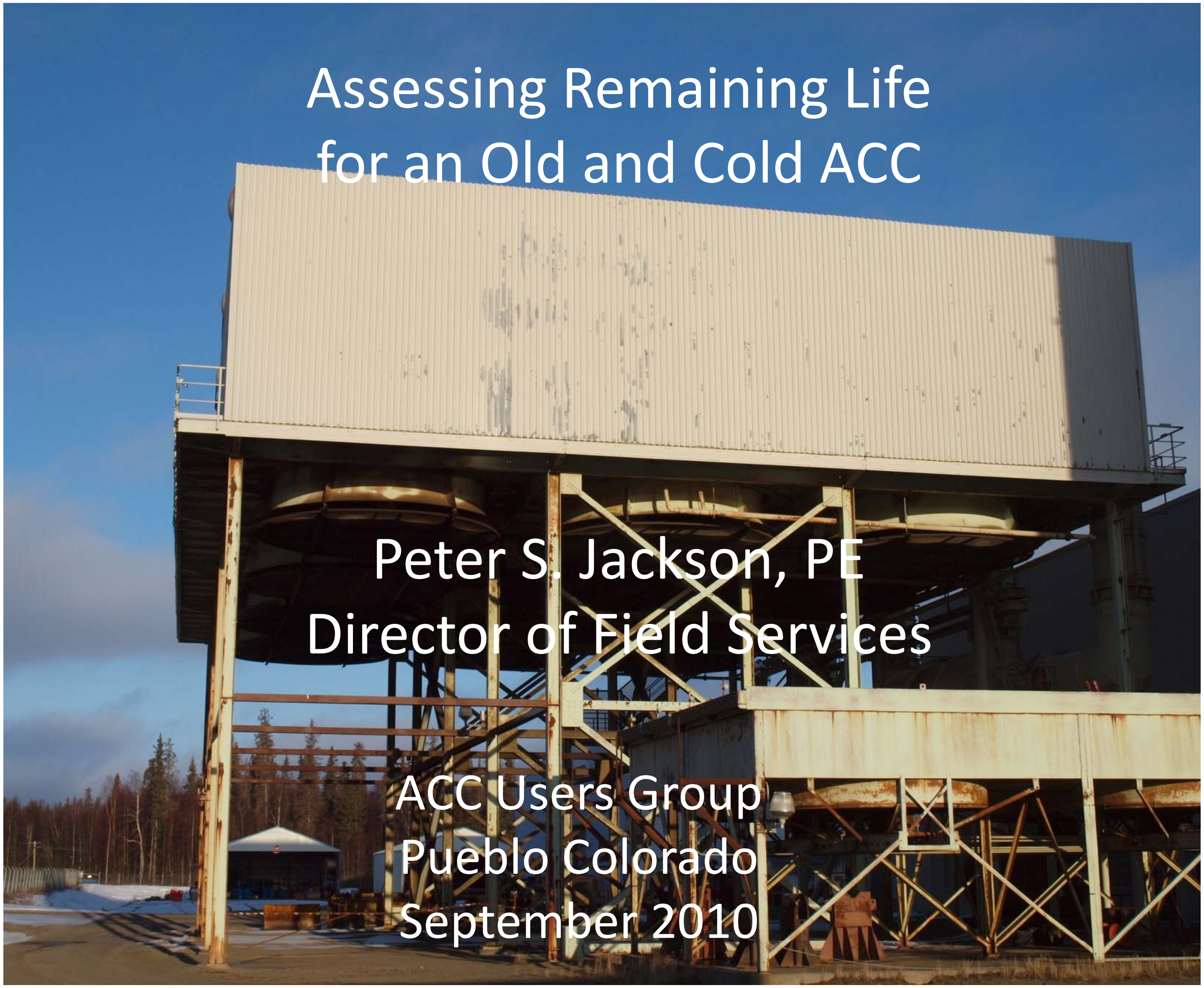
Assessing Remaining Life for an Old and Cold ACC



Peter S. Jackson, PE
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September 2010

TETRA ENGINEERING

ACC Cold Weather Installations

CCGT

- Alaska (-37F, oldest)
- Connecticut (-32F)
- Maine (-48F)
- Massachusetts (-35F)
- Nevada (-50F)
- New York (-10F)
- Oregon (-54)
- Pennsylvania (-42F)
- Rhode Island (-25F)
- Alberta, Ontario (-20F to -40F)

Radiant

- Alaska (coldest -60F)
- Wyoming (-45F)
- Iowa (-47F)
- Michigan (-51F)
- Minnesota (-40F)
- Illinois (-36F)

Plant Characteristics

- Location: Remote Site in Alaska
- Ambient Temperature Range: -40F to 80F
- 340MW (2-on-1 CCGT and 4 SCGTs, black-start capable)
- Two pressure, unfired HRSGs
- Bypass stacks enable CCGT to run Simple Cycle
- No Condensate Polisher
- CCGT COD: 1980

RLA Project History

- 2005 – Comprehensive project commenced to evaluate remaining life of steam plant at an early (i.e. “old”) combined cycle
- End of design life after operating 25 years baseload
- 8-10 years operation required before new generation brought online
- Original RLA scope: HRSGs, DAs and High Energy Piping
- Final Report submitted to support rate case

RLA Project History

- 2005 – DA identified as component limiting beyond design life operation due to oxygen pitting, FAC thinning of shell, potential for stress cracking
- 2007 – Increase in ACC tube leaks, water-side corrosion, high DO levels; recommended Helium leak testing to find the leaks
- Scope expanded to include:
  - water chemistry program, monitoring and trending
  - ACC inspection and condition assessment
- 2008 – HP and LP Deaerators replaced after ASME FFS-1 Evaluation Determined Insufficient HP DA Remaining Life
- 2009 – Helium leak testing by plant eliminates some sources of vacuum leaks external to ACC
- 2010 – Refurbishment/Life Extension of Major Components being Considered

Water Treatment (pre-'94)

- 600 psig HP system
  - 2% HRSG blowdown
- Original water treatment – soft water system
  - Reducing agent - Hydrazine (carbohydrazide)
    - fed for oxygen reduction
    - significantly overfed
  - pH Control
    - Blend of Morpholine and Cyclohexylamine fed occasionally at condensate pump discharge
    - Caustic (NaOH) fed to HRSGs/LP boiler
  - Syntehetic polymer (Polyacrylate blend) overfed
- ca. 1994 converted to demineralized system to address excess silica in HP, LP drums

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Water Treatment (today)

- Phosphate fed to control at a 3/1 sodium/phosphate ratio
- Continue feed of blend of amines to deaerating storage sections
- Feed of volatile oxygen scavenger and amine blend (Hydroxylamine) for oxygen and pH control
- Emphasis on control and fixing ACC air ingress

ACC Design Variables for CCGT

- STG Backpressure
- Design flow attributes ($T, p, \dot{m}$)
- Ambient conditions (T, barometric p, wet bulb T)
- Required heat rejection
- Footprint constraints
- Operating Modes (2-on-1, 1-on-1, cycling, AGC, etc.)
- Wind profiles
- Seismic requirements for structures, manifold piping and supports

ACC Design and Characteristics

- 478,000 lb/hr @ 35F ambient, 5.6 in HgA
- Condensate Temperature 120F
- 4-street, 12-cell supplied by GEA
- “A-Frame” Design, 6 tube rows per panel, 636,000 ft^2
- Elliptical cross-section, circular tube inlets, 0.080” wall thickness
- Constant speed fan drives

