A New Risk Based Inspection (RBI) Method for Aboveground Storage Tanks (ASTs)

to Determine Internal Inspection Intervals for Inspection of AST Tank Bottoms

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Houston, Texas

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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 RBI^3

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

Implementation of RBI^3

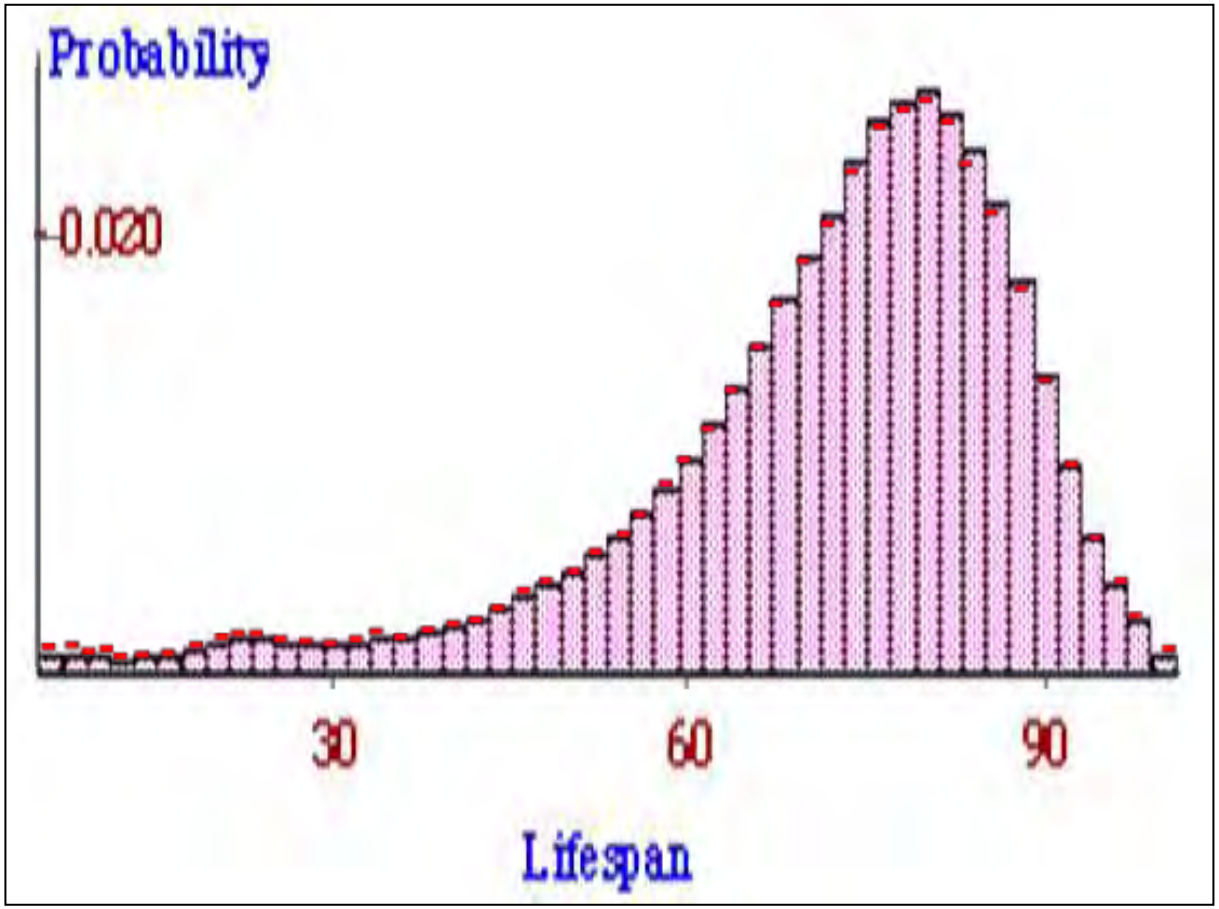
- **Uses accepted Bayesian Life Expectancy Models similar to the life insurance industry, but implements them differently and more directly using Equivalent Risk**
  - The same reliability approach used in the medical and manufacturing industries, but with a different twist
- **Uses actual measurements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

