating in drum. Also, high concentrations of iron combined with the SALP drum are deoxygenating the LP water

IP Drum Inspection Results

- IP Drums have significant two-phase FAC & show evidence of the 15 – 30 ppb DO_2 in the single-phase areas (reddish pink oxide)

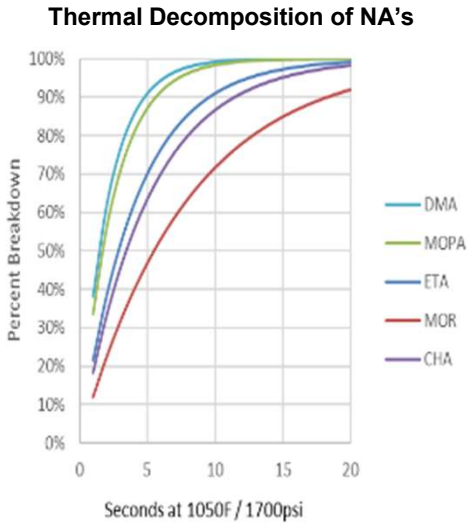


IP Drum Millipore
2017 Results
average ~10 ppb Fe

- Measured pH ~9.2 but actual pH_T will be much lower since ETA decomposition products concentrate in IP drum

Filming Amine Utilization

- Filming Amine was a blend of neutralizing amines (NA) and a filming amine
- Decomposition of NA's occurs in high temperatures of the HRSG (1040°F / 560°C)
- Filming Amine Feed Rate is too low for effective protection:
  - Minimal hydrophobicity observed
  - Calculated FA residual is much lower than chemical supplier suggested range
- Increasing feed rate will likely result in additional decomposition by-products, which lowers pH_T in other parts of the cycle / evidenced by increased cation conductivity



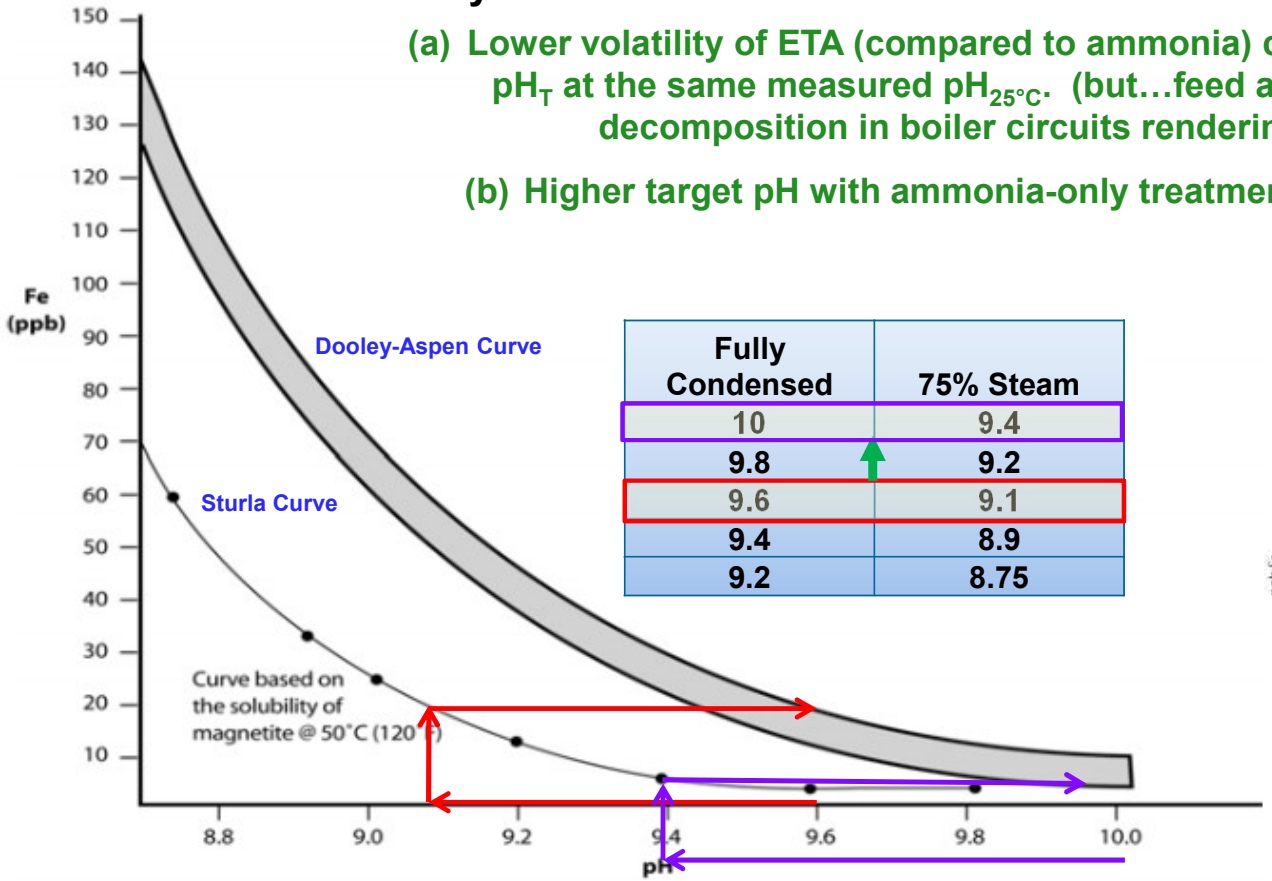
3 Take-aways from this Operating Experience

