A New Risk Based Inspection (RBI) Method for Aboveground Storage Tanks (ASTs) to Determine Internal Inspection Intervals for Inspection of AST Tank Bottoms

Joe Maresca, Steve Ford, and Doug Mann

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Houston, Texas
September 17, 2013
**RBI^3** is a New Patent Pending RBI Method to Determine Internal Inspection Intervals for Inspection of Tank Bottoms

- In compliance with the requirements in API 653 & 580/581
- Uses a novel In-service Inspection approach
- Based on *Equivalent Risk* using Bayesian analysis of the life expectancy distribution of the tank being inspected
  - Tank life expectancy model is similar to what the life insurance industry uses for the life expectancy of people
- Use actual measurements of the tank bottom to estimate floor thickness, corrosion rate, and floor integrity
  - Does not require a control tank
- Does not require a previous Out-of-Service API 653 Internal Inspection
Uses of RBI³

Reliably Addresses four API 653 internal inspection applications

(1) Initial Inspection Interval

(2) Subsequent Inspection Interval

(3) 10-year Re-assessment for RBI methods (both Initial and Subsequent)

(4) Evaluating and Updating the Inspection Interval at the time of a scheduled API 653 internal inspection

- Significant cost savings with a large ROI
- Minimizes pollution
Acknowledgement

We want to especially acknowledge Phil Myers for his technical and statistical consulting input in the development of the RBI method presented in this paper for Evaluating and Updating the Internal Inspection Interval at the Time of a Scheduled API 653 Internal Inspection based on the RBI inspection methods in API 653 and API 580/581.

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Motivation for Evaluating and Updating the Internal Inspection Interval of an AST

Vista Clients

• Excellent condition of most tanks at the time of a scheduled internal inspection

Acoustic Emission Studies by Loo and others in the 1990s

• 148 ASTs ready for an Internal Inspection were tested for corrosion and then taken out of service for an internal inspection
  – 115 Product ASTs and 33 Crude ASTs

• 64.2% of the tanks did not require any maintenance or repair
• Only 14.2% of the tanks needed maintenance and repair
• 85.8% of the tanks were in sufficiently good shape that an internal inspection would not be required at that time
ASTs Require API 653 Internal Inspections at Intervals between 10 and up to 30 Years for Initial and Subsequent Internal Inspection Intervals

Mainly Depends on the Thickness and Corrosion Rate of the Tank Floor and Whether or Not a Release Prevention Barrier is Used

1 STI SP001 and API 12R1

RBI Can be Used
Implementation of RBI^3

- **Uses accepted Bayesian Life Expectancy Models similar to the life insurance industry, but implements them differently and more directly using Equivalent Risk**
  - The same reliability approach used in the medical and manufacturing industries, but with a different twist

- **Uses actual measurements of the tank floor to determine (1) thickness, (2) corrosion rate, and (3) integrity of the tank being evaluated**
  - Uses a novel in-service measurement approach
  - Does not require but can use previous API 653 internal inspections
Implementation of RBI$^3$ (cont.)

- Uses a detailed **10 step method** to determine the life expectancy and survival probabilities for the tank being assessed
- Inspection intervals are based on the survival probabilities **GIVEN** the age of the tank (i.e., the tank has already survived to that age)
  - **Key Question:** Is the tank dead or alive at the time of the scheduled inspection
- **Equivalent Risk:** The risk or probability of survival of the tank is the same in the future as it is at the time of the scheduled inspection
  - Requires additional information about the condition of the tank
Basis for Internal Inspection Intervals
Bayesian Approach (Conditional Probabilities)

Probability Distribution of Life Expectancy at Birth
## Basis for Internal Inspection Intervals

**Bayesian Approach (Conditional Probabilities)**

<table>
<thead>
<tr>
<th>Life Expectancy</th>
<th>All</th>
<th>Men</th>
<th>Women</th>
</tr>
</thead>
<tbody>
<tr>
<td>At Birth</td>
<td>78.7</td>
<td>76.2</td>
<td>81.0</td>
</tr>
<tr>
<td>At Age 65</td>
<td>84.1</td>
<td>82.7</td>
<td>85.3</td>
</tr>
<tr>
<td>At Age 75</td>
<td>87.1</td>
<td>86.0</td>
<td>87.9</td>
</tr>
</tbody>
</table>

