RBI Integration with Inspection Programs

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energy API

ASSET INTEGRITY THROUGH CORROSION MANAGEMENT, INSPECTION AND ENGINEERING TECHNOLOGY

Outline

- Introduction to an API RP 581 Risk Assessment Example
- Probability of Failure and Risk with Inspection recommendations using Inspection Effectiveness
- Conventional NDT/Inspection used with RBI assessments
- NDT/Inspection use and assumptions
  - Manual Ultrasonic Thickness
  - Automated Ultrasonic (AUT) for general/local thinning
  - Use of Ultrasonic techniques for flaw sizing
- Using Inspection Results and Updating RBI

Table 4.1 – Basic Component Data Required for Analysis

Basic Data	Comments
Start Date	The date the component was placed in service.
Thickness, mm [in]	The actual measured thickness of the component measured at the component start date or the minimum construction thickness.
Corrosion Allowance, mm [in]	The corrosion allowance is the specified design or actual corrosion allowance upon being placed in the current service.
Design Temperature, °C [°F]	The design temperature, shell side and tube side for a heat exchanger.
Design Pressure, MPa [psi]	The design pressure, shell side and tube side for a heat exchanger.
Operating Temperature, °C [°F]	The highest operating temperature expected during operation including normal and unusual operating conditions, shell side and tube side for a heat exchanger.
Operating Pressure, MPa [psi]	The highest operating pressure expected during operation including normal and unusual operating conditions, shell side and tube side for a heat exchanger.
Design Code	The design code of the component containing the component.
Equipment Type	The type of Equipment
Component Type	The type of Component, see Table 4.2
Component Geometry Data	Component geometry data depending on the type of component (see Table 4.3)
Material Specification	The specification of the material of construction, the ASME SA or SB specification for pressure vessel components or of ASTM specification for piping and tankage components. Data entry is based on material specification, grade, year, UNS Number, class/condition/temper/ size/thickness; this data is readily available in the ASME Code [12].
Weld Joint Efficiency	Weld joint efficiency per the Code of construction,
Heat Tracing	Is the component heat traced? (Yes or No)

Drum Component Analysis

Design

Component Type	DRUM
Geometry Type	Cylinder
Component Start Date	1/1/2003
Specified Minimum Required Thickness, inch	0.3750
Minimum Required Thickness, inch	0.3850
Structural Minimum Thickness, inch	0.10
Weld Joint Efficiency	1.00
Insulation	None
PWHT	Yes

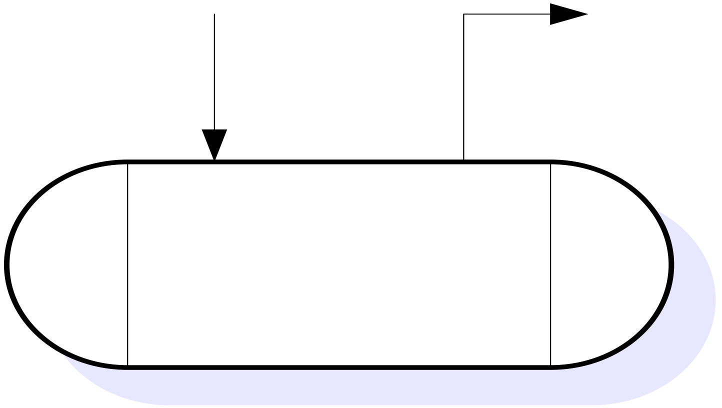
Material of Construction

Furnished Thickness, inch	0.51
Corrosion Allowance, inch	0.125
Material of Construction	A516 Gr. 70
Material Type	Carbon Steel
Allowable Stress, psi	15,000
Tensile Strength, psi	60,000
Yield Strength, psi	35,000

Drum Component Analysis

Operating Data

Operating Temperature, F	120.00
Operating Pressure, psig	187.50
Storage Product	C6-C8
Storage Phase	Liquid
Toxic Model	H2S
Toxic, %	0.11%



