API 653 TANK INSPECTION, TANK MAINTENANCE, AND CAUSES OF TANK FAILURE
API 653 Tank Inspections

Why Inspect Your Tanks?

- Prevent leaks into your secondary containment or to groundwater (if you do not have a secondary containment system)
- Establish a baseline of tank condition and corrosion rates
- Identify problems to perform repairs before you have a significant leak or release - **Maintain your capital asset**
- Minimize chance of catastrophic tank failure
PROPER INSPECTION PROTOCOL

INSPECTOR CREDENTIALS

• Certified API 653 Inspector
  ➢ Four years minimum experience with storage tanks
  ➢ Must pass test conducted by American Petroleum Institute (API)
    ➢ Inspectors receive an individual inspector number
    ➢ Inspector testing required every three years
PROPER INSPECTION PROTOCOL

• Visual inspection of welds, plates, and appurtenances
• UT (Ultra-sonic Thickness) testing of shell courses, floor, and roof
• Vacuum testing of all floor weld seams – unless epoxy coated
• Identify bottom side corrosion on floors
• Settlement Survey
  ➢ Checking for planar tilt
  ➢ Check for floor bulges or depressions
• Provide calculations for safe or maximum fill height
Interior piping corrosion

Shell corrosion
Weld deterioration and four-way junction – NON API

Four-corner insert with reinforcing backup – NON API
Evidence of interior shell corrosion

Foundation evaluation
Floor plate corrosion

Lap-welded seam leak
Floor coupon with bottom side corrosion

Floor top side corrosion
Severe roof corrosion

Star light . . . Star bright!
SHELL SETTLEMENT SURVEY
API-653 APPENDIX B SETTLEMENT EVALUATION

<table>
<thead>
<tr>
<th>File No</th>
<th>Report No</th>
<th>Client</th>
<th>Inspector</th>
<th>Tank No</th>
<th>1st Crs Plt Spec</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>HTS-10-221</td>
<td></td>
<td>Doug Perry</td>
<td>#1</td>
<td>Unknown</td>
</tr>
</tbody>
</table>

\[ S \leq 11L^2Y/2EH \]

- \( U \) = Measured out-of-plane settlement in relation to a cosine curve, in feet
- \( S \) = Deflection, in feet, (out-of-plane distortion)
- \( L \) = Arc length between measurement points, in feet
- \( Y \) = Yield strength, in pounds per square inch (psi)
- \( E \) = Young's modulus, in pounds per square inch (psi)
- \( H \) = Tank height, in feet

### Table:

<table>
<thead>
<tr>
<th>D</th>
<th>L</th>
<th>Y</th>
<th>E</th>
<th>H</th>
<th>S - Max Permissible</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>52</td>
<td>20.42</td>
<td>30000</td>
<td>29000000</td>
<td>31.5</td>
</tr>
<tr>
<td></td>
<td>0.075</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Results:

- **Point 1**: Feet: 3, Inches: 9.000, Feet: 3.75, U: 0.000, S: 0.002, Results: SAT
- **Point 2**: Feet: 3, Inches: 9.200, Feet: 3.77, U: 0.007, S: 0.000, Results: SAT
- **Point 3**: Feet: 3, Inches: 9.400, Feet: 3.78, U: 0.014, S: -0.001, Results: SAT
- **Point 4**: Feet: 3, Inches: 9.600, Feet: 3.80, U: 0.022, S: 0.016, Results: SAT
- **Point 5**: Feet: 3, Inches: 9.400, Feet: 3.78, U: -0.002, S: -0.009, Results: SAT
- **Point 6**: Feet: 3, Inches: 9.400, Feet: 3.78, U: -0.008, S: 0.008, Results: SAT
- **Point 7**: Feet: 3, Inches: 9.200, Feet: 3.77, U: -0.030, S: -0.010, Results: SAT
- **Point 8**: Feet: 3, Inches: 9.200, Feet: 3.77, U: -0.032, S: 0.008, Results: SAT
- **Point 9**: Feet: 3, Inches: 9.000, Feet: 3.75, U: -0.050, S: -0.010, Results: SAT
- **Point 10**: Feet: 3, Inches: 9.000, Feet: 3.75, U: -0.049, S: -0.024, Results: SAT
- **Point 11**: Feet: 3, Inches: 9.000, Feet: 3.75, U: -0.046, S: -0.009, Results: SAT
- **Point 12**: Feet: 3, Inches: 9.200, Feet: 3.77, U: -0.025, S: 0.008, Results: SAT
- **Point 13**: Feet: 3, Inches: 9.200, Feet: 3.77, U: -0.019, S: -0.010, Results: SAT
- **Point 14**: Feet: 3, Inches: 9.400, Feet: 3.78, U: 0.006, S: 0.017, Results: SAT
- **Point 15**: Feet: 3, Inches: 9.200, Feet: 3.77, U: -0.002, S: 0.000, Results: SAT
- **Point 16**: Feet: 3, Inches: 9.000, Feet: 3.75, U: -0.010, S: -0.009, Results: SAT