ACC Heat Transfer Characteristics

- Heat transfer from the steam exhausted from the steam turbine to the air rejected in the air cooled condenser is governed by the heat duty equation (Reference 9):

$$Q = m_a c_{pa} \left(T_{ao} - T_{ai} \right) = m_c i_{fg\,x} \quad [3.96\ 10^8 \text{ Btu/hr}]$$

- Equivalently, capacity of the heat transfer surface in the ACC to reject heat from the steam exhaust from the steam turbine while condensing is:

$$Q = UA\Delta T_{lmtd} \quad [5.00\ 10^8 \text{ Btu/hr}]$$

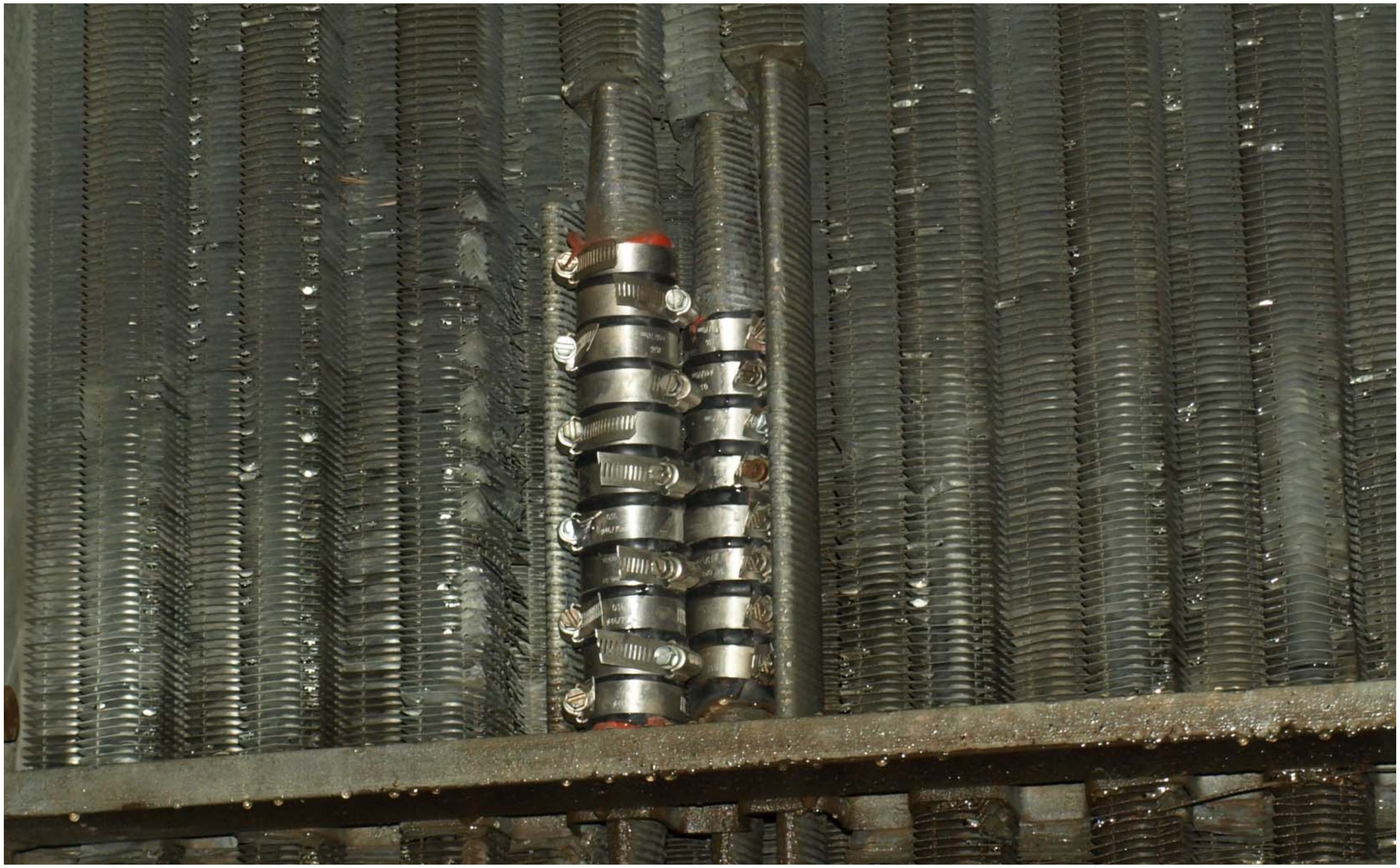
ACC Performance Degradation Causes

- Loss/degradation of vacuum in BOP
- ACC tube leaks
- Fan control/performance problems
- ACC Condensate piping corrosion and BOP issues
- Backpressure increase corresponds to STG output degradation – plant specific
- Condensing Panel Degradation, Air Ingress
- Degradation of air ejection (dephlegmating sections) due to freezing of condensate

ACC Degradation Mechanisms

Mechanism	Components Affected
Condensate Freezing	Leaks in Condensing Tubes, Dephlegmating Tubes usually mid-span with tube rows above fans at highest risk
Fatigue	Cracks in high transverse velocity regions in upper tubesheet at tube inlets
Erosion	Manifold tubesheets, tube end welds and tube wall at inlet
Caustic corrosion	Carryover from steam system
Impingement (droplet erosion)	STG Exhaust duct, ACC turning vanes in large diameter branch ducts
Flow accelerated corrosion (FAC)	Most importantly tube walls although impacts thick section components including ducting and turning vanes as well
Fan Mechanical	Fan/motor bearings and drives