Thinning Damage Factor

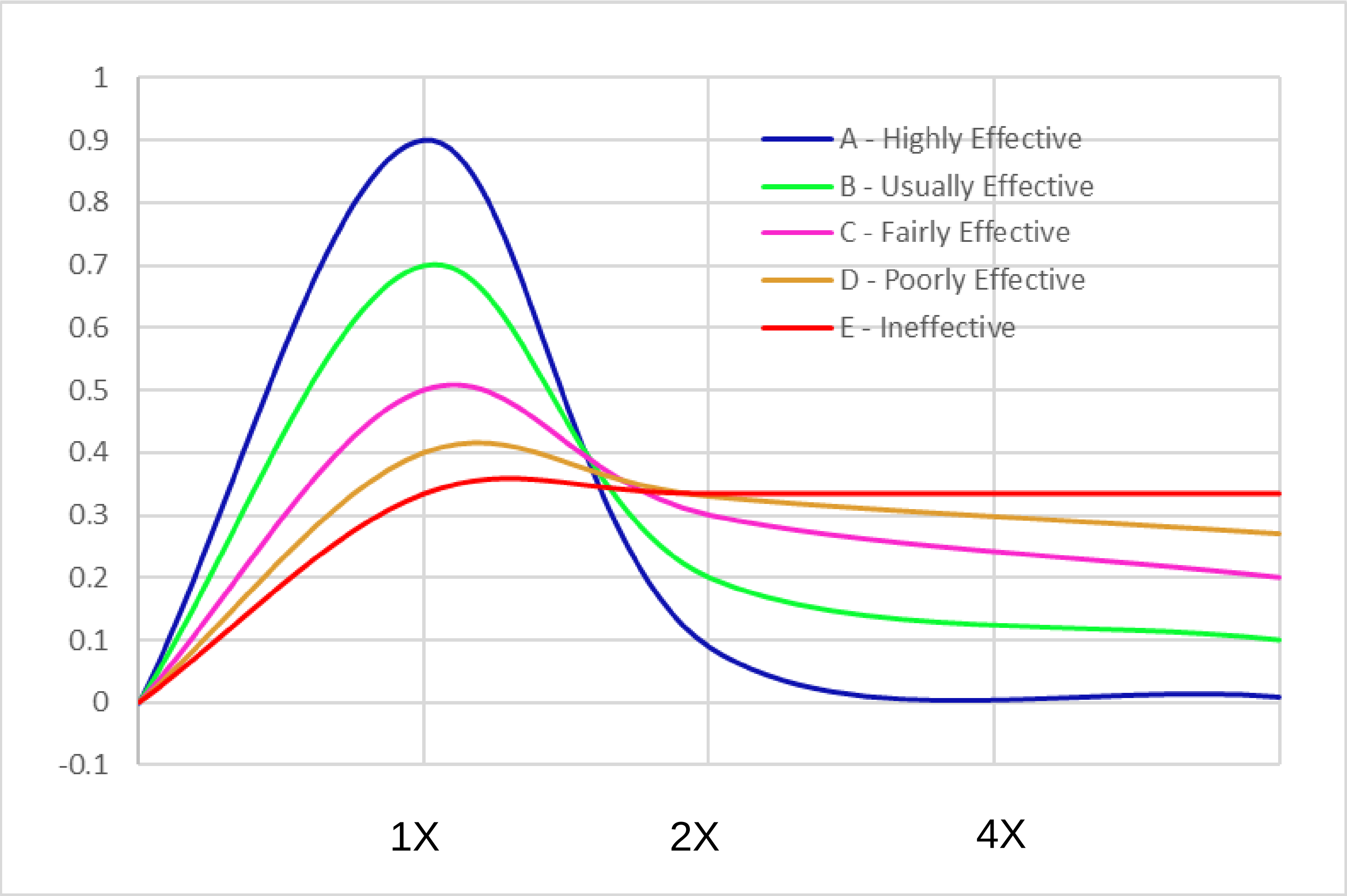
- Thickness: furnished thickness or measured thickness at any point of time as a result of an inspection
- Age: consistent with the thickness (furnished or measured)
- Inspection History: Inspection credit for inspection conducted during the assessment period
- Corrosion Rate: An average high estimated thinning long term rate based on operating conditions and material of construction (estimated or measured)
- Thinning Type: Localized or Generalized appearance of the corrosion mechanism in the component

Thinning Damage Factor

- Inspection Effectiveness
  - Inspections are graded based on the effectiveness for detecting thinning and assessing the corrosion rate
  - Inspection locations selected should be based an understanding of the damage mechanism, particularly for localized thinning
  - Probabilities for each effectiveness category are used with 3 damage states and Bayes Theorem
  - Inspection history and on-line monitoring affects the probability of higher corrosion rates
  - Increased inspection coverage, number of inspections and on-line monitoring decreases the probability of higher corrosion rates

Damage State Category	Thinning Rate
Damage State 1 The damage in the equipment is "no" worse than what is expected based on damage rate models or experience.	The rate of thinning is less than or equal to the rate predicted by past inspection records, or historical data if no inspections have been performed.
Damage State 2 The damage in the equipment is "somewhat" worse than anticipated. This level of damage is sometimes seen in similar equipment items.	The rate of thinning is as much as twice the predicted rate.
Damage State 3 The damage in the equipment is "considerably" worse than anticipated. This level of damage is rarely seen in similar equipment items, but has been observed on occasion industry wide.	The rate of thinning is as much as four times the predicted rate.