**Notes:**
Sixteen equally spaced settlement measurements were performed around the outside circumference of the tank at the floor plate that sticks out beyond the shell.
## API-653 STORAGE TANK EVALUATION

### AST Component Inspection Data

<table>
<thead>
<tr>
<th>Report No</th>
<th>Client</th>
<th>Inspector</th>
<th>Vessel</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>HTS-10</td>
<td></td>
<td></td>
<td>#2</td>
<td></td>
</tr>
</tbody>
</table>

### Component Thickness Measurements (in inches)

<table>
<thead>
<tr>
<th>CML</th>
<th>Component</th>
<th>Location</th>
<th>tml-1</th>
<th>tml-2</th>
<th>tml-3</th>
<th>tml-4</th>
<th>tml-5</th>
<th>tml-6</th>
<th>Minimum</th>
</tr>
</thead>
<tbody>
<tr>
<td>001</td>
<td>Shell Crs 1</td>
<td>Pt1</td>
<td>0.342</td>
<td>0.345</td>
<td>0.334</td>
<td>0.336</td>
<td>0.345</td>
<td>0.335</td>
<td>0.334</td>
</tr>
<tr>
<td>002</td>
<td>Shell Crs 1</td>
<td>Pt2</td>
<td>0.340</td>
<td>0.328</td>
<td>0.350</td>
<td>0.357</td>
<td>0.333</td>
<td>0.371</td>
<td>0.328</td>
</tr>
<tr>
<td>003</td>
<td>Shell Crs 1</td>
<td>Pt3</td>
<td>0.323</td>
<td>0.337</td>
<td>0.325</td>
<td>0.316</td>
<td>0.323</td>
<td>0.332</td>
<td>0.316</td>
</tr>
<tr>
<td>004</td>
<td>Shell Crs 1</td>
<td>Pt4</td>
<td>0.327</td>
<td>0.364</td>
<td>0.355</td>
<td>0.361</td>
<td>0.325</td>
<td>0.366</td>
<td>0.325</td>
</tr>
<tr>
<td>005</td>
<td>Shell Crs 1</td>
<td>Pt5</td>
<td>0.334</td>
<td>0.348</td>
<td>0.344</td>
<td>0.363</td>
<td>0.340</td>
<td>0.373</td>
<td>0.334</td>
</tr>
<tr>
<td>006</td>
<td>Shell Crs 1</td>
<td>Pt6</td>
<td>0.352</td>
<td>0.355</td>
<td>0.358</td>
<td>0.359</td>
<td>0.350</td>
<td>0.347</td>
<td>0.347</td>
</tr>
<tr>
<td>007</td>
<td>Shell Crs 2</td>
<td>Pt1</td>
<td>0.221</td>
<td>0.282</td>
<td>0.247</td>
<td>0.218</td>
<td>0.226</td>
<td>0.243</td>
<td>0.218</td>
</tr>
<tr>
<td>008</td>
<td>Shell Crs 2</td>
<td>Pt2</td>
<td>0.224</td>
<td>0.231</td>
<td>0.226</td>
<td>0.229</td>
<td>0.222</td>
<td>0.256</td>
<td>0.222</td>
</tr>
<tr>
<td>009</td>
<td>Shell Crs 2</td>
<td>Pt3</td>
<td>0.219</td>
<td>0.224</td>
<td>0.229</td>
<td>0.220</td>
<td>0.218</td>
<td>0.270</td>
<td>0.218</td>
</tr>
<tr>
<td>010</td>
<td>Shell Crs 2</td>
<td>Pt4</td>
<td>0.213</td>
<td>0.233</td>
<td>0.209</td>
<td>0.252</td>
<td>0.207</td>
<td>0.252</td>
<td>0.207</td>
</tr>
<tr>
<td>011</td>
<td>Shell Crs 2</td>
<td>Pt5</td>
<td>0.214</td>
<td>0.266</td>
<td>0.248</td>
<td>0.226</td>
<td>0.227</td>
<td>0.250</td>
<td>0.214</td>
</tr>
<tr>
<td>012</td>
<td>Shell Crs 2</td>
<td>Pt6</td>
<td>0.251</td>
<td>0.233</td>
<td>0.223</td>
<td>0.253</td>
<td>0.223</td>
<td>0.273</td>
<td>0.223</td>
</tr>
<tr>
<td>013</td>
<td>Shell Crs 3</td>
<td>Pt1 N.</td>
<td>0.212</td>
<td>0.204</td>
<td>0.195</td>
<td></td>
<td></td>
<td></td>
<td>0.195</td>
</tr>
<tr>
<td>014</td>
<td>Shell Crs 3</td>
<td>Pt2 S.</td>
<td>0.210</td>
<td>0.205</td>
<td>0.204</td>
<td></td>
<td></td>
<td></td>
<td>0.204</td>
</tr>
<tr>
<td>015</td>
<td>Shell Crs 3</td>
<td>Pt3 E.</td>
<td>0.189</td>
<td>0.185</td>
<td>0.183</td>
<td></td>
<td></td>
<td></td>
<td>0.183</td>
</tr>
<tr>
<td>016</td>
<td>Shell Crs 3</td>
<td>Pt4 W.</td>
<td>0.211</td>
<td>0.204</td>
<td>0.207</td>
<td></td>
<td></td>
<td></td>
<td>0.204</td>
</tr>
<tr>
<td>017</td>
<td>Shell Crs 4</td>
<td>Pt1 N.</td>
<td>0.196</td>
<td>0.217</td>
<td>0.194</td>
<td></td>
<td></td>
<td></td>
<td>0.194</td>
</tr>
<tr>
<td>018</td>
<td>Shell Crs 3</td>
<td>Pt2 S.</td>
<td>0.203</td>
<td>0.200</td>
<td>0.212</td>
<td></td>
<td></td>
<td></td>
<td>0.200</td>
</tr>
<tr>
<td>019</td>
<td>Shell Crs 4</td>
<td>Pt3 E.</td>
<td>0.189</td>
<td>0.190</td>
<td>0.195</td>
<td></td>
<td></td>
<td></td>
<td>0.195</td>
</tr>
<tr>
<td>020</td>
<td>Shell Crs 4</td>
<td>Pt4 W.</td>
<td>0.189</td>
<td>0.183</td>
<td>0.187</td>
<td></td>
<td></td>
<td></td>
<td>0.183</td>
</tr>
<tr>
<td>021</td>
<td>Roof</td>
<td>Pt1</td>
<td>0.213</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.213</td>
</tr>
<tr>
<td>022</td>
<td>Roof</td>
<td>Pt2</td>
<td>0.185</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.185</td>
</tr>
<tr>
<td>023</td>
<td>Roof</td>
<td>Pt3</td>
<td>0.186</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.186</td>
</tr>
</tbody>
</table>
TANK INSPECTIONS ARE NOT ALWAYS A BAD THING