Condensate Freeze-Up



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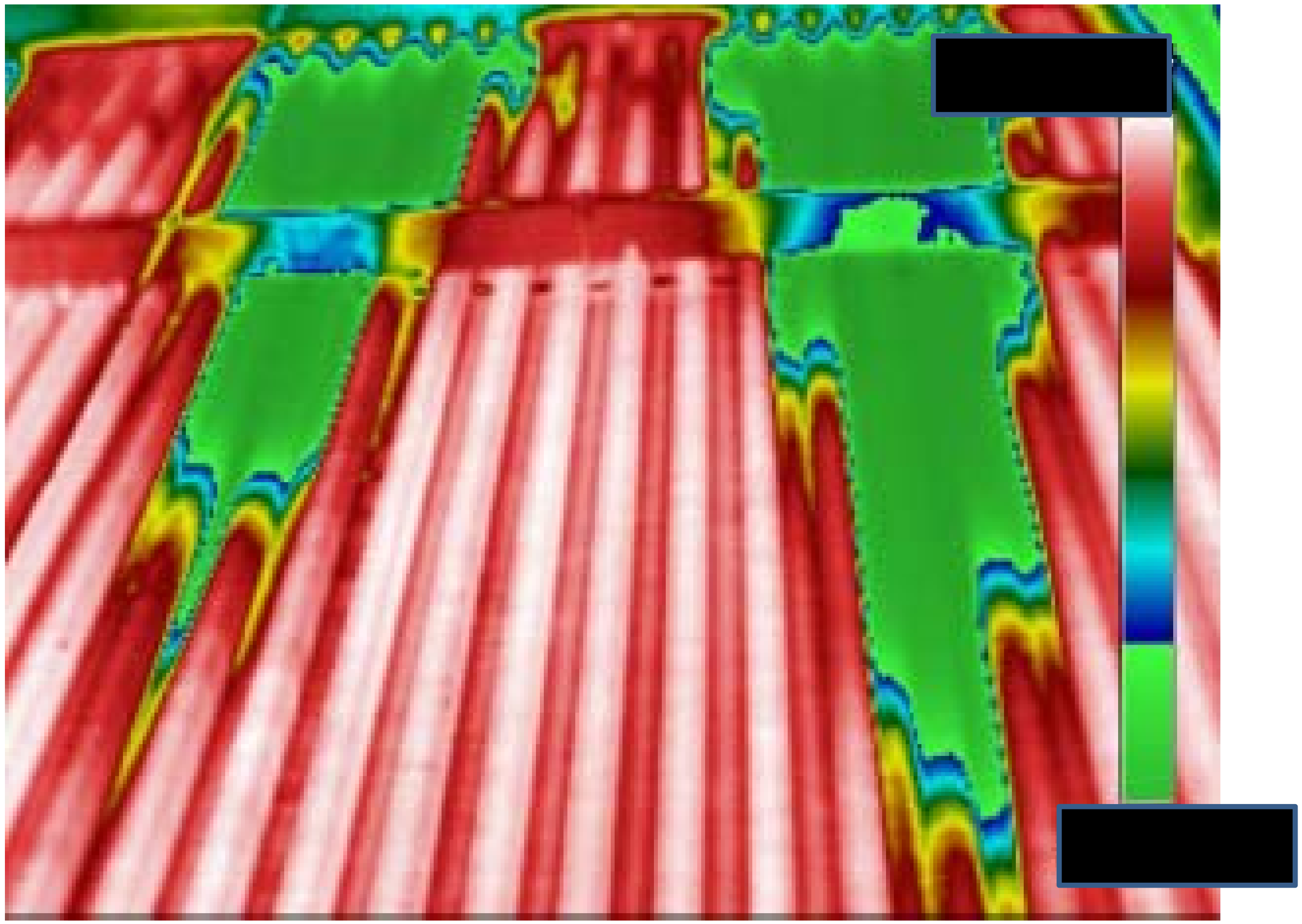
Condensing Section

Cold Tube Panel Regions



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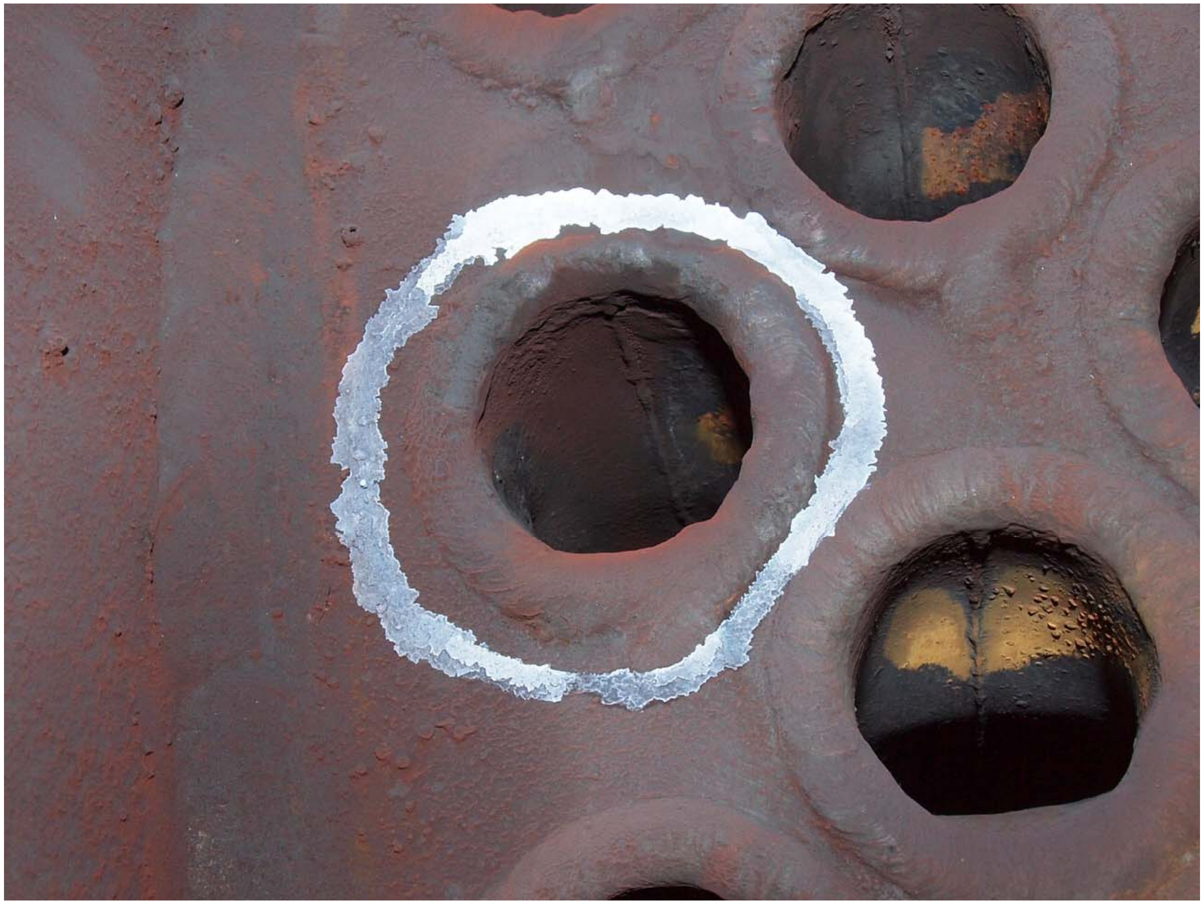
Fatigue

Leak at Opposing Cracks, Distant from Scour Mark



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Erosion

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Potential Caustic Carryover

- LP Steam supplied to DAs (HP, LP)
- Caustic injected in LP Drum for pH control
- Caustic carryover in LP steam into HP FW
- Carryover into Main Steam and Condensate
- History of caustic control issues
- 2008 - Improvements implemented to water chemistry practice, instrumentation and monitoring

Caustic Carryover and Tube Leaks

Impingement on Duct Structures

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Impingement on Turning Vanes in STG Outlet Duct

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Flow Accelerated Corrosion (FAC) Tube Leaks

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Preventive Maintenance

- Power-washing to clean finned tubes
- PMs on fans/drives/motors
- Inspections of ACC steam-side (tube inlets, manifolds, ducts)

