SAC – Is it a Problem?

- Most often causes small leaks
- Can lead to large ruptures
SAC – Who Cares?

- Owners
- Operators
- Regulators
- Insurance Companies
- Public

*Process Safety - proactive form of risk assessment combined with engineering that focuses on preventing catastrophic fires, explosions, accidental chemical releases, and structural collapses, especially in facilities that use, process, and handle hazardous materials.*
Recent History of Process Safety Reviews

Coroner’s inquest into B.C. sawmill explosion resumes

https://www.youtube.com/watch?v=BBxzXKRSjsc
A Higher Level of Reliability

SAC - Outline

- Affected equipment
- Description of mechanism
- Where to find it
- How to manage it
SAC Mechanism

- Corrosion mechanism
- Preferentially oriented along stress lines
- Develops crack-like features over time
How Does it Start?

- Magnetite scale cracks due to strain
- Base of crack re-forms magnetite which creates a small corrosion pit
- Cyclic straining of the same location causes elongated pits to form
- Individual pits join to form crack-like features
Water Side Cracking – Mechanism

Driven by Stress
- Residual (cold bends) or applied (e.g. thermal)
- Areas of restraint susceptible (e.g. welds & attachments)

Driven by Corrosion
- Oxygenated water (even at start-up)
- Tends to be at inlet locations where $O_2$ is highest
Water Side Cracking – Is this a Problem?

- Problems primarily occur on cold side
- Can be managed during yearly outages
- Very slow moving cracks
- Likely to have leaks, not ruptures

Lower furnace wall tube shown as-received and after cleaning. The internal scales mask all but the very largest crack.
Where to look?

Any place with higher stress

- Wall Corner welds
- Seal Bars
- Windbox Attachments
- Buckstays and Supports
- Cold Formed Tubes
Water Side Cracking – How do we find it?

- Screening with DR with some sizing
Water Side Cracking – How do we find it?

- DR can provide good coverage
- Indications need to be ~25% of wall and in plane for acceptable detection
Water Side Cracking – Sizing

Ultrasonic Shearwave (UTSW)  Phased Array Ultrasonics (PAUT)
Water Side Cracking – Sizing

**Ultrasonic Shearwave**
- Flaw indication (A-scan)
- Single shear wave beams
- Time intensive for volumetric measurement

**Phased Array**
- Crack indication (sector-scan)
- Multiple shear wave beams
- Three-dimensional view of defect
Water Side Cracking – Sizing

• Both DR and UT can be used to size indications
• DR – Contrast severity (shallow, mid-plane, near through wall)
• Shear Wave UT – More precise (~25%, 50%, 75% of wall – based on signal heights and skill of technician)
• Phased Array UT – Best precision, estimated to 10% of wall accuracy, say roughly ±10 thou - skill of technician important
Water Side Cracking – Should we be Concerned?

- Average age of boilers is increasing
- SAC may be active for years before it is diagnosed so it is a large problem
- Problems found now may be the result of operating conditions from many years ago
- Difficult to assess magnitude of the problem since finding SAC is a problem
What Needs Repair?

- Correlating NDT with severity of SAC damage is difficult, even with the best NDT methods like phased array UT flaw detection.
- The most probable consequence of SAC is a leak before break.
- However, substantial leaks occur when extensive SAC causes a part of the tube to break away – a ‘window leak’.
What Needs Repair?

- Analysis per Part 9 of the API 579-1/ASME FFS-1, Fitness for service, post construction code can define SAC “crack depth criteria” at each level of analysis in the code.
- Analysis and long-standing practical experience show that SAC damage typically becomes a real concern when the corrosion is more than 50% through the wall.

API 579 Part 9 FAD Fracture Mechanics Analysis of Typical SAC
SAC – Mitigation

• Modify weld design to reduce size
• Weld external attachments to membrane
• Support ducting so walls aren’t loaded
• Conservative design of floor beams
• Make flexible joints where possible
SAC Mitigation, Planning, & Resources

- Optimize boiler feedwater deaeration to limit the dissolved oxygen content below 10 ppb in boilers operating at pressure >70 bar (1,000 psi); below 15 ppb for boilers 40-70 bar (580-1,000 psi), and <20 ppb for boilers < 40 bar. Consistent boiler feedwater quality and deaeration reduce the likelihood and severity of SAC.

- Decrease the number of boiler service interruptions and of shutdowns.

- Reduce the cyclic tensile stress magnitude in the internal surface of the tube, pipe or header by altering the attachment design or by modifying the stress-concentrating geometry to mitigate flexing/bending at the internal surface.

- Inspection & operating plans should consider SAC

- See TAPPI TIP 0402-38 - Best practice guidelines for detecting and mitigating waterside cracking (stress-assisted corrosion) in power and recovery boilers
### Risk Review – COF X POF

#### Consequence Categories

<table>
<thead>
<tr>
<th>Consequence Category</th>
<th>Regulatory / Loss of Containment</th>
<th>Financial / Reliability</th>
<th>Reputation</th>
</tr>
</thead>
<tbody>
<tr>
<td>C1</td>
<td>Agency action withdrawing permits or limiting production with significant government oversight and control</td>
<td>&gt; $50M</td>
<td>Significant public response causing major long-term impact of share price; damaging reputation and resulting in the inability to expand operations for several years.</td>
</tr>
<tr>
<td>C4</td>
<td>Significant agency action that permanently limits operations for period of time; significant loss of containment with potential human health or environmental impacts.</td>
<td>$10M - $50M</td>
<td>Significant public response causing major impact on share price.</td>
</tr>
<tr>
<td>C3</td>
<td>Significant agency action that limits operations for period of time; significant loss of containment in populated area.</td>
<td>$1M - $10M</td>
<td>Significant public response causing limited short-term impact on share price.</td>
</tr>
<tr>
<td>C2</td>
<td>Reportable regulatory exceedance with agency action and significant corrective action requirements; significant loss of containment in remote area.</td>
<td>$100k - $1M</td>
<td>State/Provincial concern; major interest group concerned; regional media attention.</td>
</tr>
<tr>
<td>C5</td>
<td>Minor regulatory non-compliance resulting in administrative action</td>
<td>$10k - $100k</td>
<td>Isolated concern / Minor short-term, no local media attention.</td>
</tr>
</tbody>
</table>
Inspection Plans

• Written plans that are a living document
• Where to look – industry practices, susceptible locations, risk based
• When to look
• Update plans based on inspection data – review annually and after each inspection