THIS IS A HAPPY TANK
TANK MAINTENANCE – COMMON SENSE APPROACH

• Conduct monthly/weekly walk-around of your tank(s)
  • Look for stains on steel where leak may be occurring
  • Check valve function and nozzle welds
  • Check associated piping
  • Check foundation for wash-out/deterioration
• Keep good records of product in and out
TANK MAINTENANCE – COMMON SENSE APPROACH

• Open up your tank a minimum of every two years and conduct your own visual inspection inside
  • Check for weld deterioration and corrosion
  • If tank is coated, visually check coating for blisters or cracks
• Keep a record of inspections and results
• If tank has an internal containment liner, check leak monitor weekly
• Conduct an API-653 inspection of your tank every five years as recommended by TFI (The Fertilizer Institute)
Salting out of liquid fertilizer in lined tank
WHAT IS THE API 650 SPECIFICATION

**API - AMERICAN PETROLEUM INSTITUTE**
Worldwide Standard for Above Ground Storage Tank Design and Construction

- Provides requirements for calculations of shell plate thickness, man-way and nozzle design
- Provides procedures for shell, roof and floor construction
- Specifies material requirements and minimum thickness requirements
- Specifies weld construction requirements, weld spacing, and x-ray requirements
CAUSES OF CATASTROPHIC TANK FAILURE
TANK FAILURES – COMMON CAUSES

• #1 Cause: Corrosion
  ➢ Weld deterioration/corrosion – especially in lower horizontal and vertical seams

• #2 Cause – Lack of Weld Penetration
  ➢ Lack of full weld penetrations (lack of weld fusion)
  ➢ Improper weld seam spacing
  ➢ Lack of radiograph (x-ray) of newly constructed tanks or on repaired tanks
TANK FAILURES – COMMON CAUSES

• # 3 Other Causes
  ➢ Operational errors
    ▪ Over-filling of tank – excessive pressure
  ➢ Brittle fracture of steel
  ➢ Poorly designed or inappropriately installed
  ➢ Lack of proper certified inspection
  ➢ Tank erectors who know little about API Specifications and procedures – these companies attract customers with a “cheap” price. Make certain your contractor can verify that your tank meets API Specifications. **DO YOUR OWN HOMEWORK**
Cut-down and re-welded tank

Improper weld spacing
Double wall 500,000 gallon tank, Illinois 2008
Site Gauge after Earthquake.avi