Hanford Double-Shell Tank Corrosion Control Overview

A. J. Feero
K. D. Boomer
R. E. Mendoza

July 2016
Double-Shell Tank Corrosion Control

- Ultrasonic Inspection
- Chemisty Control
- Corrosion Testing
- Corrosion Probes
- Visual Inspection
Chemistry Control

• Purpose of chemistry control is to minimize corrosion by maintaining the tank waste compositions within specifications

• Key elements
  – Chemistry control limits by OH\(^-\) and NO\(_2^-\)
  – Tracking and maintaining chemical compositions
  – Waste compatibility assessments

• Operating specification OSD-151-T-00007, *Operating Specifications for the Double-Shell Tanks*
## Why are Hydroxide (OH\(^{-}\)) and Nitrite (NO\(_2^{-}\)) Important for DST Chemistry Corrosion Control?

Pitting and stress cracking are the principal forms of corrosion attacking the carbon steel DSTs. OH\(^{-}\) additions increase the pH, preventing pitting; and NO\(_2^{-}\) additions prevent initiation of nitrate-induced stress cracking corrosion.

### Double-Shell Tank Waste Corrosion Chemistry Controls

<table>
<thead>
<tr>
<th>FOR [NO(_3^{-})] RANGE</th>
<th>VARIABLE</th>
<th>FOR WASTE TEMPERATURE (T) RANGE</th>
<th>T &lt; 167 °F</th>
<th>167 °F ≤ T ≤ 212 °F</th>
<th>T &gt; 212 °F</th>
</tr>
</thead>
<tbody>
<tr>
<td>[NO(_3^{-})] ≤ 1.0M</td>
<td>[OH(^{-})]</td>
<td></td>
<td>0.010 M ≤ [OH(^{-})] ≤ 8.0 M</td>
<td>0.010 M ≤ [OH(^{-})] ≤ 5.0 M</td>
<td>0.010 M ≤ [OH(^{-})] ≤ 4.0 M</td>
</tr>
<tr>
<td></td>
<td>[NO(_2^{-})]</td>
<td></td>
<td>0.011 M ≤ [NO(_2^{-})] ≤ 5.5 M</td>
<td>0.011 M ≤ [NO(_2^{-})] ≤ 5.5 M</td>
<td>0.011 M ≤ [NO(_2^{-})] ≤ 5.5 M</td>
</tr>
<tr>
<td></td>
<td>[NO(_3^{-})] / ([OH(^{-})] + [NO(_2^{-})])</td>
<td></td>
<td>&lt; 2.5</td>
<td>&lt; 2.5</td>
<td>&lt; 2.5</td>
</tr>
<tr>
<td>1.0M &lt; [NO(_3^{-})] ≤ 3.0M</td>
<td>[OH(^{-})]</td>
<td></td>
<td>0.1 (NO(_3^{-}))) ≤ [OH(^{-})] ≤ 10 M</td>
<td>0.1 (NO(_3^{-}))) ≤ [OH(^{-})] ≤ 10 M</td>
<td>0.1 (NO(_3^{-}))) ≤ [OH(^{-})] ≤ 4.0 M</td>
</tr>
<tr>
<td></td>
<td>[OH(^{-})] + [NO(_2^{-})]</td>
<td></td>
<td>≥ 0.4 (NO(_3^{-})))</td>
<td>≥ 0.4 (NO(_3^{-})))</td>
<td>≥ 0.4 (NO(_3^{-})))</td>
</tr>
<tr>
<td>[NO(_3^{-})] &gt; 3.0M</td>
<td>[OH(^{-})]</td>
<td></td>
<td>0.3 M ≤ [OH(^{-})] &lt; 10 M</td>
<td>0.3 M ≤ [OH(^{-})] &lt; 10 M</td>
<td>0.3 M ≤ [OH(^{-})] &lt; 4.0 M</td>
</tr>
<tr>
<td></td>
<td>[OH(^{-})] + [NO(_2^{-})]</td>
<td></td>
<td>≥ 1.2 M</td>
<td>≥ 1.2 M</td>
<td>≥ 1.2 M</td>
</tr>
<tr>
<td></td>
<td>[NO(_3^{-})]</td>
<td></td>
<td>≤ 5.5 M</td>
<td>≤ 5.5 M</td>
<td>≤ 5.5 M</td>
</tr>
</tbody>
</table>
Tracking and Maintaining Chemical Composition

- Establish and maintain a database to track the nitrite, nitrate, and hydroxide concentrations in each DST
  - Best-Basis Inventory
  - RPP-13639, *Caustic Limits Report*, updated every year
- Conduct periodic sampling of the waste in DSTs to determine the OH\(^-\), NO\(_2\)-, and NO\(_3\)- concentrations are within limits
- Sampling requirements identified in annual update to RPP-7795, *Chemistry Control Technical Basis*
  - Hydroxide depletion estimated by predictive modeling
    - Empirical modeling – Hobbs equation
    - Mechanistic modeling –
      - Supernatant Chemistry Evaluation Model
      - Dynamic Mixing Model (interstitial liquid)
Corrosion Testing

• Purpose of corrosion testing
  – Investigate the potential for stress corrosion cracking (SCC), pitting, and vapor space corrosion (VSC) in the tanks
  – Develop testing protocols
  – Determine improved corrosion specifications
  – Investigate new tank environments

• Testing conducted at DNV-GL, SRNL, and 222-S laboratories with guidance for the Tank Integrity Expert Panel Corrosion Subgroup
Corrosion Testing – Stress Corrosion Cracking

• Testing techniques
  – Slow strain rate testing (ASTM G129-00)
  – Crack growth rate testing