1. (a) Increase liquid phase pH with ETA Feed upstream of the ACC, not the CPD *or* (b) Maintain at least pH 9.8 – 10 consistently with ammonia at CPD

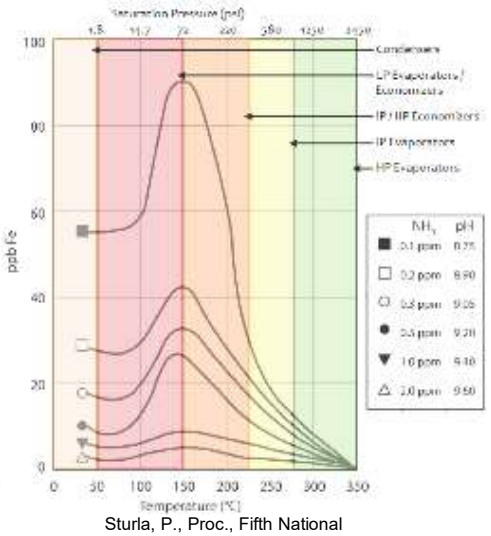
Why?…

(a) Lower volatility of ETA (compared to ammonia) can produce higher liquid phase pH_T at the same measured $pH_{25°C}$. (but…feed at CPD subjects ETA to thermal decomposition in boiler circuits rendering it useless in the ACC)

(b) Higher target pH with ammonia-only treatment can raise liquid phase pH_T



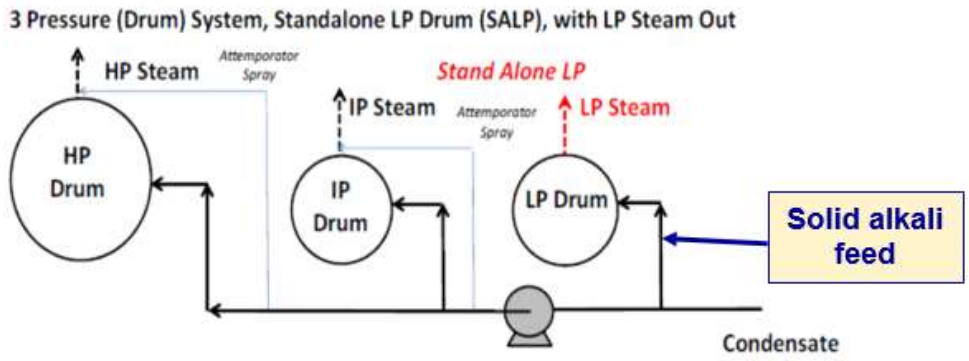
Fully Condensed	75% Steam
10	9.4
9.8	9.2
9.6	9.1
9.4	8.9
9.2	8.75