Inspection Confidence



Drum Component Analysis

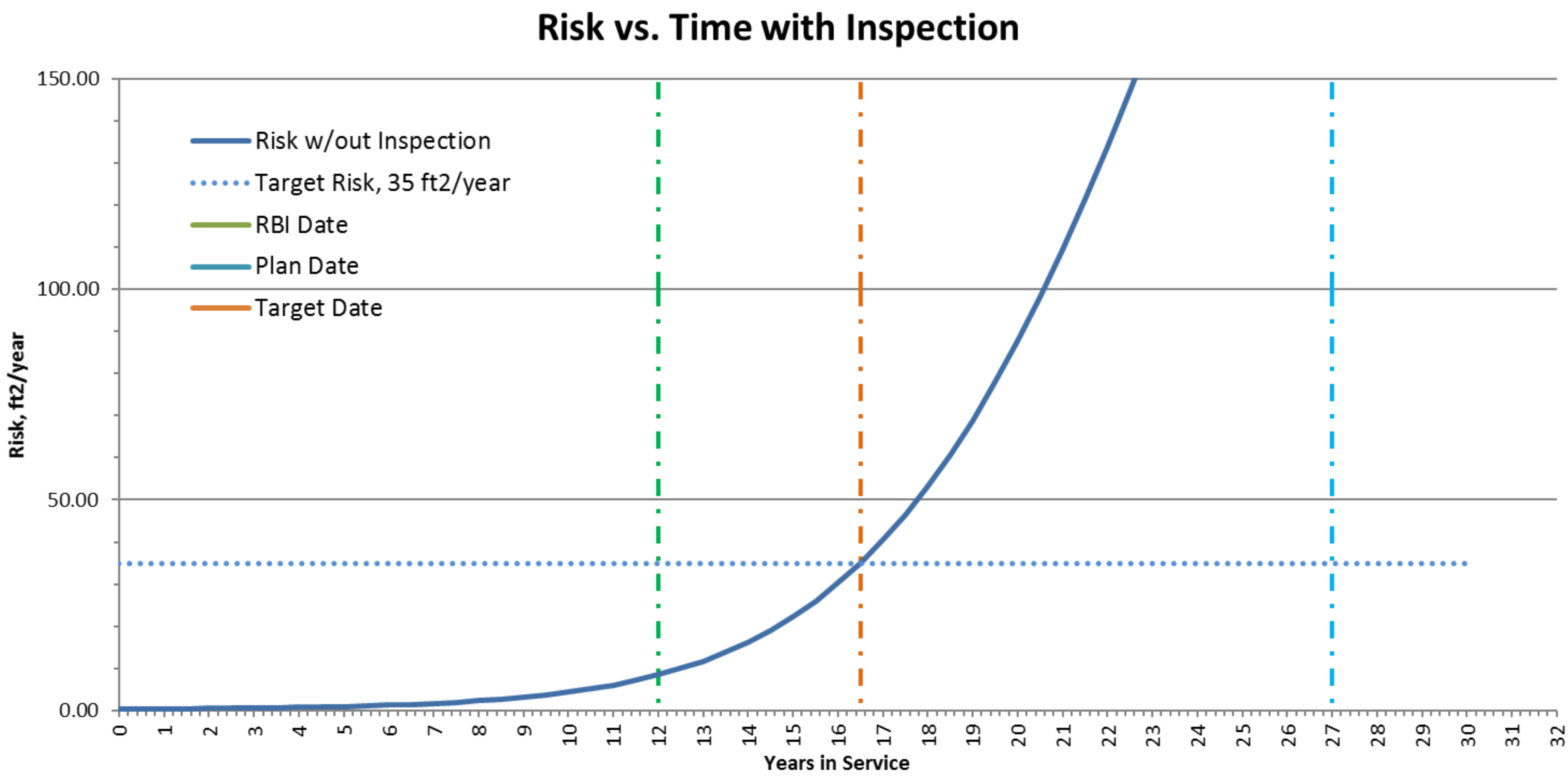
Base Material

Corrosion Rate Data	
Estimated, mpy	1
Measured, mpy	2.5
Calculated (Base Rate), mpy	2
Thinning Type	Localized
Corrosion Rate Basis	Measured
Data Reliability	Low Reliability Data

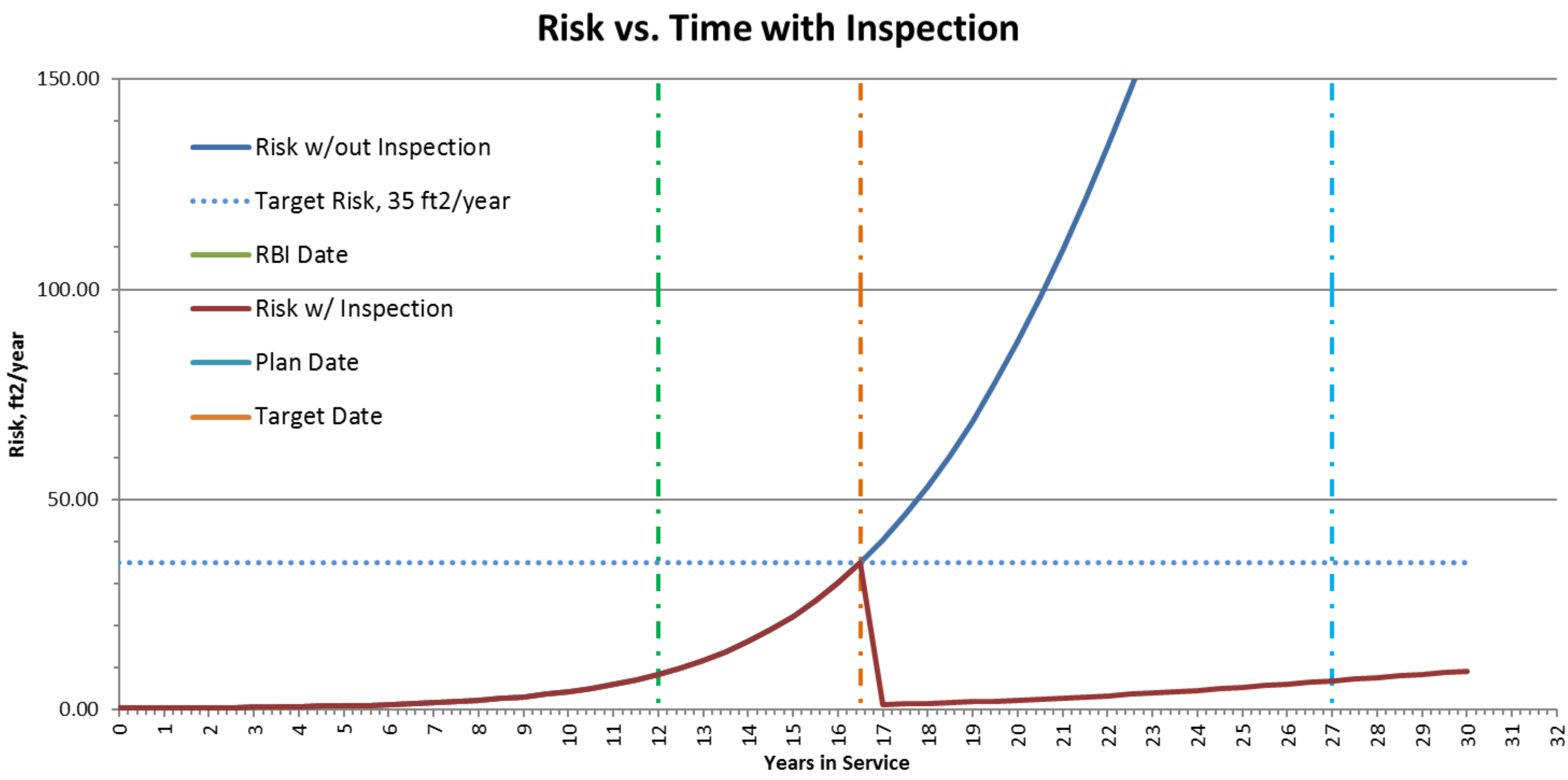
Inspection History

Last Inspection Date	1/1/2003
Risk-Based Last Inspection Date	1/1/2003
Risk-Based Thickness, inch	0.510
Number of A Thinning Inspections	0
Number of B Thinning Inspections	0
Number of C Thinning Inspections	0
Number of D Thinning Inspections	0