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ACC Automated Power Washing

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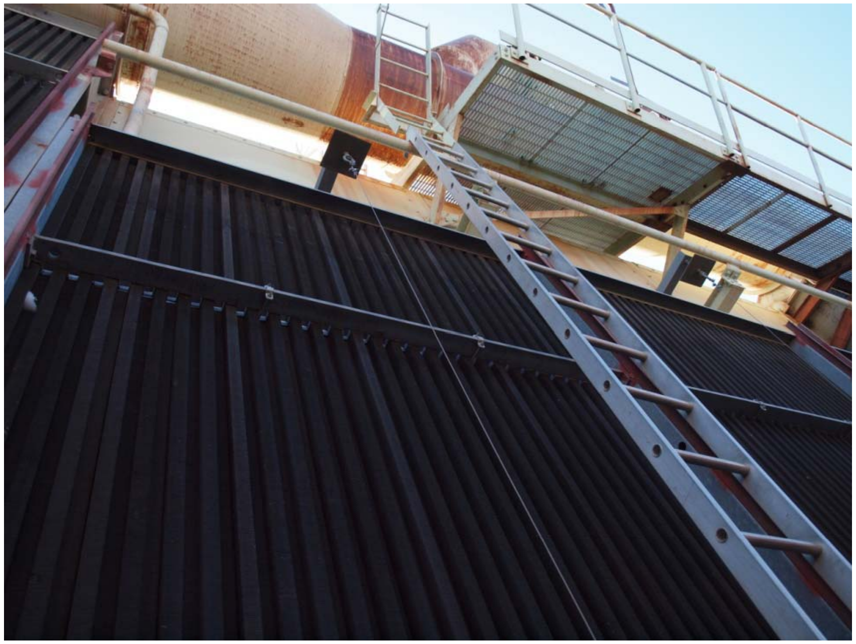
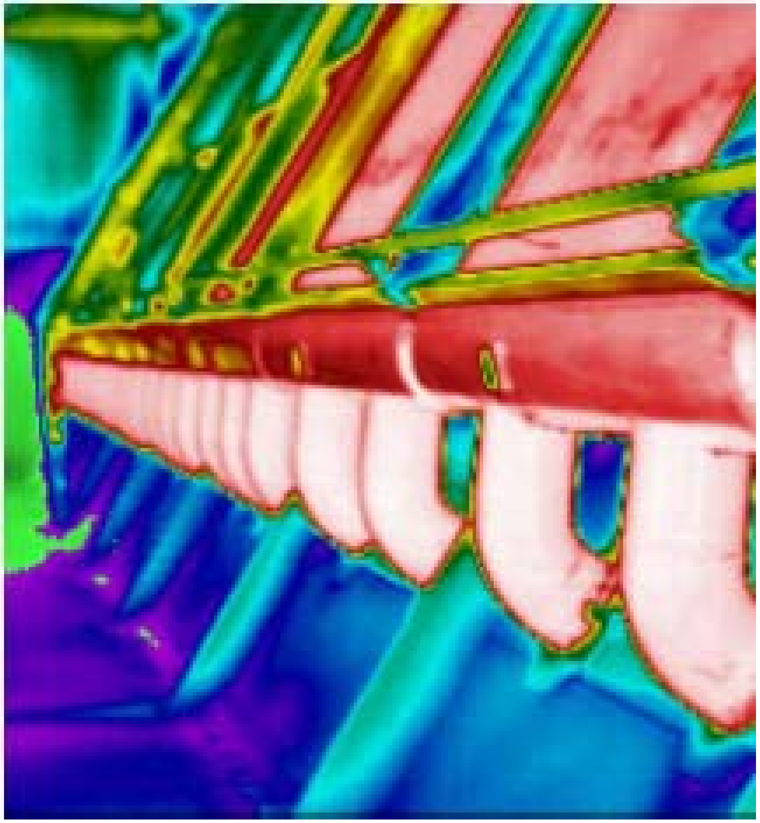
Heat Transfer Surface Inspections

- Air-Side
  - Visual
  - Thermography
  - Helium Leak Detection
- Steam-Side
  - Visual
  - UT/borescope