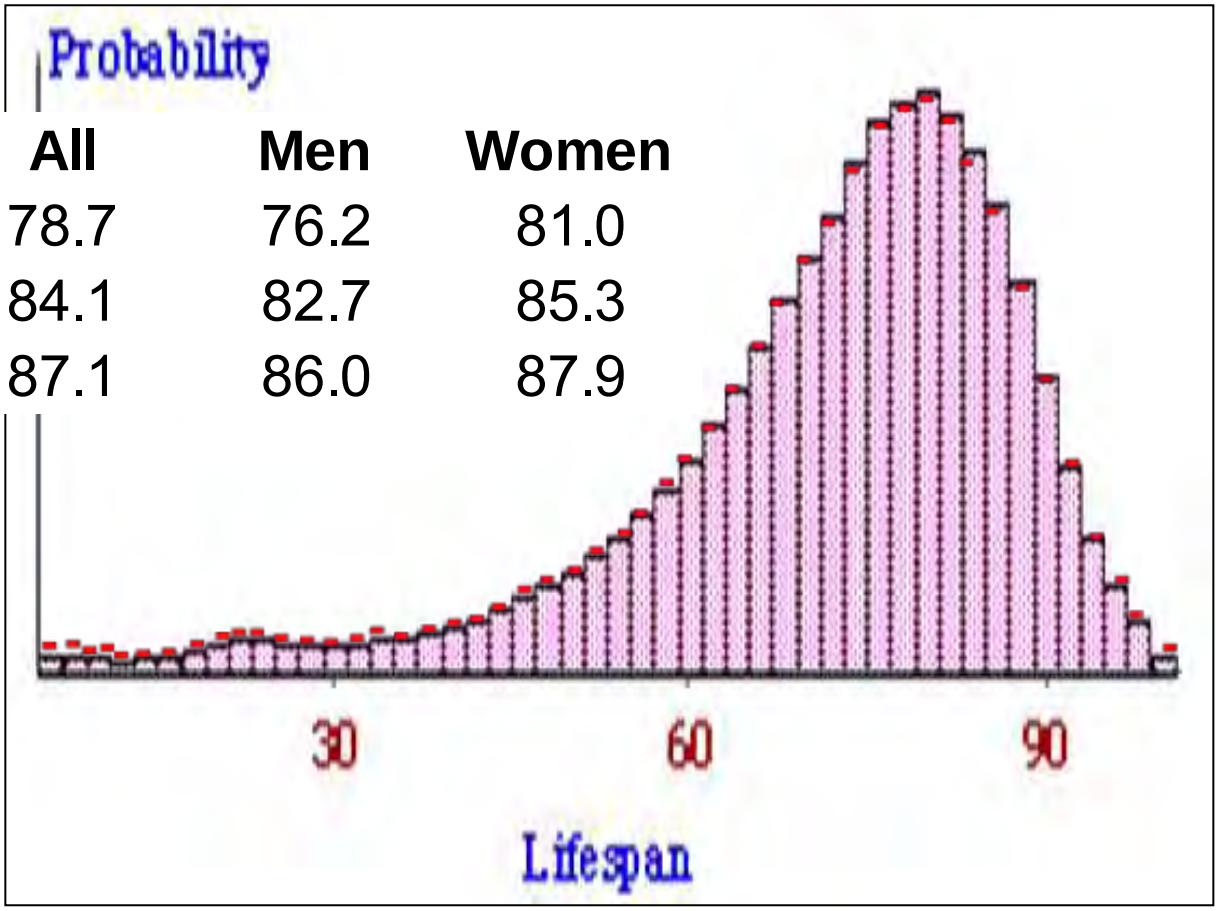


Probability Distribution of Life Expectancy at Birth

Basis for Internal Inspection Intervals

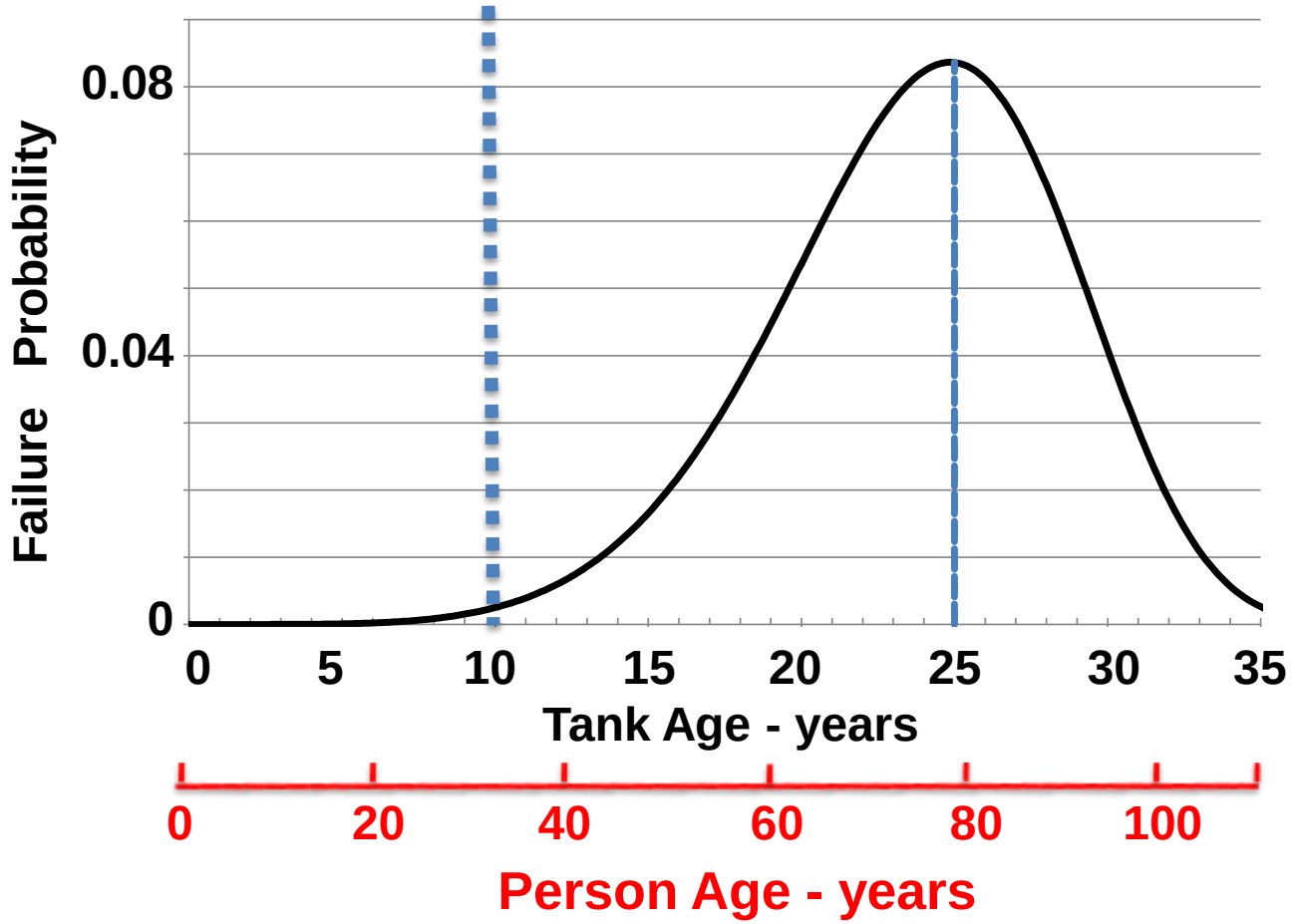
Bayesian Approach (Conditional Probabilities)

Life Expectancy	All	Men	Women
At Birth	78.7	76.2	81.0
At Age 65	84.1	82.7	85.3
At Age 75	87.1	86.0	87.9