Risk Plot without Inspection



Risk Plot with A Inspection



Inspection Effectiveness

Table 2.C.8.2 – LoIE Example for Local Thinning

Inspection Category	Inspection Effectiveness Category	Intrusive Inspection Example	Non-intrusive Inspection Example
A	Highly Effective	For the total surface area: 100% visual examination (with removal of internal packing, trays, etc.) **AND** 100% follow-up at locally thinned areas	For the total suspect area: 100% coverage of the CML's using ultrasonic scanning or profile radiography
B	Usually Effective	For the total surface area: >75 % visual examination **AND** 100% follow-up at locally thinned areas	For the total suspect area: >75% coverage of the CML's using ultrasonic scanning or profile radiography
C	Fairly Effective	For the total surface area: >50% visual examination **AND** 100% follow-up at locally thinned areas.	For the total suspect area: >50% coverage of the CML's using ultrasonic scanning or profile radiography
D	Poorly Effective	For the total surface area: >20% visual examination **AND** 100% follow-up at locally thinned areas	For the total suspect area: >20% coverage of the CML's using ultrasonic scanning or profile radiography

Inspection Effectiveness

Note:

1. Inspection quality is high.
2. Percentage coverage in non-intrusive inspection includes welds.
3. Follow-up inspection can be UT, pit gauge or suitable NDE techniques that can verify minimum wall thickness.
4. Profile radiography technique is sufficient to detect wall loss at all planes.

Detailed Inspection Plan Development

RBI General Inspection Plan of "Example Drum"	
Factors Considered	NDT Methods Employed/Comments on Inspection
a. "A" Level Inspection Needed b. Intrusive Inspection performed, with several areas of localized thinning on the drum cylinder c. All areas are in base metal, not on weldments d. Previous history, was "low reliability data", RBI would like high quality e. Material, temperature, and thickness of drum leads to optimal inspection	• Automated UT Thickness Survey • UT Scan plan developed by NDT Level III, with factors considered, approved by RBI Consultant • Cleaning and preparation of scan areas, critical and steps are laid out. • Areas scanned shall overlap, noted local thinning by a factor of 4x, to ensure coverage and comparison to adjacent wall • High resolution scans, with low scan speed for maximum data accuracy. • Data to be reviewed/approved by NDT level III • Data presentation to RBI consultant is determined prior to data collection to make sure the results obtained, are of maximum usefulness.

Conventional NDT Methods for RBI

- Visual Testing (VT) and Surface testing
  - Oldest and most common inspection type
  - Easily abused, takes a trained eye
  - Magnetic Particle (MT), Liquid Penetrant (PT) are most common types
- Radiographic Testing (RT)
  - For RBI is typically used for thickness verifications, and sometimes in-service weld quality
  - Being replaced by UT methods in the RBI world

Conventional NDT Methods for RBI

- RT, PT, MT and VT are generally considered as “safe” methods.
  - These skills sets can be performed by qualified technicians
  - If performed correctly, results are repeatable
  - These methods yield results that can be passed on “visually for verification”
    - Photograph with a ruler next to indication
    - RT film/digital image with annotations

Cautionary NDT Methods and Assumptions as related to RBI Assessments

- Why do I consider these “Cautionary” methods?
  - Some of these methods are commonly used, and easily abused if considerations are not taken.
  - The ease of RBI engineers to accept data, at face value, with no “assumed percentage of error”.
  - Extremely dependent on NDT technician performing the examination, and the equipment/procedure in use.

Ultrasonic Techniques for RBI

- Typical Ultrasonic (UT) methods used for flaw determination/sizing and material inspections in RBI assessments:
  - Thickness Determination
    - Manual UT Thickness
    - Automated Methods
  - Automated or Semi-Automated Ultrasonics (AUT) of weld seams

Ultrasonic Thickness for RBI

- Thickness Determination Case – Scenario Example
  - Description: Manual Thickness Determination, Sample with local corrosion, ambient temperature relative to calibration block, carbon steel, normal commercial couplant (Again, one of the most basic things done with RBI). This is the spot of local (0.250”) corrosion from Automated Scenario, labeled for test. Basically, the technician was told where to look.
  - 5 technicians on (3 different companies, 4 different machines), scan the sample. The technicians were allowed to choose probes, based on company procedure and experience.
  - Sound easy enough?

Ultrasonic Thickness for RBI

- Thickness Determination Case – Scenario Results

Technician	Max Depth Size	"Inch Error"	"% error"
Sample Manu	0.250"	0	**0.000%**
Clay Savoy	0.253"	+ 0.003"	**1.200%**
Tech #1	0.240"	- 0.010"	**4.000%**
Tech #2	0.232"	- 0.018"	**7.200%**
Tech #3	0.262"	+ 0.012"	**4.800%**
Tech #4	0.254"	- 0.004"	**1.600%**
Tech #5	0.245"	- 0.005"	**2.000%**