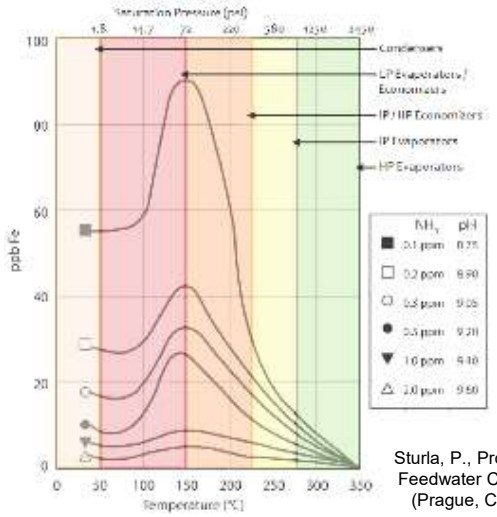


Sturla, P., Proc., Fifth National Feedwater Conference, 1973 (Prague, Czechoslovakia)

2. Stand Alone LP Drum and IP Drum pH Control with Phosphate (TSP)

- High susceptibility for FAC
  - LP Operating Temp 300°F (150°C)
    - No oxygen to stifle FAC in single phase
    - Low liquid phase pH_T in two-phase areas
  - IP Operating Temp 420°F (215°C)
    - Low liquid phase pH_T in two-phase areas