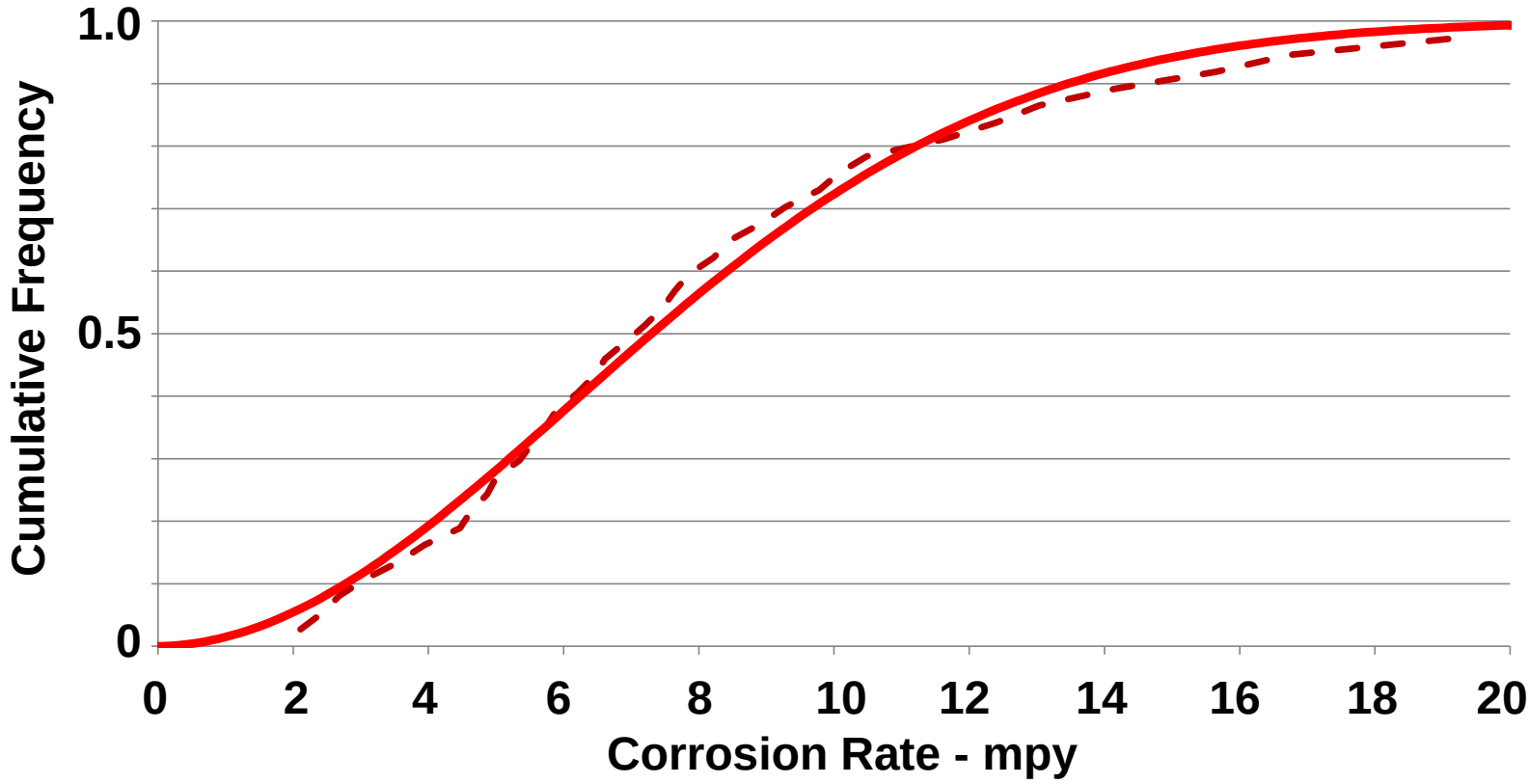
The longer you live, the better chance you have of living longer