• Results
  – Results imply that tank chemistries do not pose a significant threat for SCC except
    • at low pH (11)
    • high temperature (>60 °C)
    • high plastic strain, and
    • high potential (>0 mV vs. SCE)
  – New specification criteria are suggested in RPP-RPT-47337, Specifications for the Minimization of the Stress Corrosion Cracking Threat in Double-Shell Tank Wastes
Corrosion Testing – Pitting Corrosion

• Testing techniques
  – Cyclic potentiodynamic polarization (CPP) (ASTM G61-86e1)
  – Tsujikawa Hisamatsu Electrochemical Test (ASTM G192)
  – Long-term tests as needed (OCP or applied potential)

• Results
  – Results indicate that for current tank waste compositions and temperatures, there is no evidence of pitting corrosion

• Additional testing
  – Evaluation of leaked waste in Tank AY-102 annulus
  – Additional testing as needed to support new waste chemistries, such as DFLAW returns
Corrosion Testing – Vapor Space Corrosion

• Concern for VSC arose from VSC in Savannah River tanks

• Gas species likely to impact corrosion
  – CO₂
  – NH₃

• Testing underway to
  – Identify vapor components that may cause or inhibit corrosion
  – Explore methods to improve laboratory testing
  – Explore methods to measure NH₃ present in tanks
Corrosion Testing – Leak Detection Pit

- Liquid level increases in leak detection pits (LDPs) raised concerns that secondary liner external surface was exposed to moisture.
Corrosion Testing – Leak Detection Pit (cont.)

• Testing
  – Total immersion, VSC, and LAI testing
    • LDP water simulant
    • Ground water simulant
    • Actual LDP water samples

• Results
  – Simulant and actual samples indicate there is a risk of pitting and general corrosion in the LDP system, and thus, exterior surface of the secondary liner
  – Conservative corrosion rate estimates range from 5 to 10 mils/yr
Corrosion Testing – Leak Detection Pit (cont.)

- Exterior secondary liner corrosion is currently the biggest known threat to secondary liner integrity, and steps are currently being taken to monitor the threat
  - UT scans of the secondary liner
  - Maximum authorized LDP levels are specified in OSD-T-151-00007

Steel Specimen after Two Months
50% Submerged in Leak Detection Pit Water
Corrosion Probes Purpose

- **Purpose of corrosion probes**
  - Measure corrosion potential ($E_{corr}$) in the tank
  - Compare measured potential to safe regions of $E_{corr}$ determined from laboratory testing

AN-102

Onset of stress corrosion cracking unlikely at

*Potentials more negative than -100 mV vs. SCE*

241-AN-102 MPCMS Average Monthly Tank and SS Tank Material Electrode Potentials (Field Measurements Taken with Respect to SS-AGCL).
Corrosion Probes

- Two corrosion probe systems installed in DSTs
  - Multi-probe corrosion monitoring system (MPCMS)
    - Reference electrode test array
    - Electrical resistance sensors
    - Coupons
  - Retractable corrosion monitoring probes (RCMP)
    - Reference electrodes
    - Simple, retractable design
## Corrosion Probe Status as of June 2015

<table>
<thead>
<tr>
<th>Tank</th>
<th>System Install Date</th>
<th>Average Tank Potential for Current Reporting Period (vs. SCE)</th>
<th>Threshold Potential for Onset of Stress Corrosion Cracking (vs. SCE)</th>
<th>Corrosion Rate (mils per year)</th>
<th>Disposition</th>
</tr>
</thead>
<tbody>
<tr>
<td>241-AN-102</td>
<td>05/2008</td>
<td>-373 mV</td>
<td>-100 mV</td>
<td>&lt;&lt; 1</td>
<td>System in reasonably good condition; continue operation</td>
</tr>
<tr>
<td>241-AY-102</td>
<td>03/2009</td>
<td>Failed System.</td>
<td>50 mV</td>
<td>--</td>
<td>Replace system due to multiple electrode failures</td>
</tr>
<tr>
<td>241-AY-101</td>
<td>04/2009</td>
<td>23 mV</td>
<td>0 mV</td>
<td>&lt;&lt; 1</td>
<td>Replace system due to multiple electrode failures</td>
</tr>
<tr>
<td>241-AN-107</td>
<td>06/2010</td>
<td>-415 mV</td>
<td>-100 mV</td>
<td>&lt;&lt; 1</td>
<td>System in reasonably good condition; continue operation</td>
</tr>
<tr>
<td>241-AW-104</td>
<td>07/2010</td>
<td>-383 mV</td>
<td>-100 mV</td>
<td>&lt;&lt; 1</td>
<td>Replace system due to multiple electrode failures</td>
</tr>
<tr>
<td>241-AW-105</td>
<td>08/2013</td>
<td>-321 mV</td>
<td>-100 mV</td>
<td>N/A</td>
<td>Replace system due to multiple electrode failures</td>
</tr>
<tr>
<td>241-SY-101</td>
<td>07/2014</td>
<td>-259 mV</td>
<td>-50 mV</td>
<td>N/A</td>
<td>System in reasonably good condition; continue operation</td>
</tr>
</tbody>
</table>
Summary

• Corrosion control program is comprised of three elements
  – Chemistry control to mitigate risk
  – Corrosion testing to investigate risk
  – Corrosion probes to monitor risk
• Corrosion testing and corrosion probe results support and improve the chemistry control program
• Testing and monitoring is consistently improving
  – Improved modeling techniques
  – Additional corrosion testing
  – Simplified, yet upgraded in-tank monitoring designs