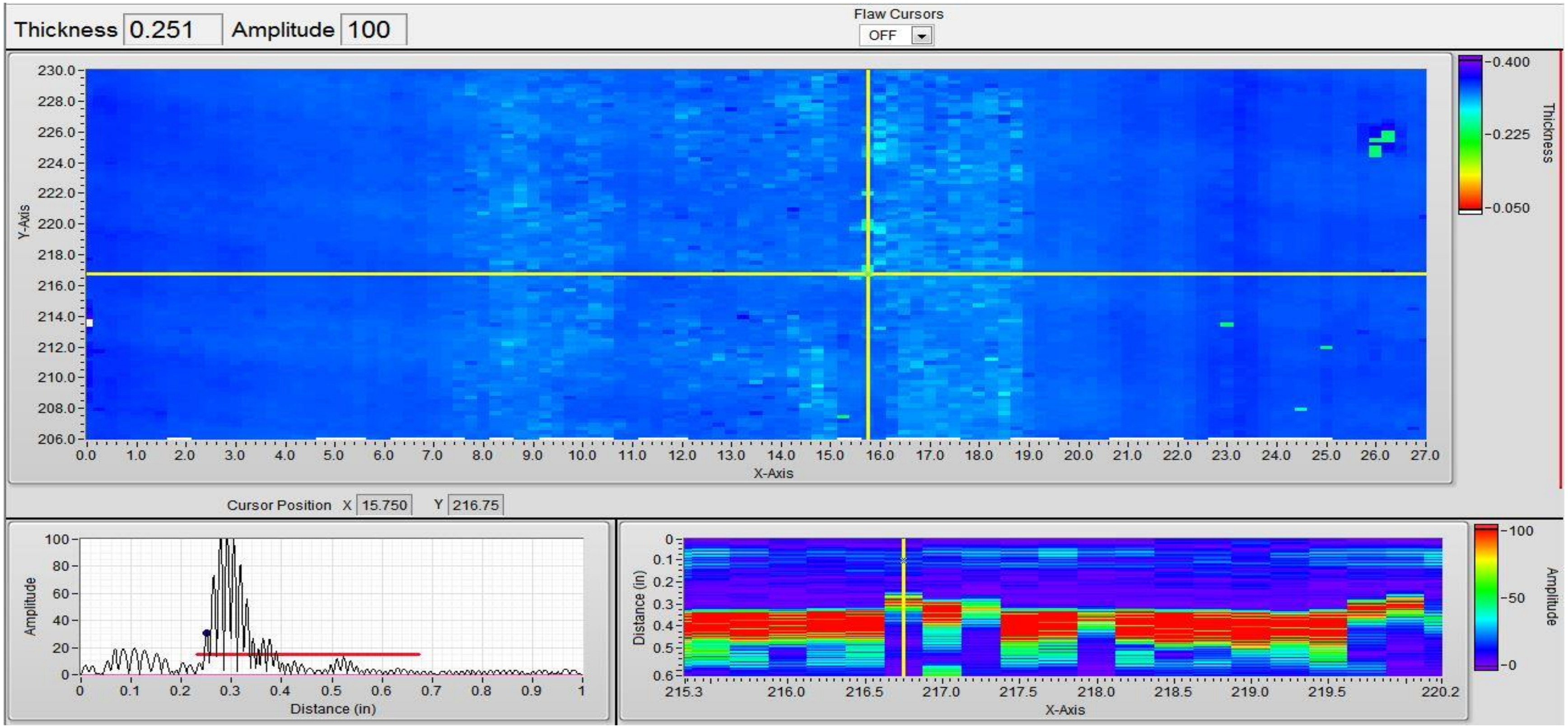
Ultrasonic Flaw Detection for RBI

- Manual Shearwave
  - Lumping all categories of UT that are “hand-manipulated” by the operator
  - Common “Cautionary Tales”
    - Many different techniques, probes and equipment available
    - Extremely technician skill set dependent
    - Many variables that can lead to errors (temperature differences, couplant inconsistencies, probe pressure, calibration variances, etc.)

Ultrasonic Thickness for RBI

- Thickness Determination Case – Scenario Example
  - Description: Thickness Determination, Automated (AUT) Scanning of sample with general and local corrosion, ambient temperature relative to calibration block, carbon steel, water couplant (Again, one of the most basic things done with RBI).
  - 5 technicians on (3 different companies, 2 different machines), scan the sample. The technicians were allowed to choose probes, based on company procedure and experience.
  - Sound easy enough?

Ultrasonic Thickness for RBI



Typical C-Scan, A-Scan, B-Scan, from Sample

Ultrasonic Thickness for RBI

- Thickness Determination Case – Scenario Results

Technician	Max Depth Size	"Inch Error"	"% error"
Sample Manu	0.250	0	**0.000%**
Clay Savoy	0.251"	+ 0.001"	**0.400%**
Tech #1	0.246"	- 0.004"	**0.160%**
Tech #2	0.259"	+ 0.009"	**3.600%**
Tech #3	0.253"	+ 0.003"	**1.200%**
Tech #4	0.247"	- 0.003"	**1.200%**
Tech #5	0.262"	+ 0.012"	**4.800%**