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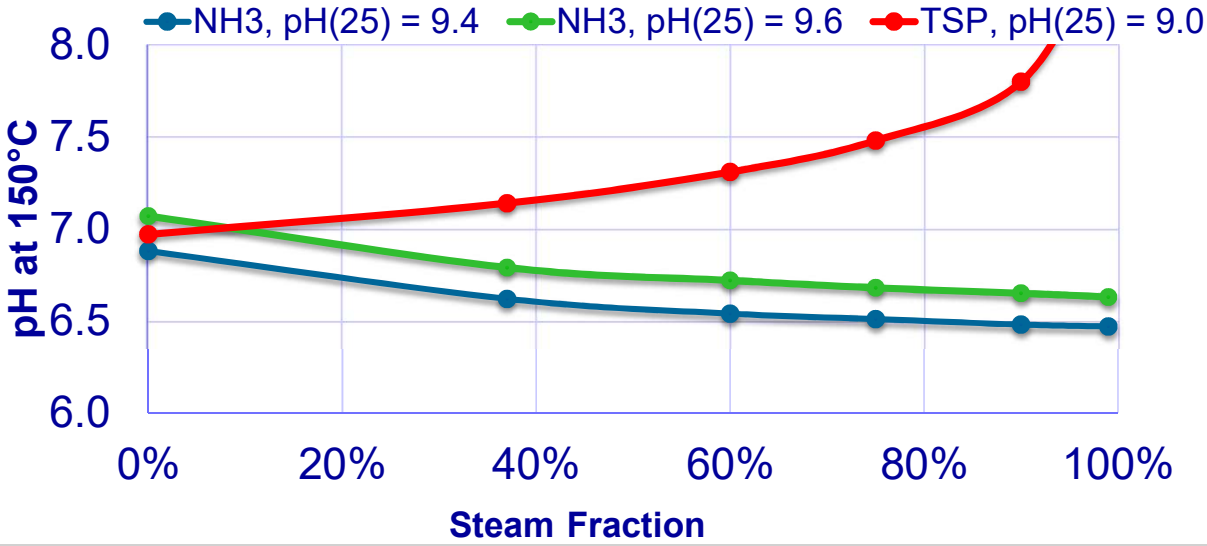
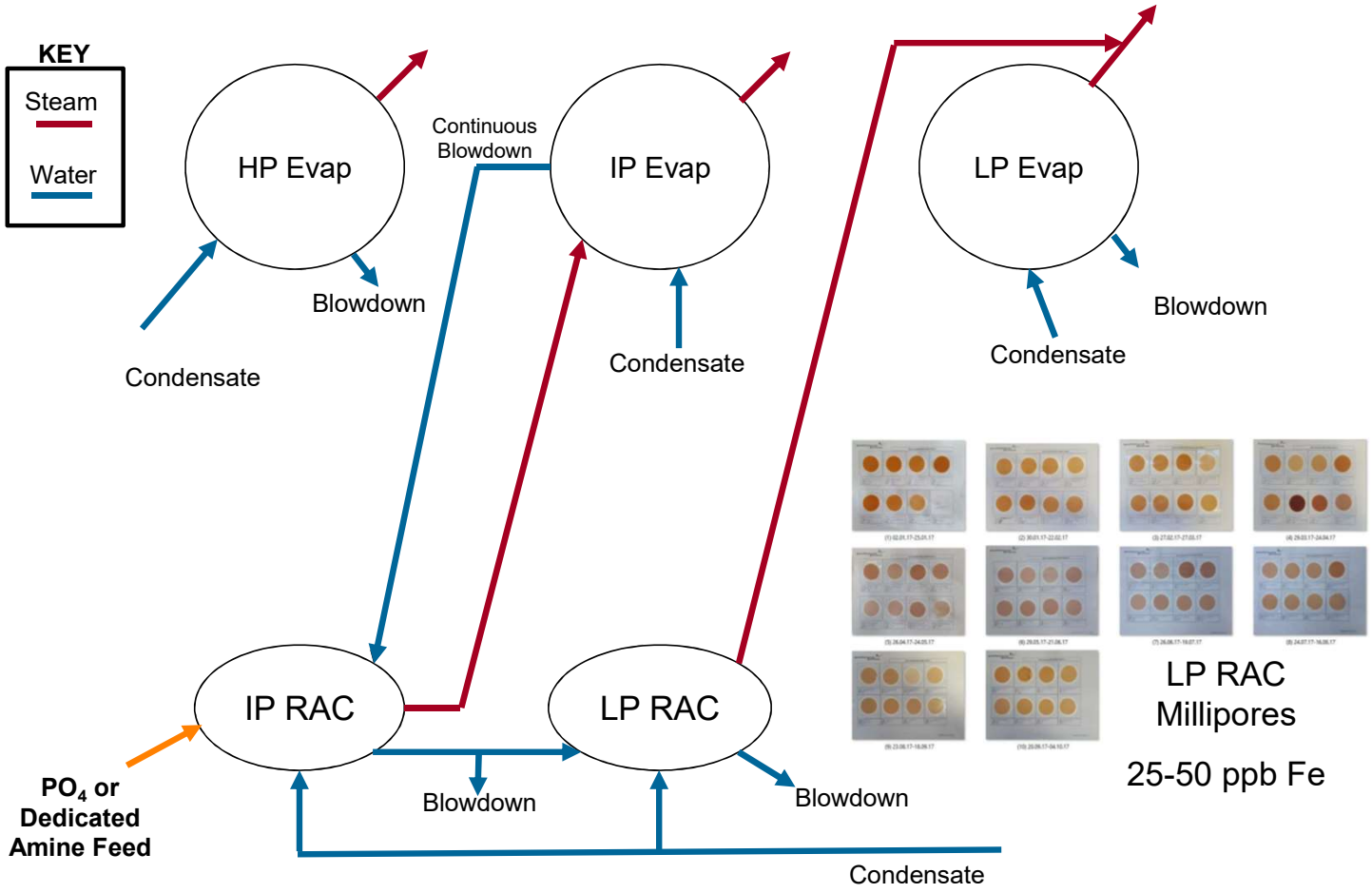