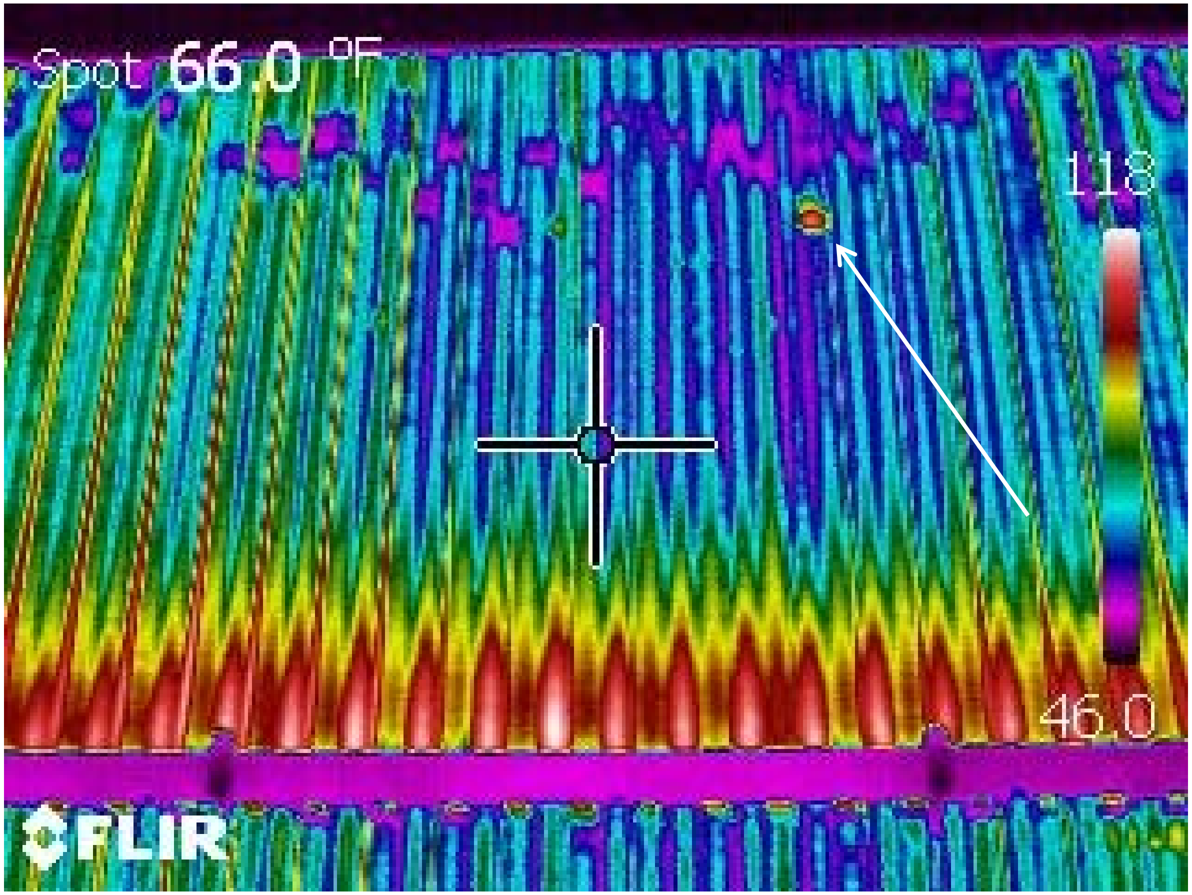
Thermography

- Panel Temperatures
- Flow Anomalies
- Indicates Local Freezing



ACC Tube Leak – Fan Side

Identified by IR, Confirmed by He Leak Detection



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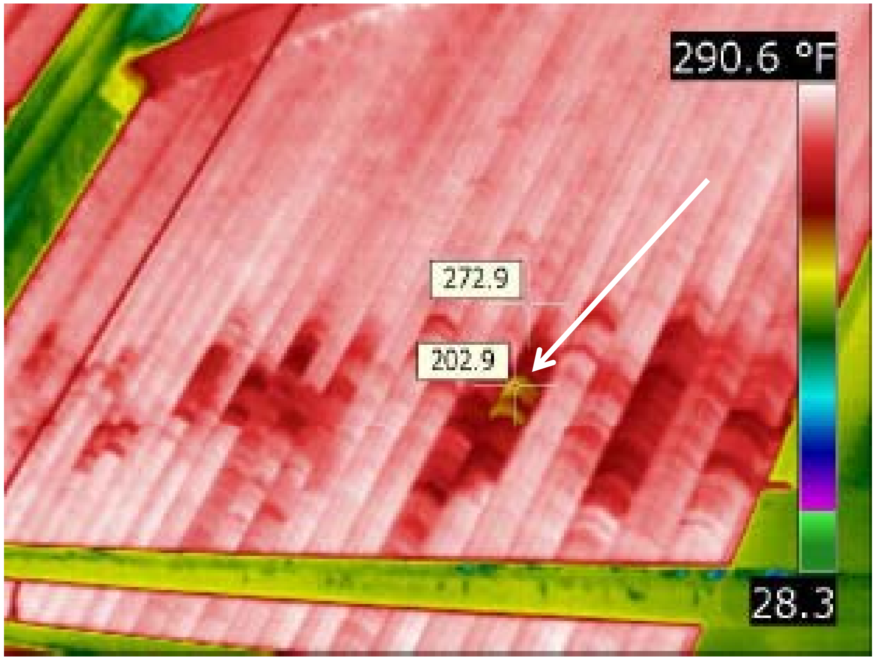
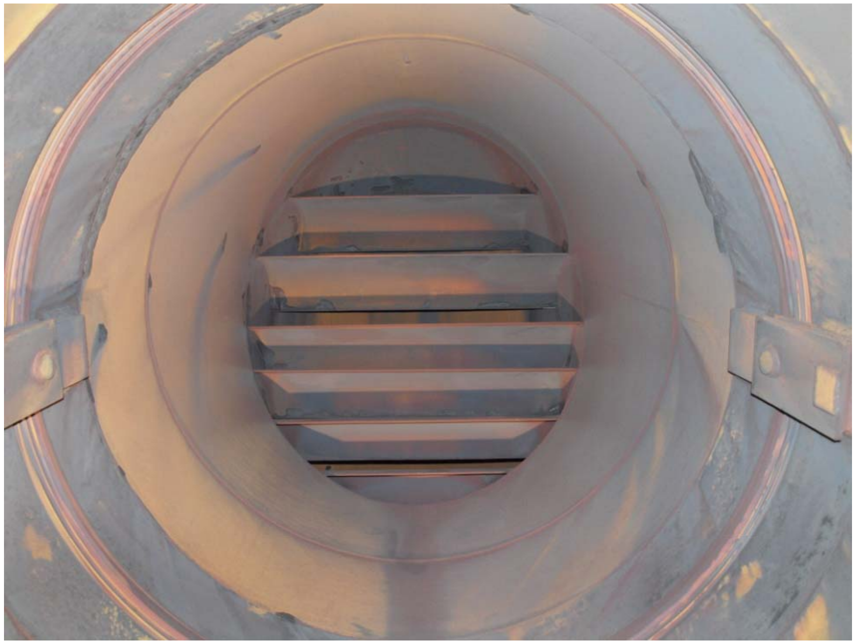
ACC Tube Leak – Above Panel