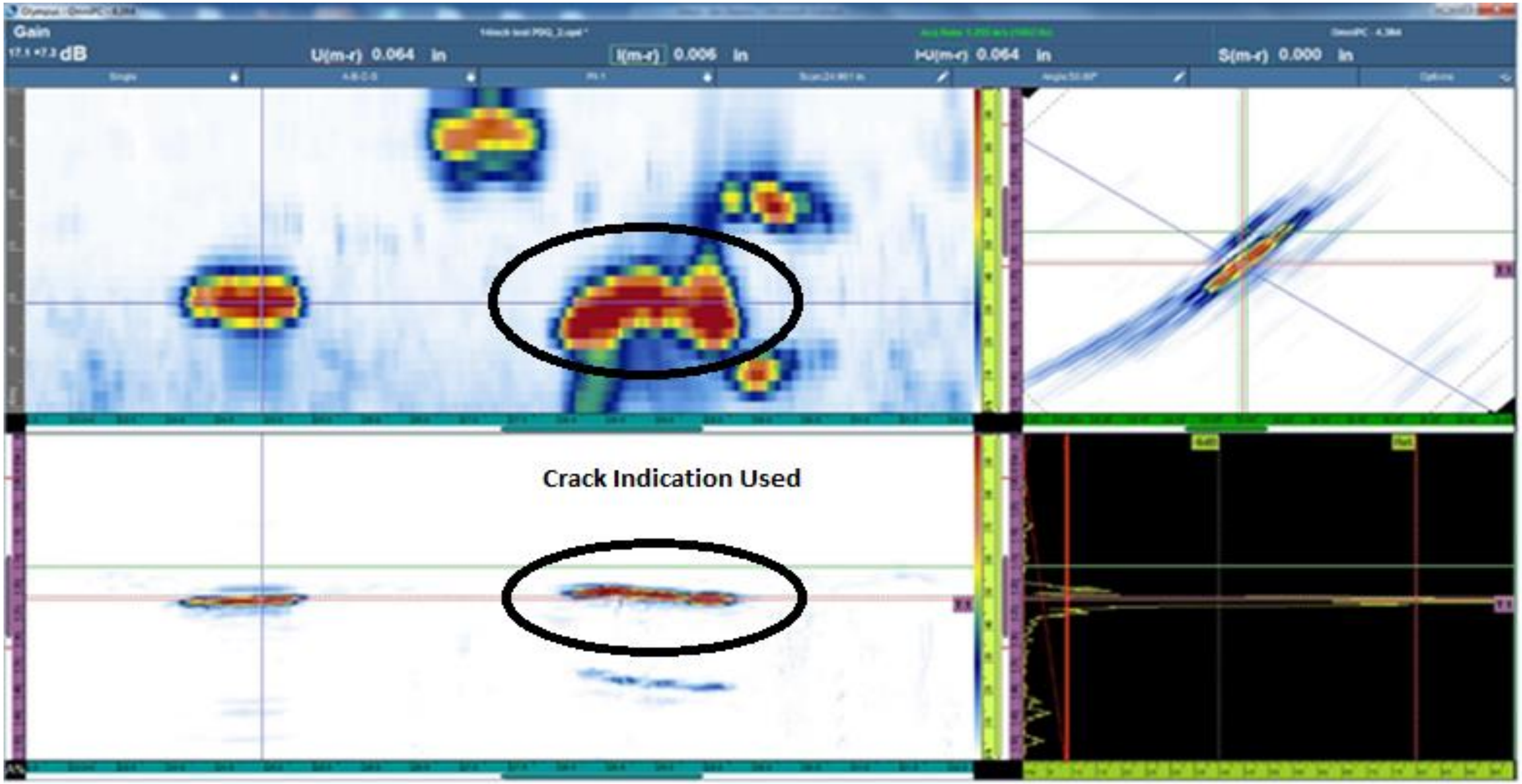
Post Inspection RBI Analysis

- Compare actual inspection plan and coverage to the inspection effectiveness recommended
  - Often inspection recommendations are not specifically followed and can result in a lower than expected inspection grading credit
- Compare results of the inspection findings to the data used for risk analysis
  - Corrosion rate measured compared to estimated and previously measured
  - Component thickness and wall loss compared to previous data and expected thickness (using corrosion rate)
  - If cracking (environmental or mechanical) is found, RBI alone is not sufficient and a FFS evaluation should be performed unless equipment is repaired or replaced
- Compare date of inspection compared to the recommended inspection date (Target Date)

Ultrasonic Flaw Detection for FSS

- Manual Sizing Case – Scenario Example
  - Description: Phased Array technique, ambient temperature relative to calibration block, carbon steel, sizing a crack for length (one of the most basic things done with FSS strategy).
  - 5 technicians on (3 different companies, 3 different machines), scan the sample. The technicians were allowed to choose probes, based on company procedure and experience.
  - Sound easy enough?

Ultrasonic Flaw Detection for FSS



Typical B-Scan, S-Scan, D-Scan, and A-Scan from Sample

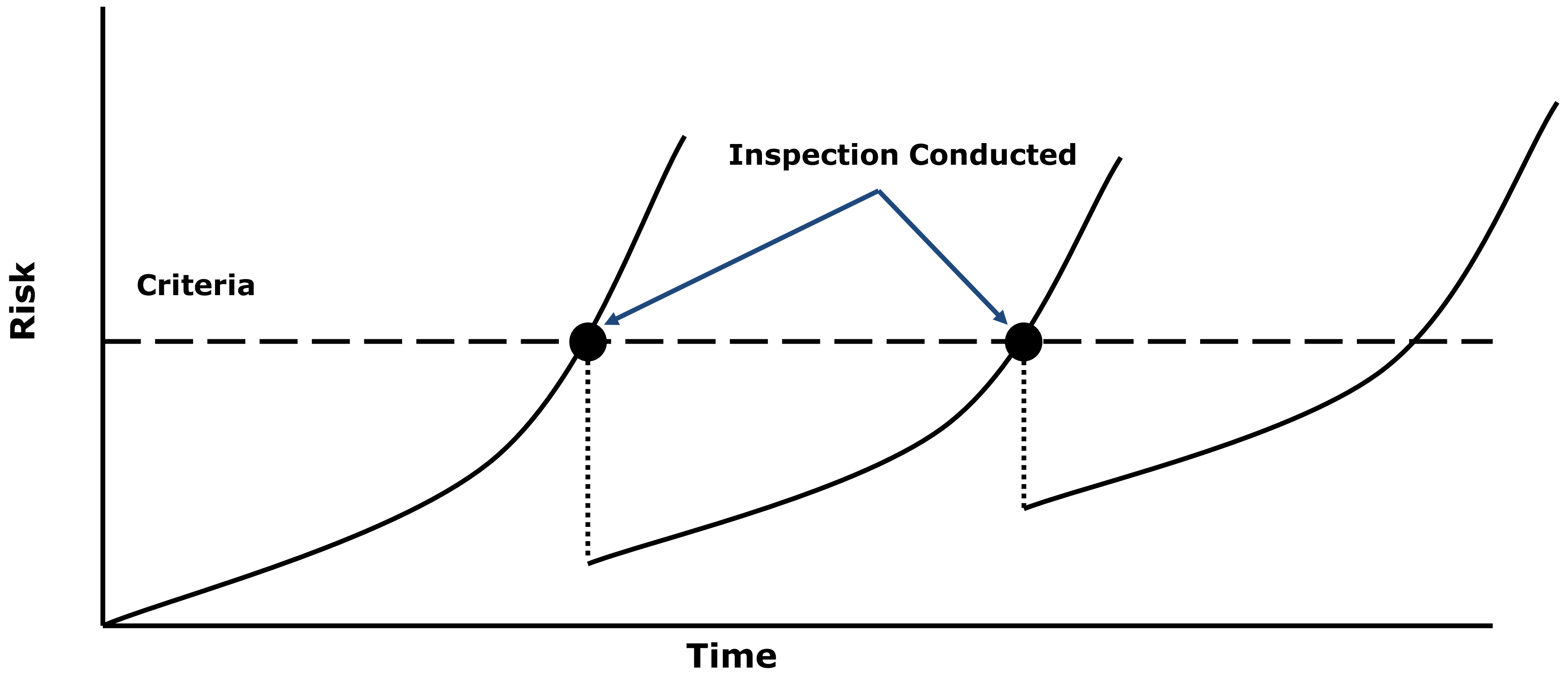
Ultrasonic Flaw Detection – FSS Assessments