Caveat – HRSG's with RAC's



LP RAC Millipores

25-50 ppb Fe

Cycle Chemistry Challenges and Mitigation

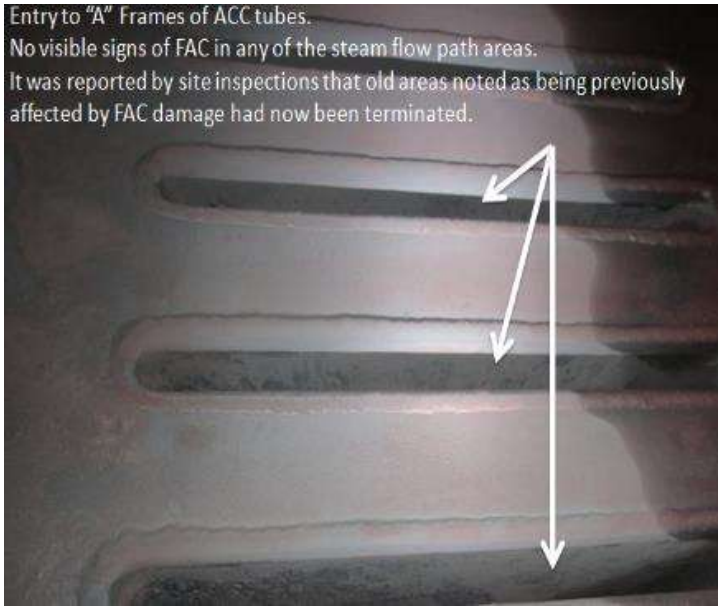
- IP RAC needs TSP for pH control
- If carryover into LP steam is a concern, dedicated amine feed can be used
- IP RAC steam can increase two-phase FAC in IP Drum

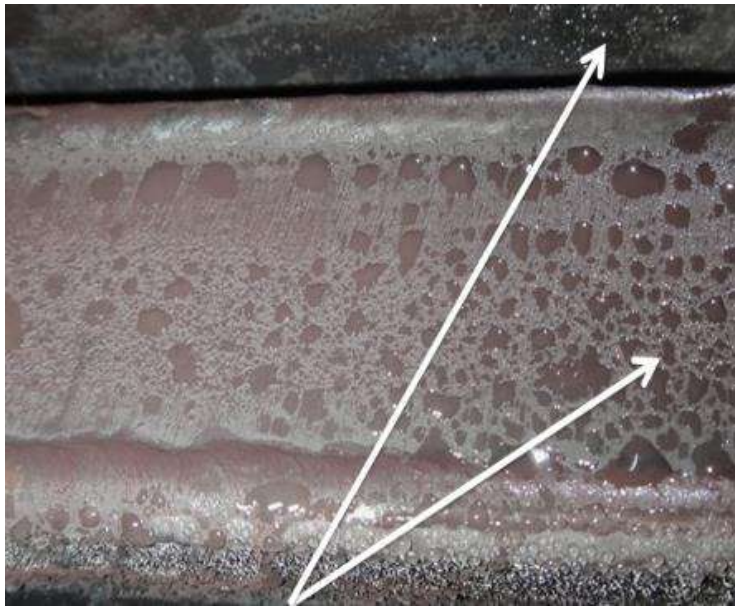
IP Drum Near the End at the IP RAC Steam Return with Significant FAC

3. If using a Filming Amine or Filming Product, choose one with minimal blended constituents so that target residual can be achieved without dramatic CC impacts

Elements to Developing a FFP Treatment
Function of Surface Area
Concentration and Time Dependent
Achieve Equilibrium Concentration

- Protection is possible in ACC's if these elements are achieved





Photos courtesy of B. Utton, NV Energy

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