Life Expectancy of a Person or an AST can be Reliably Modeled



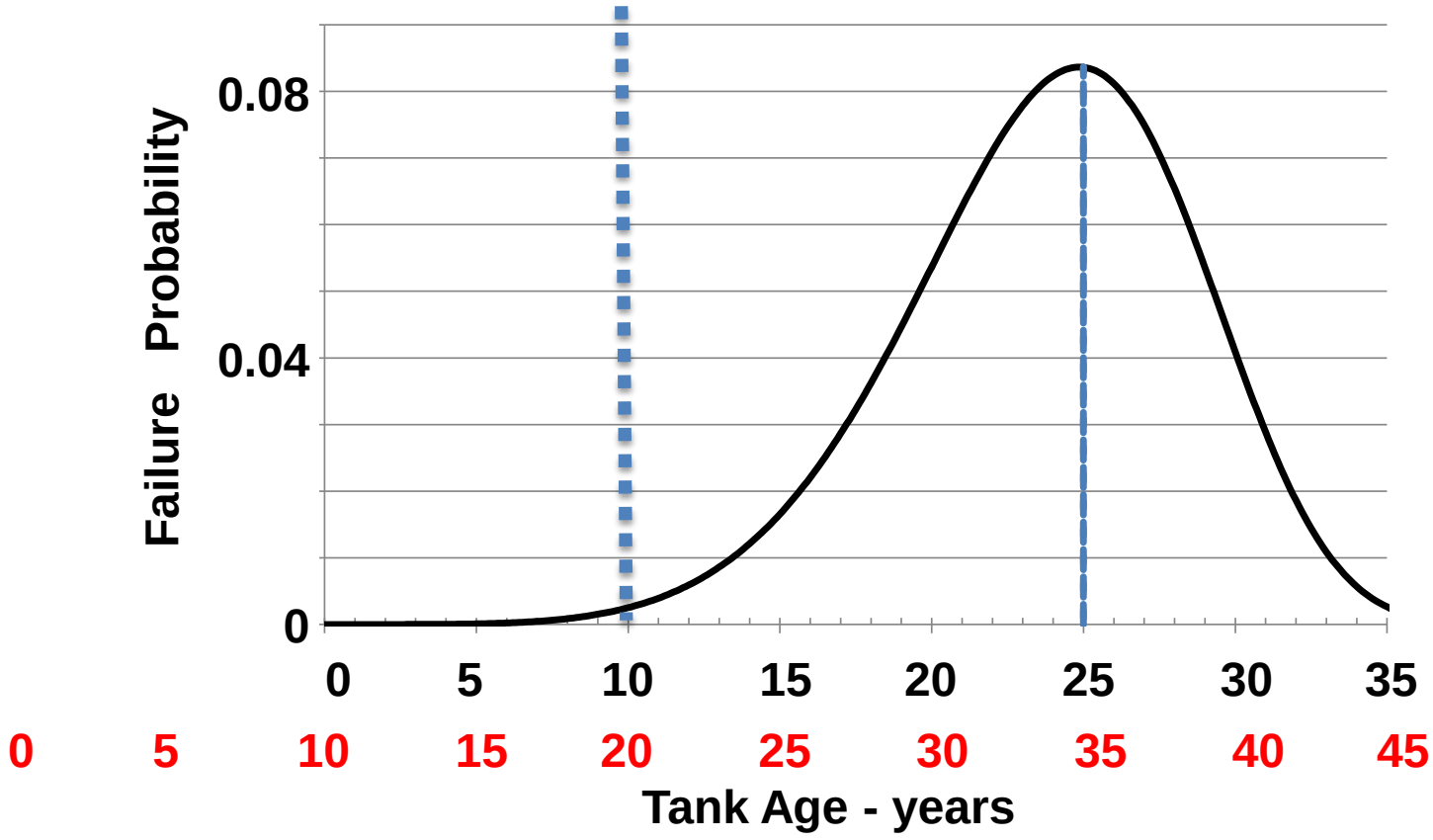
A Corrosion Rate Probability Distribution is Used to Develop an AST Life Expectancy Distribution