*The longer you live, the better chance you have of living longer*
Life Expectancy of a Person or an AST can be Reliably Modeled

Failure Probability

Tank Age - years

Person Age - years
A Corrosion Rate Probability Distribution is Used to Develop an AST Life Expectancy Distribution

Based on 18 Years of Corrosion Data at 47 Sites Representative of the US
Life Expectancy of an AST
Corrosion Rate of ~ 6 mpy or **Corrosion Rate of ~ 4 mpy**

![Graph showing failure probability over tank age](image)
Tank Age Failure CFD

Mean = 24.0 yrs; StDev = 3.7 yrs

Cum Failure Probability vs Tank Age - years

Tank Failure Age = 25.0
Tank Age Survival CFD
Mean = 24.0 yrs; StDev = 3.7 yrs
Updated Time Interval at 28 Years based on Equivalent Risk

For a Survival Distribution with a mean = 24.0 years and a StDev = 3.7 years

Survival Probability Distribution GIVEn the tank has survived to 28 yrs

UTI = 3.6 years

Underlying Survival Probability Distribution for All Tanks with Similar Corrosion

Cum Survival Probability

Tank Age - years

Survival Prob Given Actual Tank Age: $P(SB/SA)$

Survival Probability: $1 - F(A) = R(A)$

Person Age - years
Method Implementation Depends on the Age Category of the Tank

Mean = 24.0 yrs; StDev = 3.7 yrs

Key Question: Is the tank dead or alive at the time of the scheduled inspection
RBI³ Measurement Suite
Uses a Detailed, 10-Step, Flow-Chart Methodology with Statistical Computations Done in a Special Worksheet

• Measurements

(0) **External Inspection** following API 653

(1) **PASS** a third-party approved Leak Detection Precision Integrity Test to determine if the tank is dead or alive

(2) **Local** measurement of floor thickness and corrosion rate with a UT sensor or equivalent
   – Used to determine the Survival Distribution of the tank
   – Can be used to determine the corrosion rate if spatial measurements are available

(3) **Spatial** estimates of floor thickness and corrosion rate will result in the most accurate inspection intervals
   – Current AE Corrosion Activity Test, **and/or**
   – Previous API 653 Internal Inspection of the entire floor thickness

• Other spatial measurement methods and bottom thickness measurements can be used
AE Tank Test Results* (148 ASTs)

<table>
<thead>
<tr>
<th>AE Test Results</th>
<th>Maintenance and Repair</th>
</tr>
</thead>
<tbody>
<tr>
<td>A: Very minor</td>
<td>No maintenance necessary (30.5% of the ASTs tested)</td>
</tr>
<tr>
<td>B: Minor</td>
<td>No maintenance necessary (27.5%)</td>
</tr>
<tr>
<td>C: Intermediate</td>
<td>Some maintenance is needed (25%)</td>
</tr>
<tr>
<td>D: Active</td>
<td>Give priority in maintenance schedule (7.5%)</td>
</tr>
<tr>
<td>E: Highly active</td>
<td>Give highest priority in maintenance schedule (9.5%)</td>
</tr>
</tbody>
</table>

Out-of-Service Internal Inspection Results

- FU1: No damage/No repair (100% of A)
- FU2: Minor damage/No repair (76% of B, 39% of C, 20% of D&E)
- FU3: Damage/Some repair (B, C, D, E)
- FU4: Damage/Major repair/New floor (B, C, D, E)

General Conclusion: The AE Corrosion Activity Test is highly accurate and reliable when indicating NO corrosion activity (i.e., Category A by itself and Category B with additional information)

*Loo (1999)
Summary

- The RBI$^3$ is a new risk-based inspection tool for reliably determining the internal inspection intervals in API 653.

- RBI$^3$ is particularly useful for establishing the internal inspection interval for:
  1. Initial and Subsequent Inspection Intervals
  2. 10-year assessment for Initial and Subsequent RBI methods
  3. Evaluating and updating the Internal Inspection Interval at the time of a scheduled API 653 internal inspection

- The RBI$^3$ method uses (1) well accepted in-tank measurements used by Oil & Gas industry and (2) the life expectancy procedures used by the life insurance industry and others.
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