Corrosion and Performance Issues for Immersion Service Shell and Tube Heat Exchangers
Condenser & Heat Exchanger Applications

- Tubesheet coatings
- Tube-end ID coatings
- Full-length tube coatings
- Waterbox & channel heads coatings
- Flange sealing
- Coating Service And Circulating Water Piping
Tubesheet Problems

- Mechanical stress – may break the rolled tube joint
- Erosion/Corrosion – lost tubesheet metal
- Galvanic corrosion
- Dealloying
- MIC – (Microbiological Influenced Corrosion)
- Crevice Corrosion
- Pitting
Tube-end Problems

- Erosion/Corrosion – lost tube metal
- Crevice Corrosion
- MIC
Aluminum bronze tubesheet with titanium tubes
Microbiological Corrosion (MIC) on Stainless
Galvanic Attack – Stainless Tubes with Carbon Steel Tubesheet
Environmental Control Equipment
- dehumidification, and dust collection
ultra high pressure cleaning to remove coatings and decontaminate surface
Protective plugs installed – tubesheet abrasive blasted
Protective plugs removed
Coating plugs installed
Many different sizes of plugs often required
Coating plug tops are leveled off – this determines the thickness of the coating.
First coat applied
Second, “build coat” applied
Excess build coat sanded off to tops of coating plugs
Coating plugs are removed
Top coat applied to fill in sanding marks
note: Tube-End coating can seal small holes

deteriorated tube
first coat (white)
second coat (grey)
third coat (red)

three coats are feathered for a turbulent free termination
Crevise Corrosion and MIC on Stainless
Inlet tube erosion on copper alloy tubes
If required, tube-end coating is applied
Second tube-end coat applied
Final Product
Full-Length Tube Problems

- General thinning

- Pitting
  - Under deposit corrosion
  - Crevice
  - MIC

- Copper Release From Tubes
Objectives for Conventional Tube Coatings

- Apply a uniform film in one or more coats
- Coating thickness sufficient to protect the whole tube
Pit

Tube Wall
Pit With Insufficient Coating

Coating Film
Pit Completely Filled With Coating

Minimal Coating Film
Objectives for New Approach

- Target and fill (Remediate) the existing pits and holes
- Apply a uniform but minimal film over unpitted tube surface
- Take advantage of the alloy substrate
Specifics of the New Method

- Cleaning the tube
  - Rough cleaning
  - Decontamination
  - Final cleaning

- Coating the tube
  - Patented “squeegee pig”
  - Pits completely filled
  - Coating thickness < 1 mil
Sealing Pits & Holes

- Tube Pit Filled With Coating
- Squeegee Edge for Coating Control
- Thin Deposition of Coating
- Squeegee Pig
- Undistributed Tube Coating
- Sealed Tube Hole
- Uncoated Tube Pit
- Pull Line
- Uncoated Tube Hole
Before and After

Hydrogen Cooler holes and pits
Before and After

Hydrogen Cooler holes and pits
Characteristics of the Tube Coating

- 100% solids
- Low viscosity
- Durable
- Thermal Conductivity
- Anti-fouling
Environmental Control Equipment
Do or Die

- Un-Plugged 1,150 brass tubes
- Coated 5,564 brass tubes
- 10 day project duration
- Hydro -- 55 brass tubes still leaking and were re-plugged
- Unit has run reliably with no apparent heat rate issue.
Do or Die
Do or Die

epoxy “dots” on tube OD showing repaired holes
Copper Stopper

- 500 Mw unit on Lake Michigan
- Admiralty tubes
- In 2006 regulations mandated a reduction in copper discharge from 100 ppb to 12 ppb by 2011
Actions Taken

- Retubed the condenser with 304 SS
- Still had not met goal of 12 ppb
- Coated the tubes of two Bearing Cooling Water Heat Exchangers
  - 1,600 Admiralty tubes, 20’ long
Results

(graph courtesy of NIPSCO)
Hydrogen & Exciter Coolers

- Siemens Energy during re-wind of generator 11-23-13 call for emergency response to coat 1 hydrogen cooler and 2 exciter coolers 2 weeks before RFO

- Hydrogen cooler 572, 7/8”, 20 BWG, 316L SS tubes 45’ long AND 2 exciter coolers with 100, 7-8”, 20 BWG, 316L SS tubes 7’ long
Hydrogen & Exciter Coolers

- Tubes were 3 years old

- At RFO with 18 months in service tubes had an average wall loss of 10%, and at current RFO had 36 months in service with an average wall loss of 60%

- 157 tubes being 90-100% thru wall.
Innovation in Individual Tube Testing

➢ Typical Pressure Equipment
Innovation in Individual Tube Testing

- First Improvements
  - Written protocol with recorded results
  - Change out the pressure gauge to digital
    - Easier to read
    - More accurate
Innovation in Individual Tube Testing

- Second Improvement
  - Automate the entire process
  - Computer controlled with variable inputs
    - Tube length and ID
    - Test pressure
    - Dwell time
    - Pass / Fail criteria
  - Correlates to target criterial for hole size
Innovation in Individual Tube Testing

➢ Components of the new system
  ➢ Computer / Software
Report on Activity

➢ Past nine months:
  ➢ All Condenser Tubes
    ➢ Six Units
    ➢ 60,000 tubes (400 miles)
    ➢ 48,000 tubes tested with new system

➢ To Date:
  ➢ 32 Generating Units
  ➢ Over 200,000 tubes coated
  ➢ Over 14,000 miles of tubes coated
Equipment Package
Waterbox and Channel Heads

- Coatings protect surfaces and can help with fouling control
- Thickness of coating determines longevity and ability to withstand abuse
Flange Sealing

- Stops Air Inleakage
- Stops raw water Inleakage around bolts and gaskets
CATAWBA SERVICE WATER INTAKE PIPE PROJECT