Based on 18 Years of Corrosion Data at 47 Sites Representative of the US



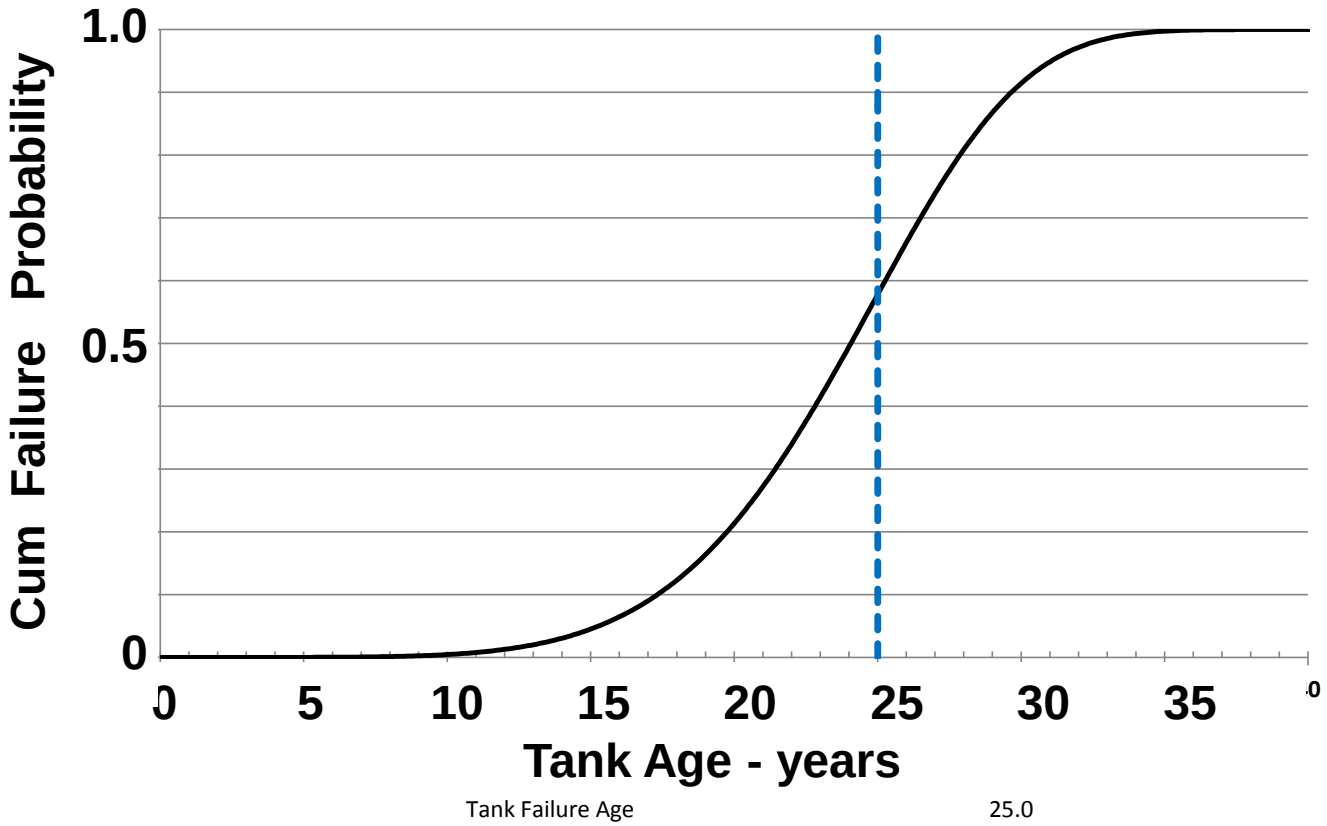
Life Expectancy of an AST

Corrosion Rate of ~ 6mpy or Corrosion Rate of ~ 4 mpy



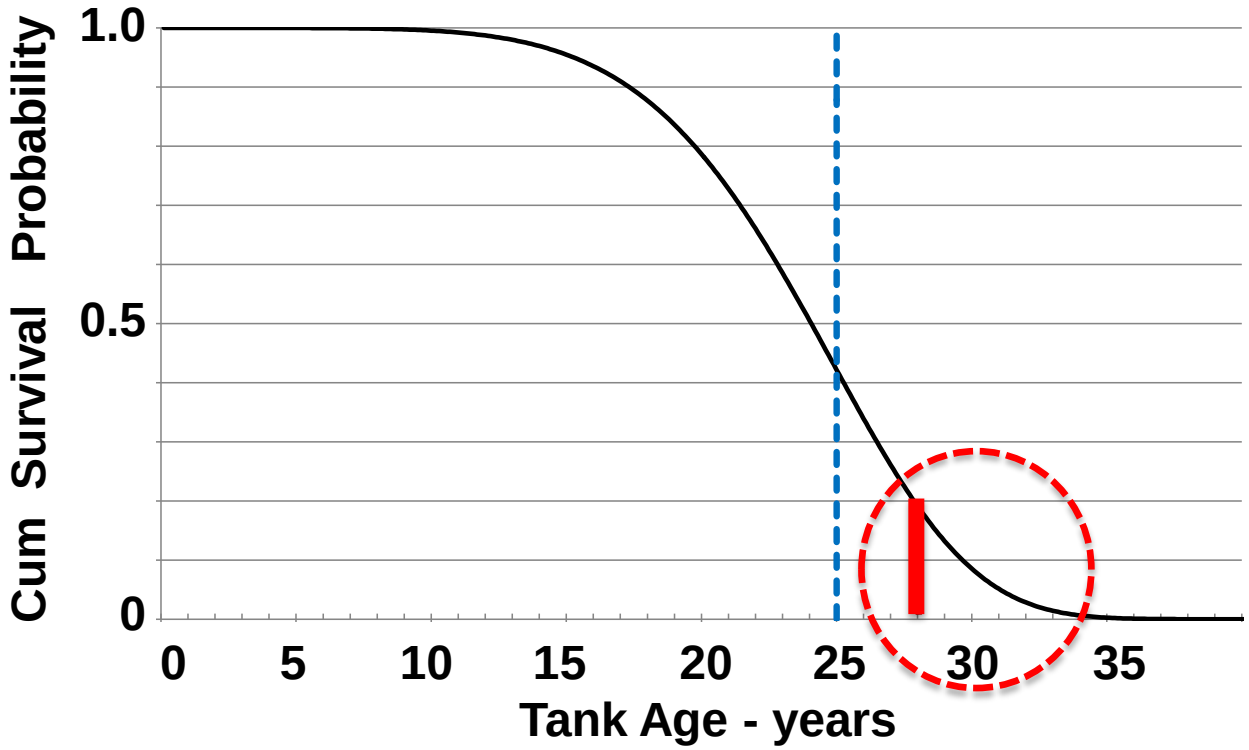
Tank Age Failure CFD

