Reinhold Environmental Ltd.

2007 NOx Round Table & Expo Presentation

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Waterwall Corrosion Due to Low NOx Combustion – Material Choices

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Overview

- Waterwall Construction – Metallurgy
- Impact of Low NOx Burners
- Scale Formation and Effect of Environment
- Controlling Wastage
- Discussion Topics

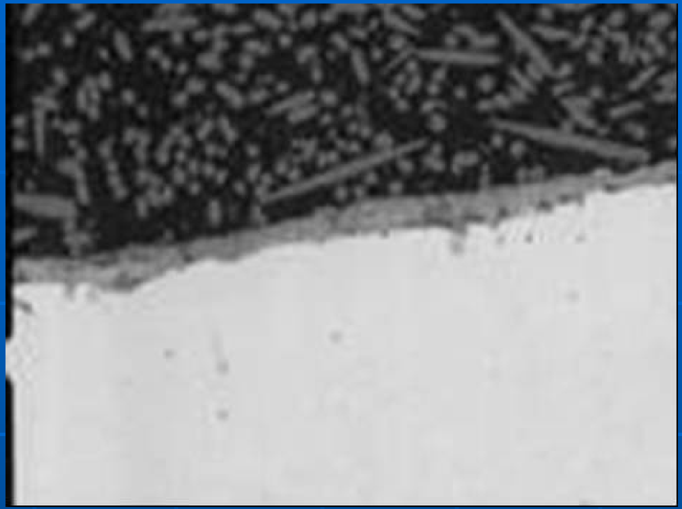
Waterwall Corrosion

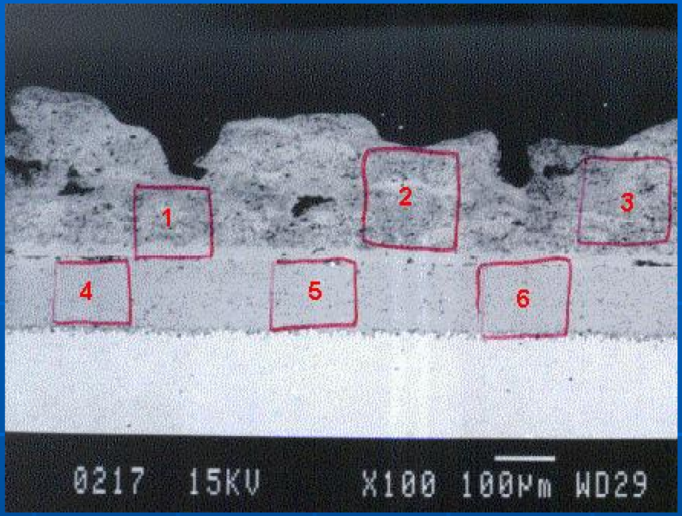
- Tube Metallurgy – Generally Carbon Steel Tubing (SA 178 A/C, SA 192, SA 210).
- Maximum Metal Temperature (Oxidation Limit) 800 F – Based on Saturation Temperature
- Wall Thickness Determined during Design Phase (ASME B & PV Code)
- Failures – Significant Impact on Availability and Maintenance Costs
- Integrity Relies on Formation of Protective Oxide Scale (Magnetic Iron Oxide – Fe_3O_4)
- Scale is Adherent, Dense, and Intact

