API RP 581 Risk-Based Inspection Methodology Document Revisions

Lynne Kaley

Trinity Bridge, LLC
Principal

7TH BIENNIAL INSPECTION SUMMIT

JAN. 30-FEB. 02 | GALVESTON ISLAND | TEXAS

energy API

ASSET INTEGRITY THROUGH CORROSION MANAGEMENT, INSPECTION AND ENGINEERING TECHNOLOGY

Outline

- API RP 581 Short History
- Overview of Document Changes
- Changes to Part 1 Inspection Planning Methodology
- Changes to Part 2 Probability of Failure (POF) Methodology
- Changes to Part 3 Consequence of Failure (COF) Methodology
- Fourth Edition Plans
- Conclusions/Summary

"I am presenting this information as an individual who is making personal observations on the Recommended Practice. This presentation is not an official position of the American Petroleum Institute."

API RP 581 History

- Initial Base Resource Document (BRD) was published in 1994 to an API lead sponsor group project
- The First Edition of the BRD was published by API in 2000 as a qualitative and semi-quantitative RBI technology released by the sponsor group
- API RP 581 Second Edition was released in 2008 as a recommended practice
  - Release reflected a major document reorganization
  - Concentrated on the documentation of the calculation procedures
  - Final document release by the sponsor group
  - Used as a basis to initiate an API task group for 581
- API RP 581 Third Edition was released in 2016 with significant changes
  - Started in 2008 with a list of recommended changes or revisions that didn't make the Second Edition release
  - Ongoing activity with regular API document review and revision process

API RP 581 Overall Document Changes

- Document with 3 main parts:
  - Part 1 Inspection Planning Methodology
  - Part 2 Probability of Failure (POF) Methodology
  - Part 3 Consequence of Failure (COF) Methodology
- Changed Risk-Based Technology to Risk-Based Methodology
  - Reflects a practical, systematic set of methods to develop equipment inspection plans based on risk
  - Not just a technology
- All Inspection Effectiveness information, guidance and examples were combined into a new Part 2, Annex C
- Objective was to help users follow the calculation steps

API RP 581 Overall Document Changes

- Editorial changes throughout the document
  - Consolidated definitions and acronyms in Part 1
  - Consistent use of definitions and acronyms in all document Parts
  - Added guidance for users when using the RBI approach
  - Streamlined and clarified discussions and technology
  - Clarified concepts, reorganize sections better readability
  - Revised/corrected calculation procedures to improve, add omissions or correct errors
- Remainder of presentation will discuss changes to the technical content

API RP 581 Part 1 Summary of Changes

- Section 4 Basic Concepts
- Added discussion on Weibull distribution, related to POF for heat exchanger bundles (4.1)
- Risk (4.3)
  - Removed COF dependence on time in Risk equation (4.3.1)

$$R(t) = P_f(t) \cdot C_f \quad (1.6)$$

  - Added examples for when COF may change over time
- Risk Results (4.3.2) Modified
  - POF/COF categories
  - Risk Matrix
  - Iso-Risk plots

API RP 581 Part 1

- Modified POF and COF category ranges
  - Orders of magnitude (Tables 4.1 and 4.2)

Table 4. 1 – Numerical Values Associated with POF and Area-Based COF Categories

Category	Probability Category (1,2)		Consequence Category (3)	
	Probability Range	Damage Factor Range	Category	Range (ft^2)
1	$P_f(t, I_E) \le 3.06\text{E}-05$	$D_{f-total} \le 1$	A	$CA \le 100$
2	$3.06\text{E}-05 < P_f(t, I_E) \le 3.06\text{E}-04$	$1 < D_{f-total} \le 10$	B	$100 < CA \le 1{,}000$
3	$3.06\text{E}-04 < P_f(t, I_E) \le 3.06\text{E}-03$	$10 < D_{f-total} \le 100$	C	$1{,}000 < CA \le 10{,}000$
4	$3.06\text{E}-03 < P_f(t, I_E) \le 3.06\text{E}-02$	$100 < D_{f-total} \le 1{,}000$	D	$10{,}000 < CA \le 100{,}000$
5	$P_f(t, I_E) > 3.06\text{E}-02$	$D_{f-total} > 1{,}000$	E	$CA > 100{,}000$

Notes:

1. POF values are based on a GFF of 3.06E-05 and an F_{MS} of 1.0.
2. In terms of POF, see Part 1 Section 4.1.
3. In terms of the total DF, see Part 2, Section 3.4.2.
4. In terms of consequence area, see Part 3, Section 4.11.4.