Identified by IR by Plant

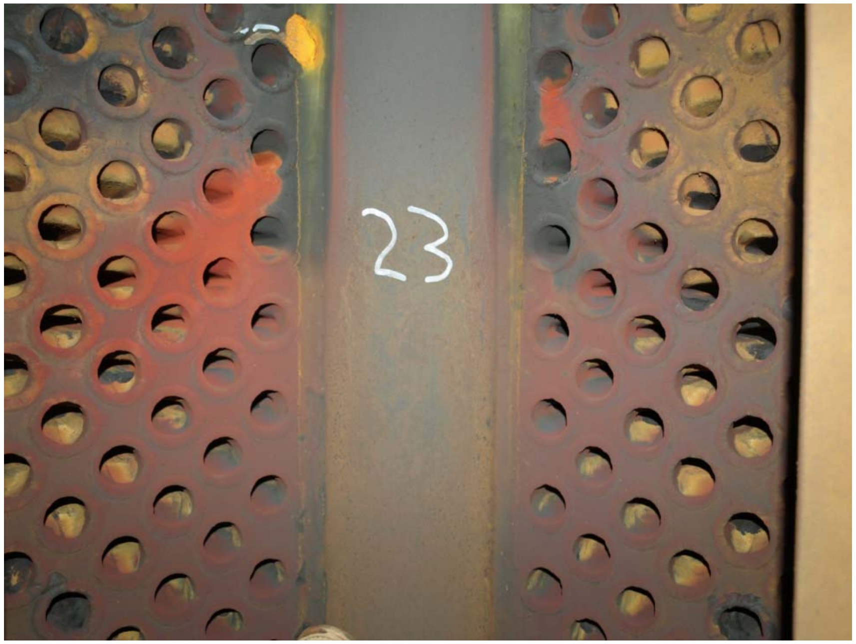


Manifold Steam-Side Inspections

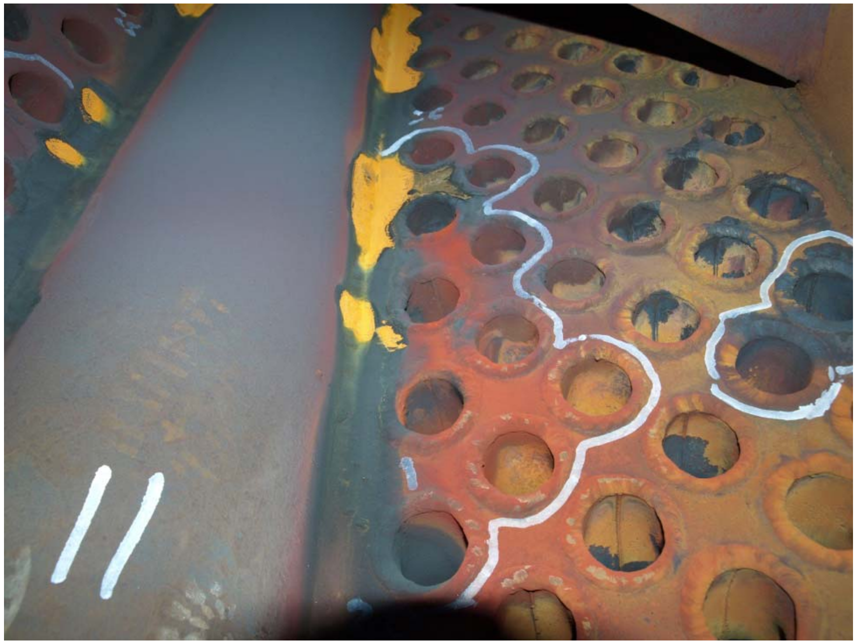


Tube Inlet Inspections

Tube Leaks



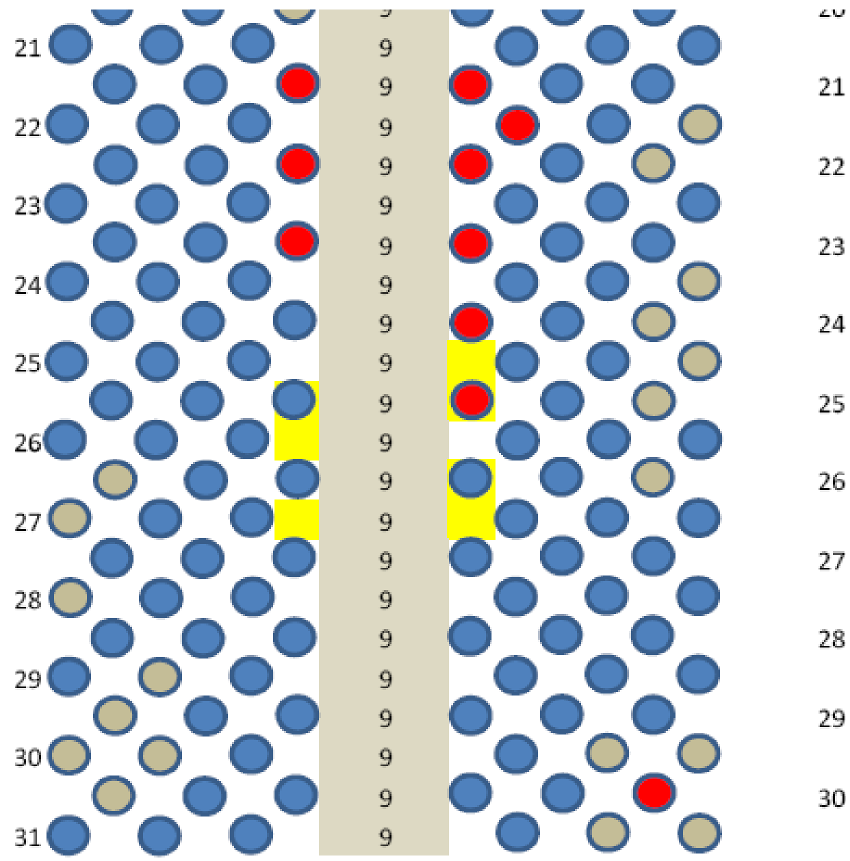
Tube Leaks



Tubesheet Damage Maps

- Identify tube leaks for repairs
- Trend progression of damage

Clamp Repair	
Leak Detected by Helium	
Water-Side Crack/Leak	
High Turbulence Scoured Area	
Chemical Deposits	
Leak Suspected by IR	
Weld Erosion/Damage	
Obstruction	
Polymer Repair	



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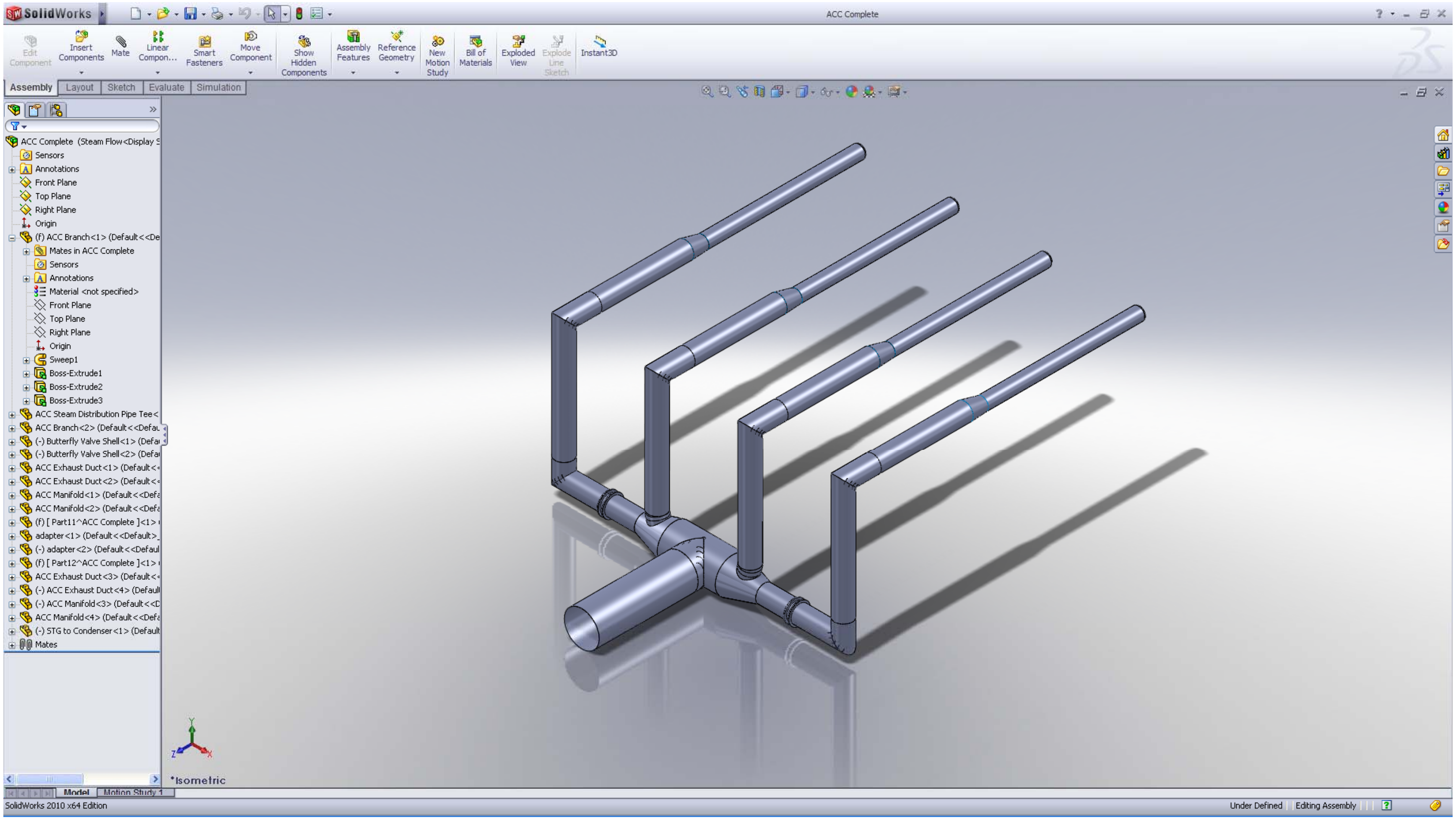
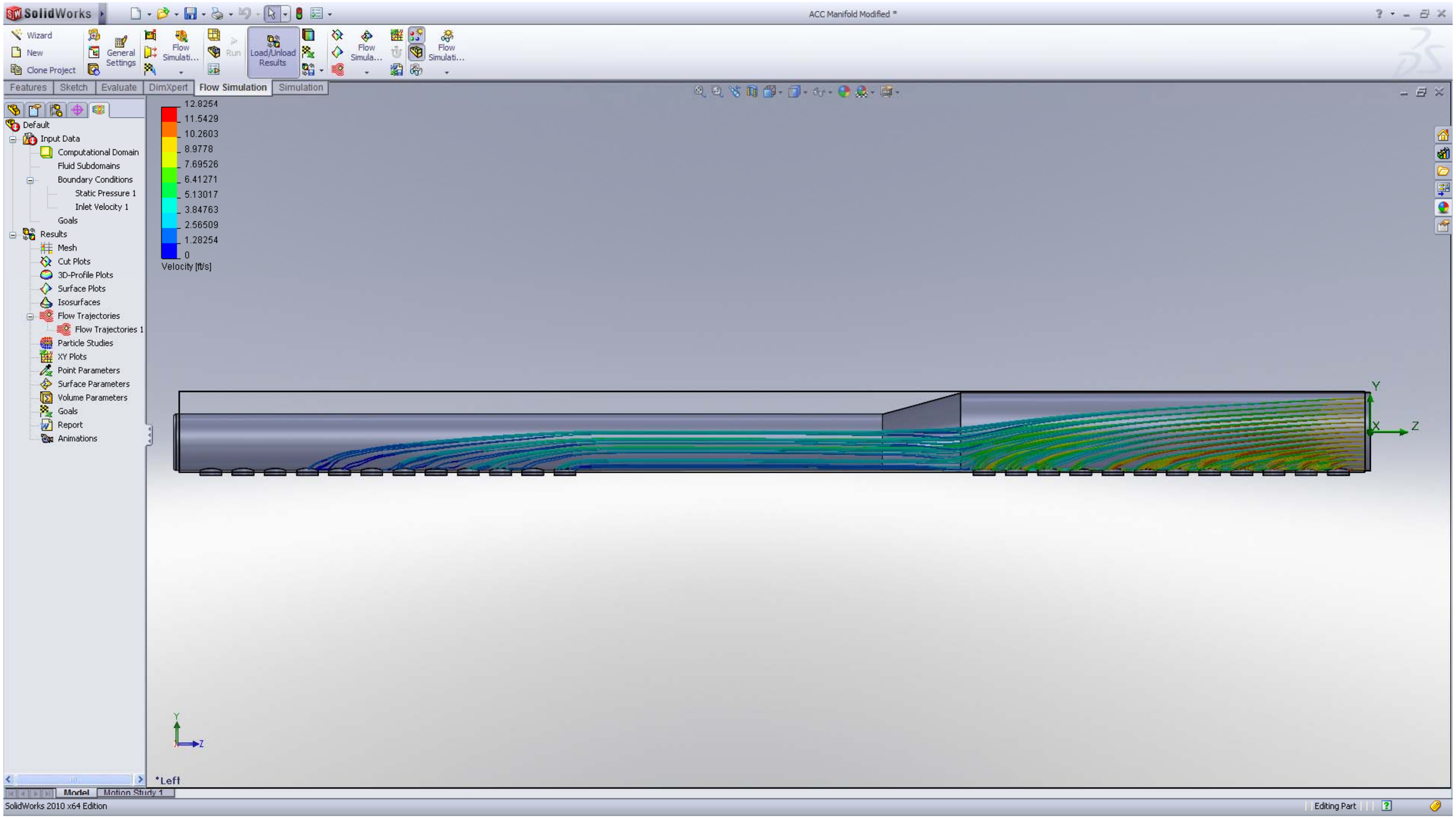
Engineering Evaluations