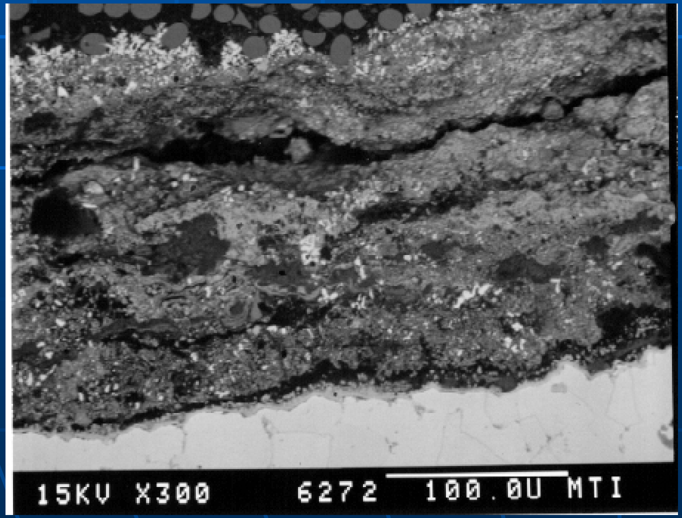
Tube Integrity

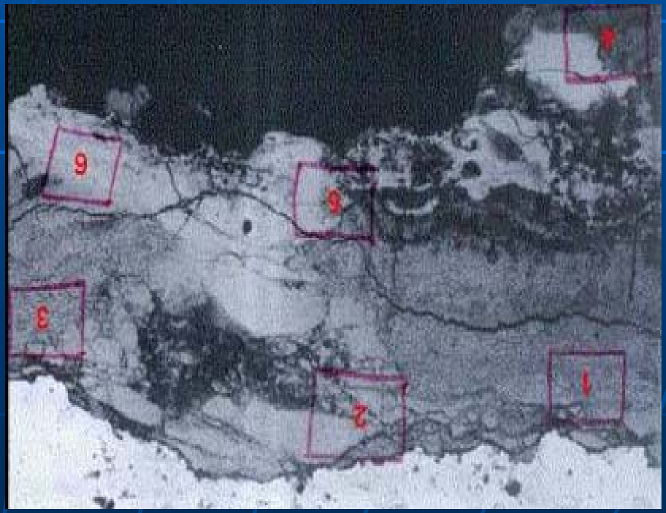
- Carbon Steel Should Last Indefinitely at Temperatures below 850 F
- Major Degradation Due to Tube Wall Thinning (Erosion/Corrosion)
- Processes that Compromise Protect Scale Rate – Corrosion/Wastage - FAILURES
- ID Scale and Water/Steam Flow – Causes Increase in Metal Temperature
- Flue Gas:
  - Hot > 2300 F
  - Contains SO_2/SO_3
  - Carbon (Reducing Agent)
  - Ash
  - Oxygen

Scale Morphologies - Examples









Impact of Low NOx

- Change to combustion environment to reduce Thermal NOx
- Different Technologies and Approaches
- Change Burners – Fuel/Air Ratios, Swirl, etc.
- Change Location/Orientation
- Overfire Air (Deep Staging)
- Ash Chemistry
- RESULTS IN DIFFERENT ENVIRONMENT AT METAL SURFACES

Can We Predict Specific Environment at Tube Surface

- NO!
- Very complex Kinetic and Thermodynamic Processes
- % SO_3
- Effect of Thickness/Morphology and Composition of Scale/Deposit Already Present
- Tube Metallurgy – Fe, Mn, Si, C
- Carbon in Deposit (Size and Reactivity)
- CO and Oxygen Partial Pressures

Operations

- Minimize Substoichiometry with Available Technology
- Repair WW When Required (Controlled Wastage)
- Upgrade Tube Metallurgy
- Clad/Protect Tubes
- Limit S/Cl content of Fuel - OEM
- Ensure Burners and Mills Operating Correctly to Minimize UBC
- Control Metal Temperatures (ID Deposits/Circulation)

Limiting Stoichiometry

- Apply CFD Modeling to Establish Effect on Oxygen and CO levels in the Furnace
- Obtain General Trends – Not Specific to WW Surfaces
- Establish Balance Between NOx Levels and Operations
- How Low to Go Before Impacting Tube Integrity – Rate of Wastage

Repair/Replace WW

- Need to Understand Processes
- Determine Rates – ? years between WW Replacement (Specific Areas)
- Fit with Outage Schedule
- Sacrificial Material – Not a Good Option
- Corrosion Resistant Material
  - Upgrade Costs
  - Code Requirements
  - Best Material for Service Conditions

Cladding/Protection

- Install Corrosion Resistant Surface on WW Tubes
- Different Alloys and Materials Available
  - Price
  - Preparation
  - Location
  - Quality
- Need to establish Susceptible Regions – Historical Data or CFD Modeling

Fuel Selection

- Limit S and Cl – Basis?
- Total S or Pyritic/Organic S
- Size Distribution of Pyritic S
- Ash Chemistry/Mineralogy
- Deposit Chemistry/Mineralogy
- Guidelines from OEMs (Experience and Guarantees)
- Monitoring – Ash Sampling and Tube Sampling

Controlling Unburned Carbon

- Carbon on WW Surfaces Leads to Local Reducing Conditions
- Fuel Characteristics (Inertinite Fraction)
- Particle Size – Milling
- Flame Trajectory – Impacting Wall

Discussion Issues

- Material Upgrade – Selection and Cost Benefit
- Protection – Cladding/Coating Selection and Effectiveness (Monitoring and Maintenance)
- Fuel Switching/Selection
- Monitoring – Wall Thickness, Tube Sampling
- Modeling – Impact of Operation/Fuel on Gas Atmospheres
- Prediction Techniques – Role of Ash/Metallurgy and Environment on Corrosion Process