- Manual Sizing Case – Scenario Results

Technician	Crack Size	"Inch Error"	"% error"
Sample Manu	1.35"	0	**0.000%**
Clay Savoy	1.41	+ 0.06"	**4.225%**
Tech #1	1.45	+ 0.1"	**6.897%**
Tech #2	1.32	- 0.03"	**2.273%**
Tech #3	1.25	- 0.1"	**8.000%**
Tech #4	1.52	+ 0.17"	**11.184%**
Tech #5	1.32	- 0.03"	**2.273%**

Inspection Results Summary

- Inspection alone will not return risk to as new condition or initial risk levels



Drum Component Analysis

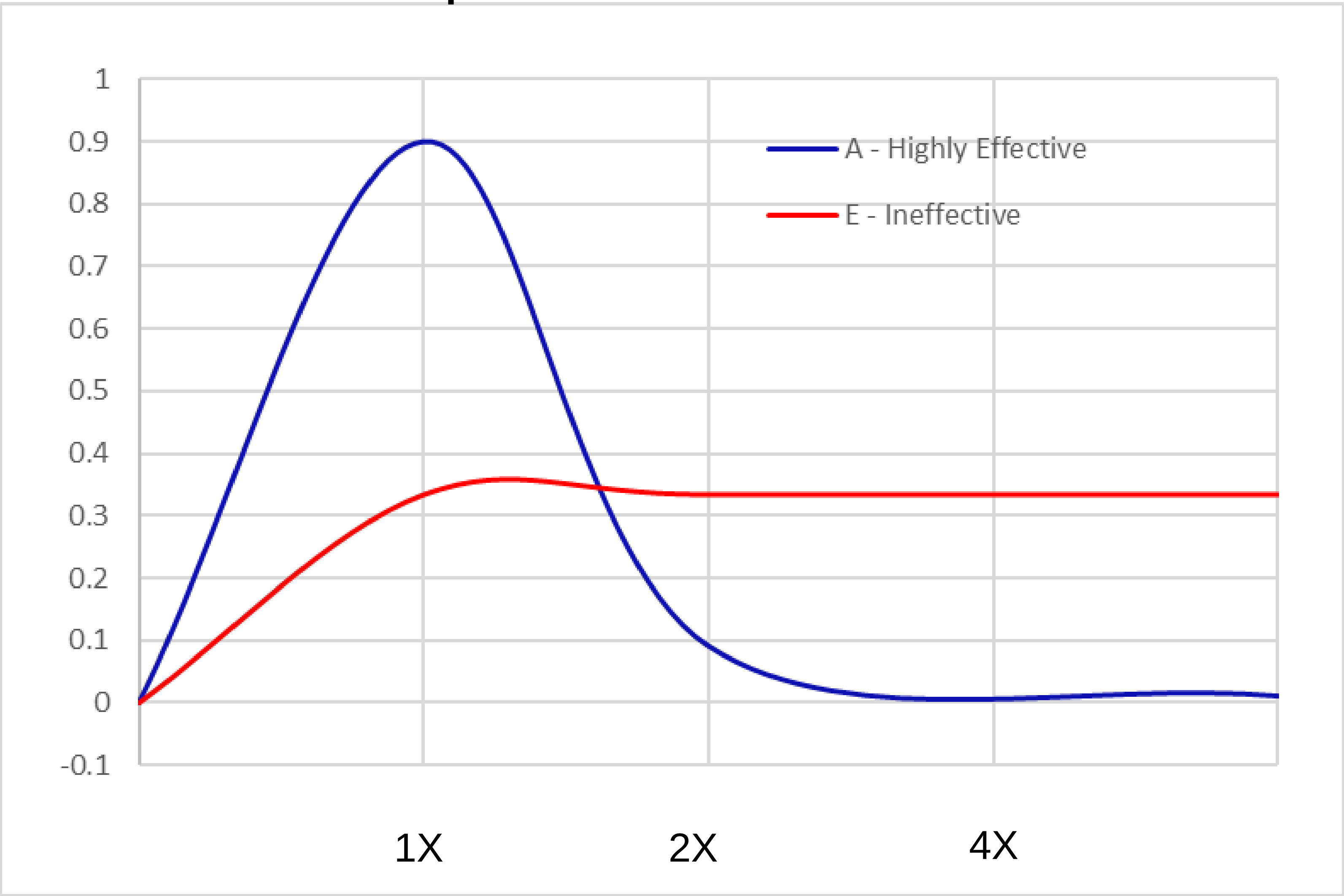
Base Material

Corrosion Rate Data	
Estimated, mpy	2
Measured, mpy	3.5
Calculated (Base Rate), mpy	
Thinning Type	Localized
Corrosion Rate Basis	Measured
Data Reliability	Low Reliability Data