- Inspection Trending
- CFD Flow Modeling
- Time-trends of tube leaks
- Backpressure changes via operating data
- Calculated lost MW

CFD Flow Models



CFD Flow Models



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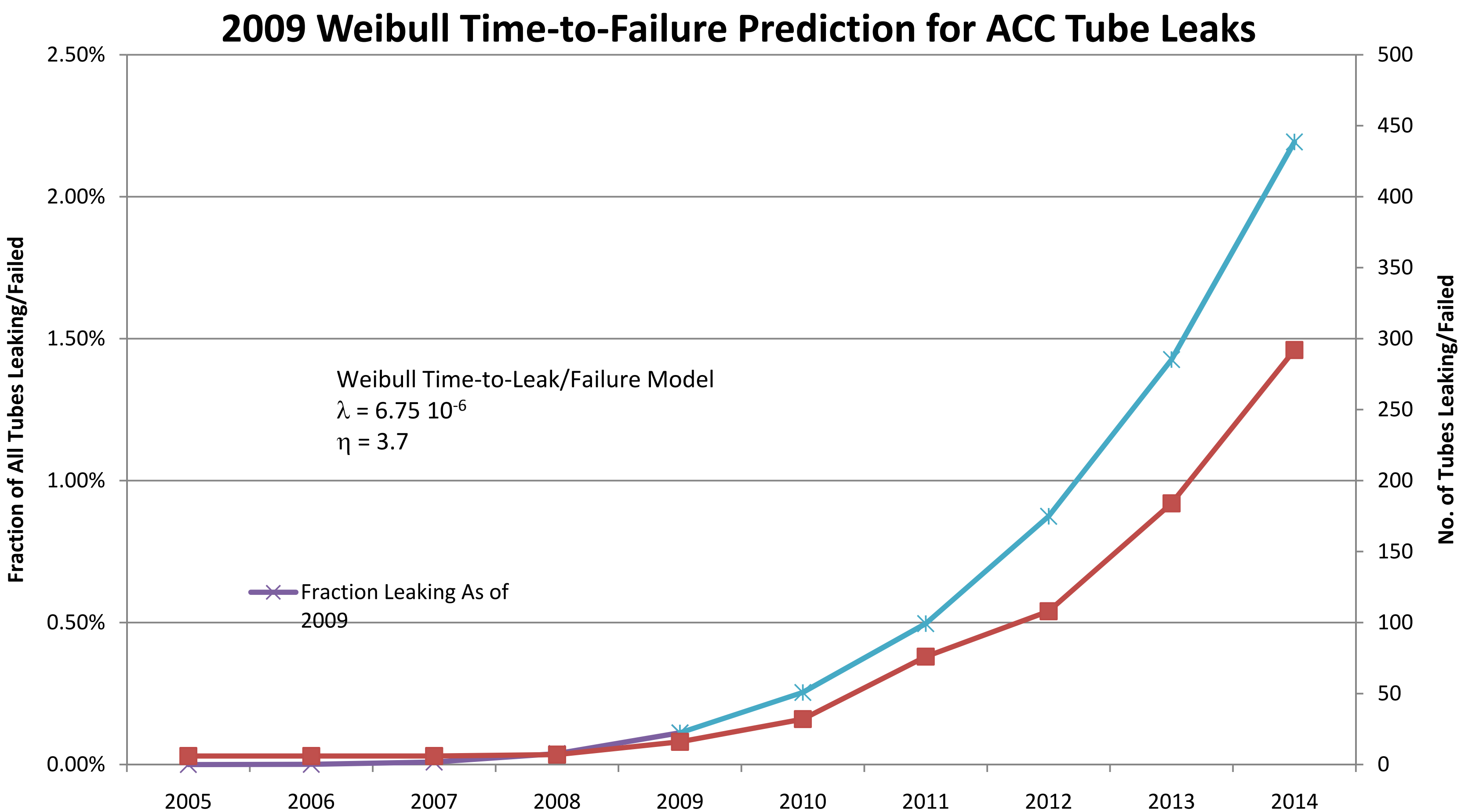
Statistical Model – ACC Tube Leaks