Mean = 24.0 yrs; StDev = 3.7 yrs



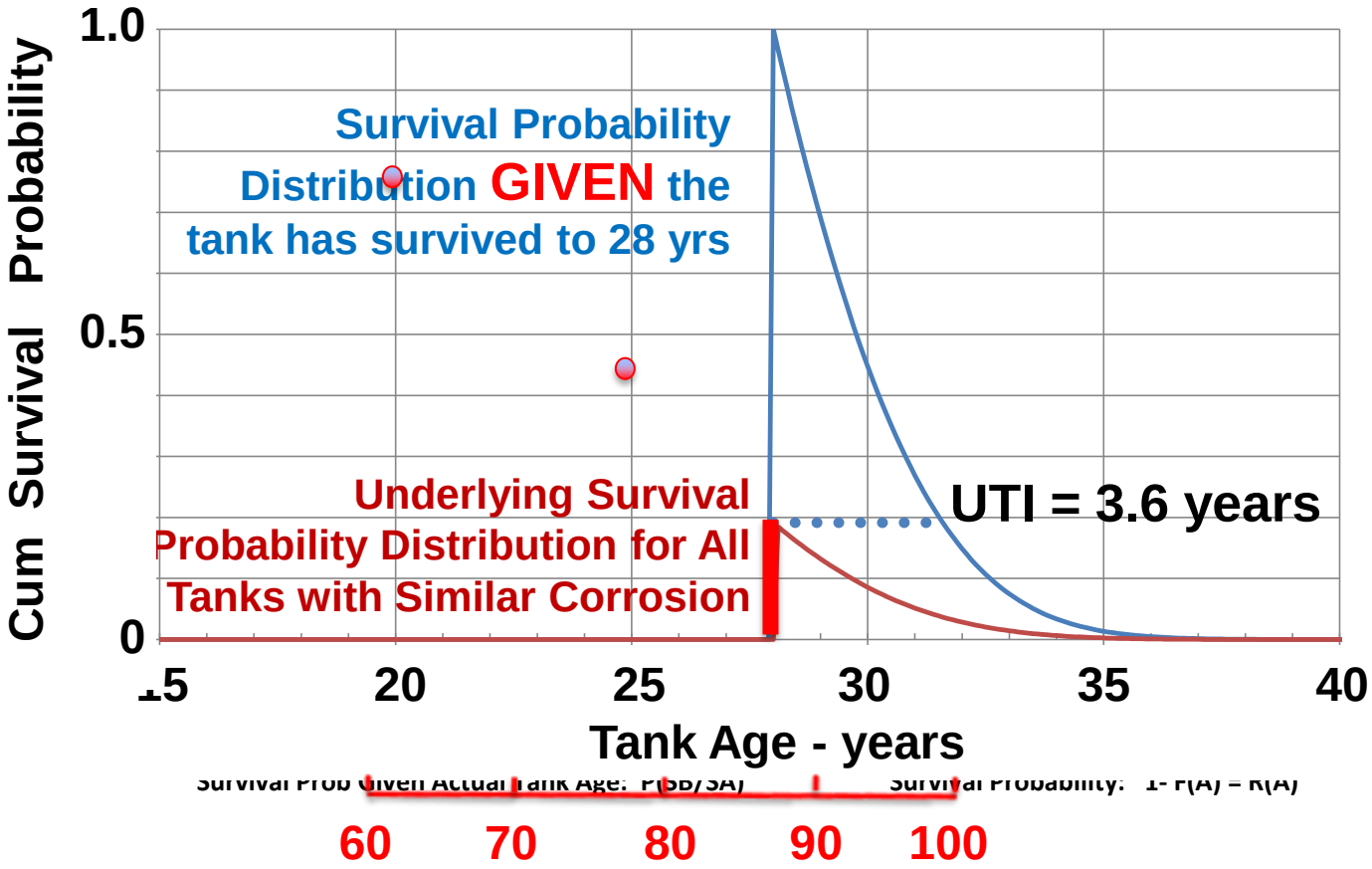
Tank Age Survival CFD

Mean = 24.0 yrs; StDev = 3.7 yrs



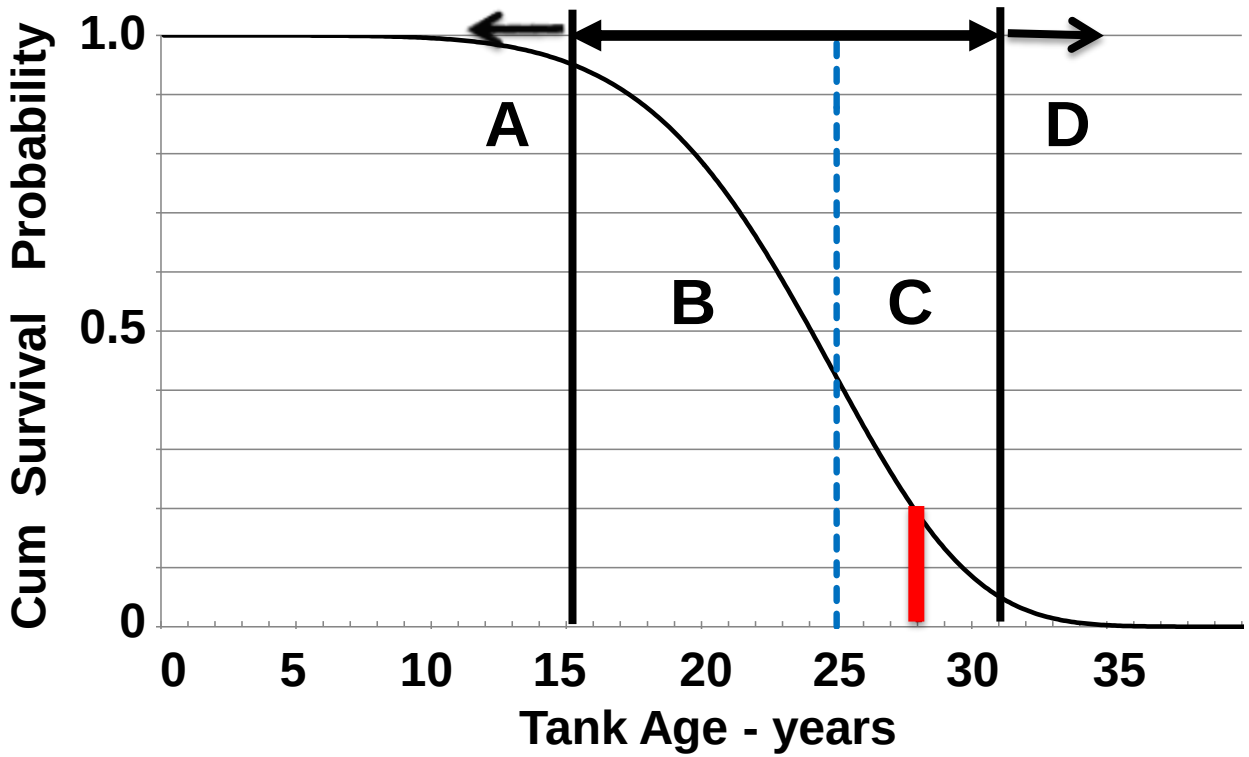
Updated Time Interval at 28 Years based on Equivalent Risk

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



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**

RBI^3 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)

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

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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