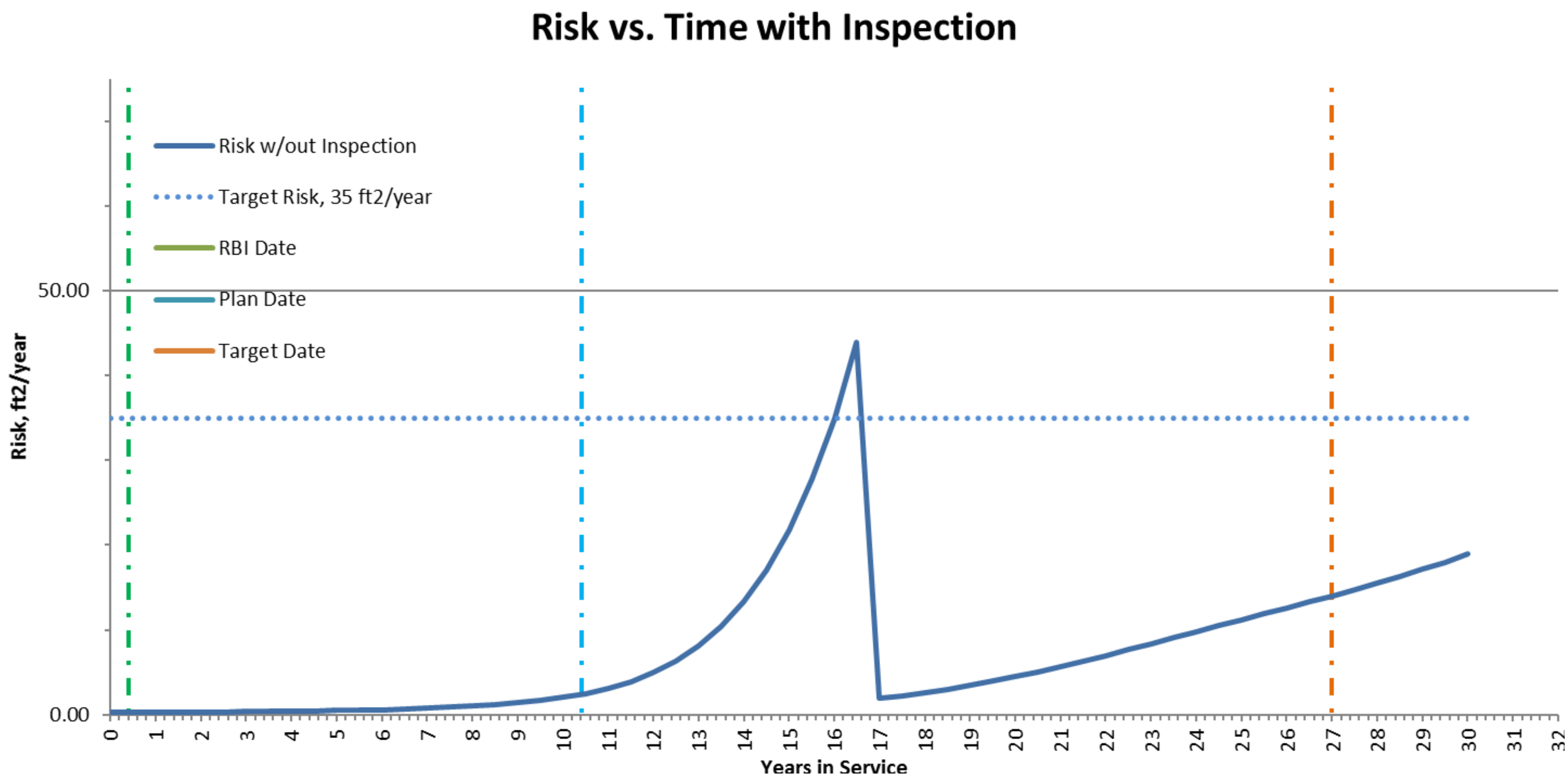
Inspection History

Last Inspection Date	1/1/2003
Risk-Based Last Inspection Date	7/2/2019
Risk-Based Thickness, inch	0.4383
Number of A Thinning Inspections	1
Number of B Thinning Inspections	0
Number of C Thinning Inspections	0
Number of D Thinning Inspections	0

Inspection Confidence



Risk



Risk vs. Time with Inspection
Risk w/out Inspection
Target Risk, 35 ft2/year
RBI Date
Plan Date
Target Date
50.00
0.00
Risk, ft2/year
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32
Years in Service

Summary

- Use reasonably conservative values for Risk Analysis using inspection results to account for inspection measurement error and data scatter
- Develop a detailed inspection plan to assure the desired inspection credit and improved confidence is achieved
- Lay out a work plan with the technicians prior to inspection
  - Provide all relevant information including historical measurements, test results and findings
  - Provide acceptance criteria
  - Not providing the relevant data and waiting to “see what you can find”, can lead to errors and wasted effort
  - Include how inspection data is to be reported
  - Use the philosophy, “You get what you ask for, not necessarily what you expect” – Jimmy Veillon (2016)

Summary

- Know the advantages of each inspection technique and inherent limitations
- All inspection has a percentage of error in the data
  - Define the acceptable range for inspection results
  - Consider the inherent error in the risk calculation, where applicable
- Create mock scenarios to measure accuracy of method
  - Not only important for UT, but the other techniques are well are important to demonstrate
- Scrutinize data with verification on critical measurements
- Compare findings to data used for initial Risk analysis
- Update Risk Analysis with results and compare risk to expected risk
- Plan next inspection activity based on updated results

Questions?

Thank you for your time