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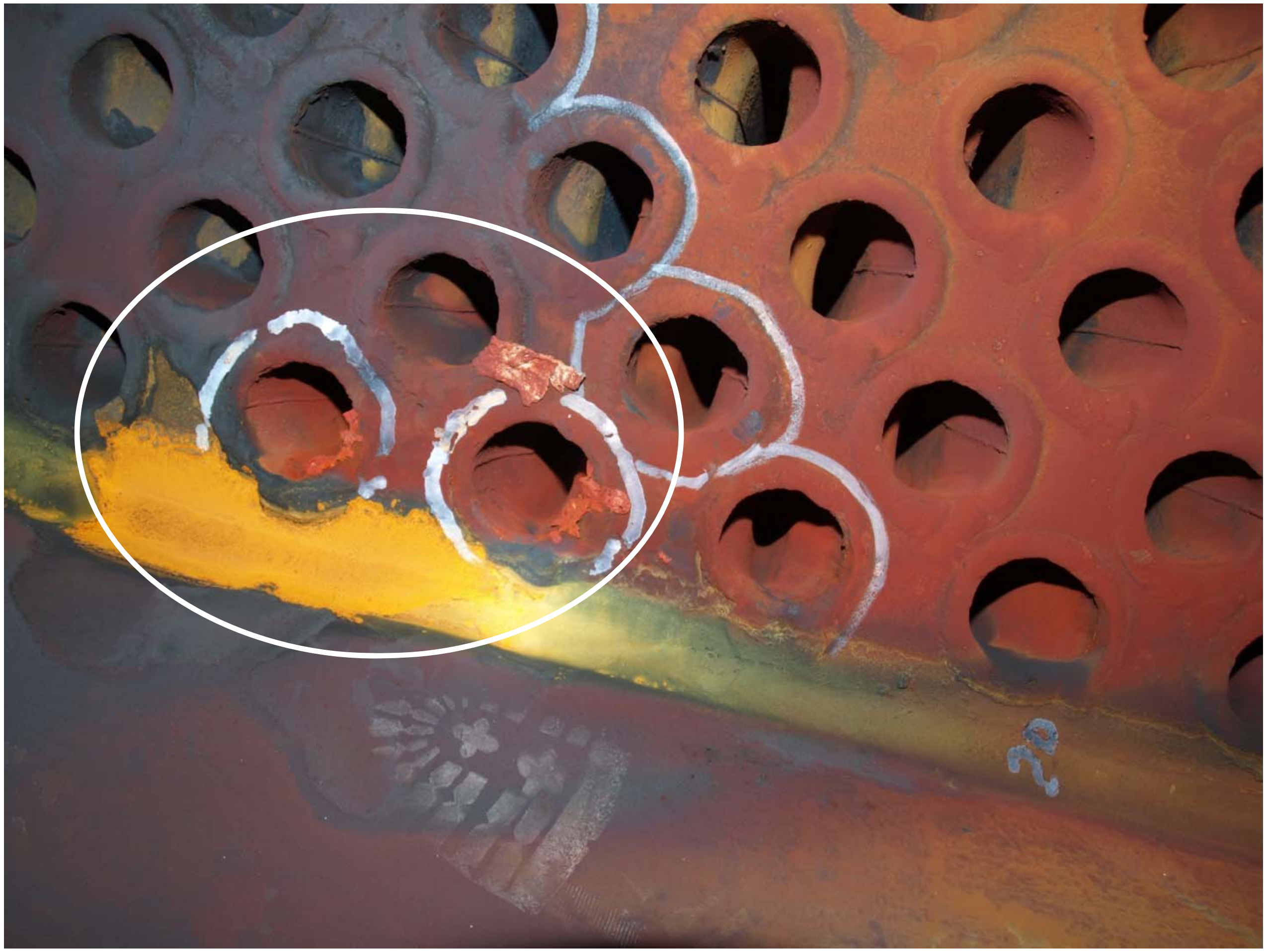
Remedies/Upgrades

- Long-chain polymer sealant repairs to (accessible) tube leaks
- Helium leak testing
- Tube panel/module replacement

Long-Chain Polymer Sealant



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Summary

- Cold Weather Site Characteristics
- Multiple Damage Mechanisms
- Beyond Water Chemistry Control
- Engineering Assessments of Remaining Life
- Options for Repowering/Life Extension
- Practical Considerations for Upgrades

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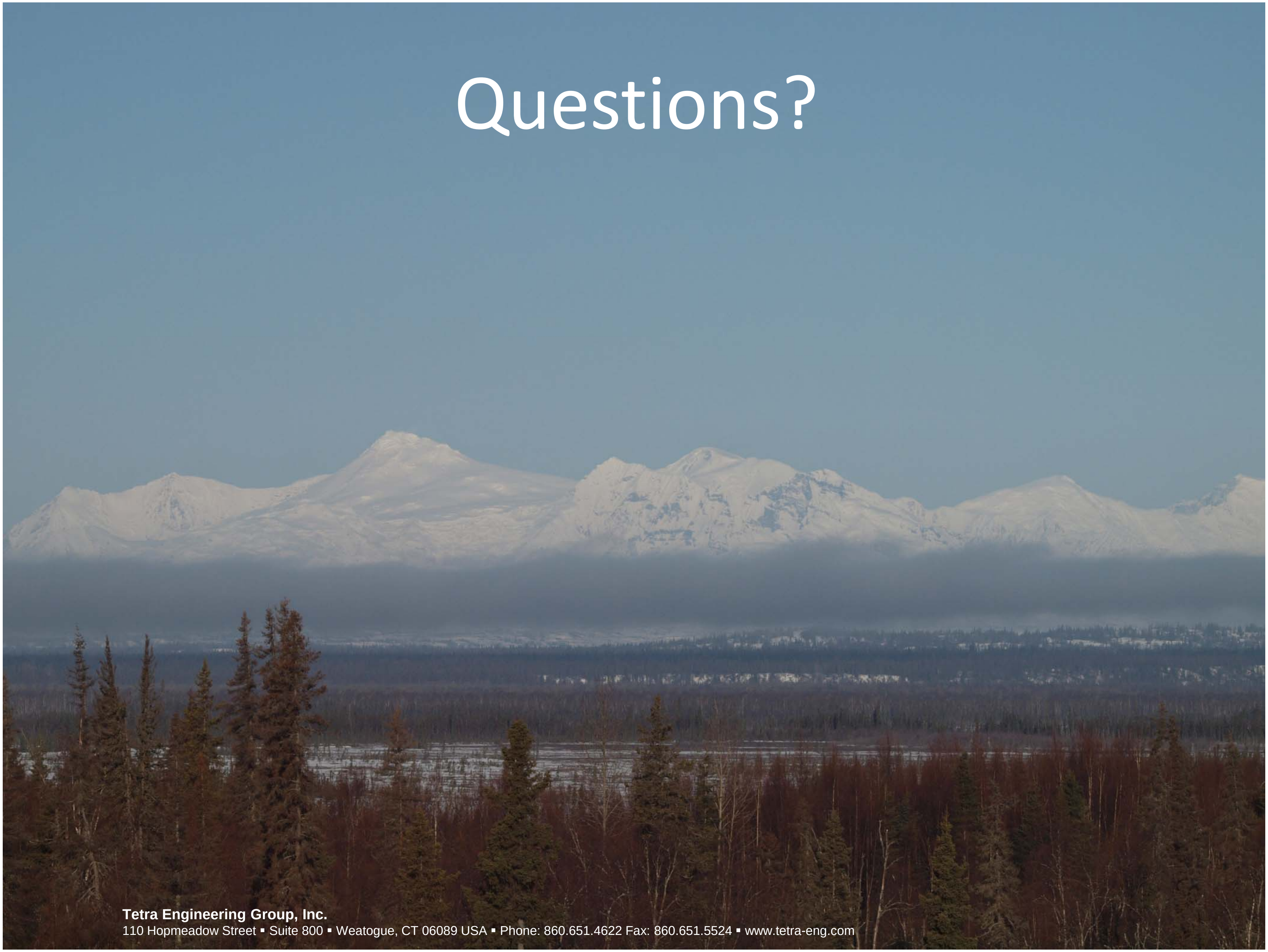
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