API RP 581 Part 1

- Risk Matrix Unbalanced (Figure 4.2)

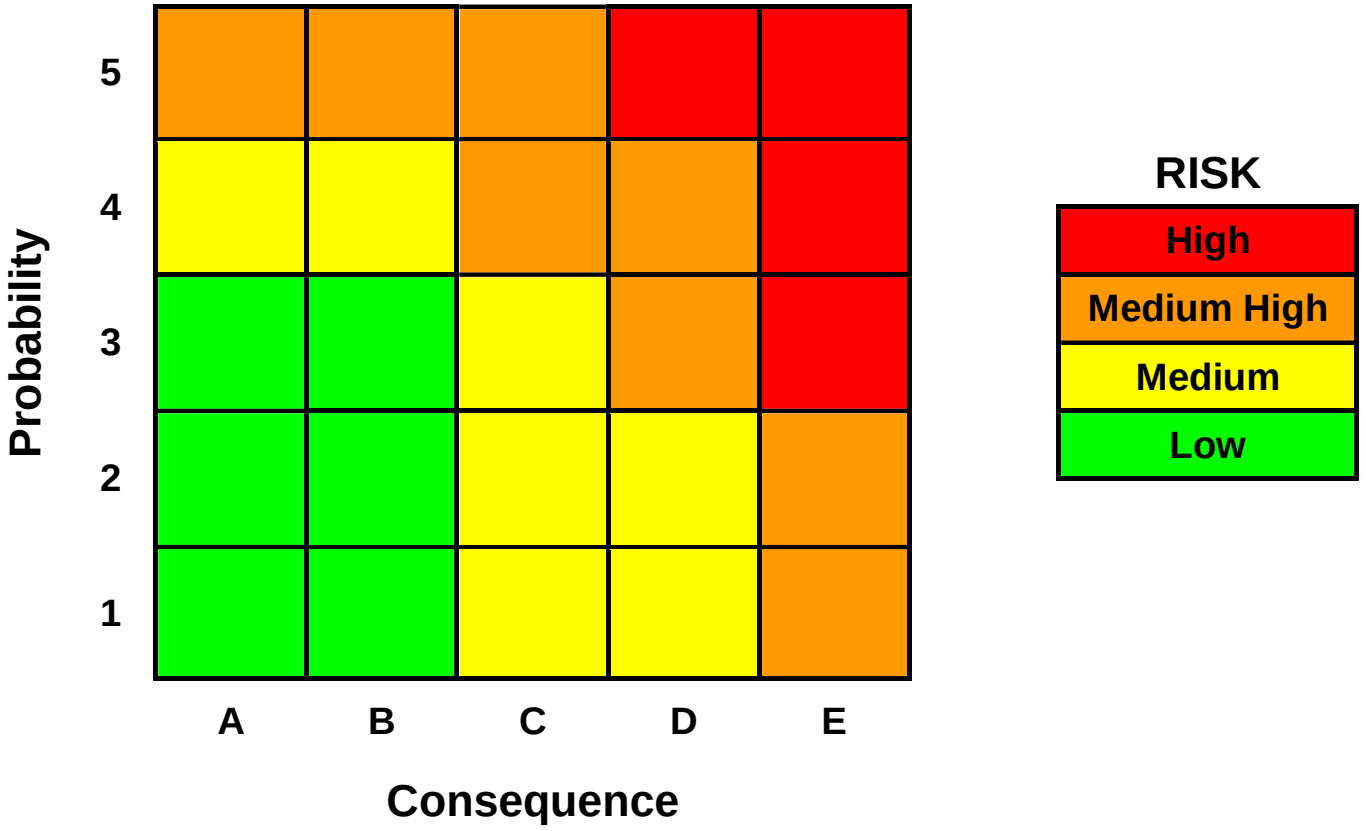


Figure 4.2 – Unbalanced Risk Matrix

API RP 581 Part 1

- Risk Matrix Balanced (Figure 4.3)

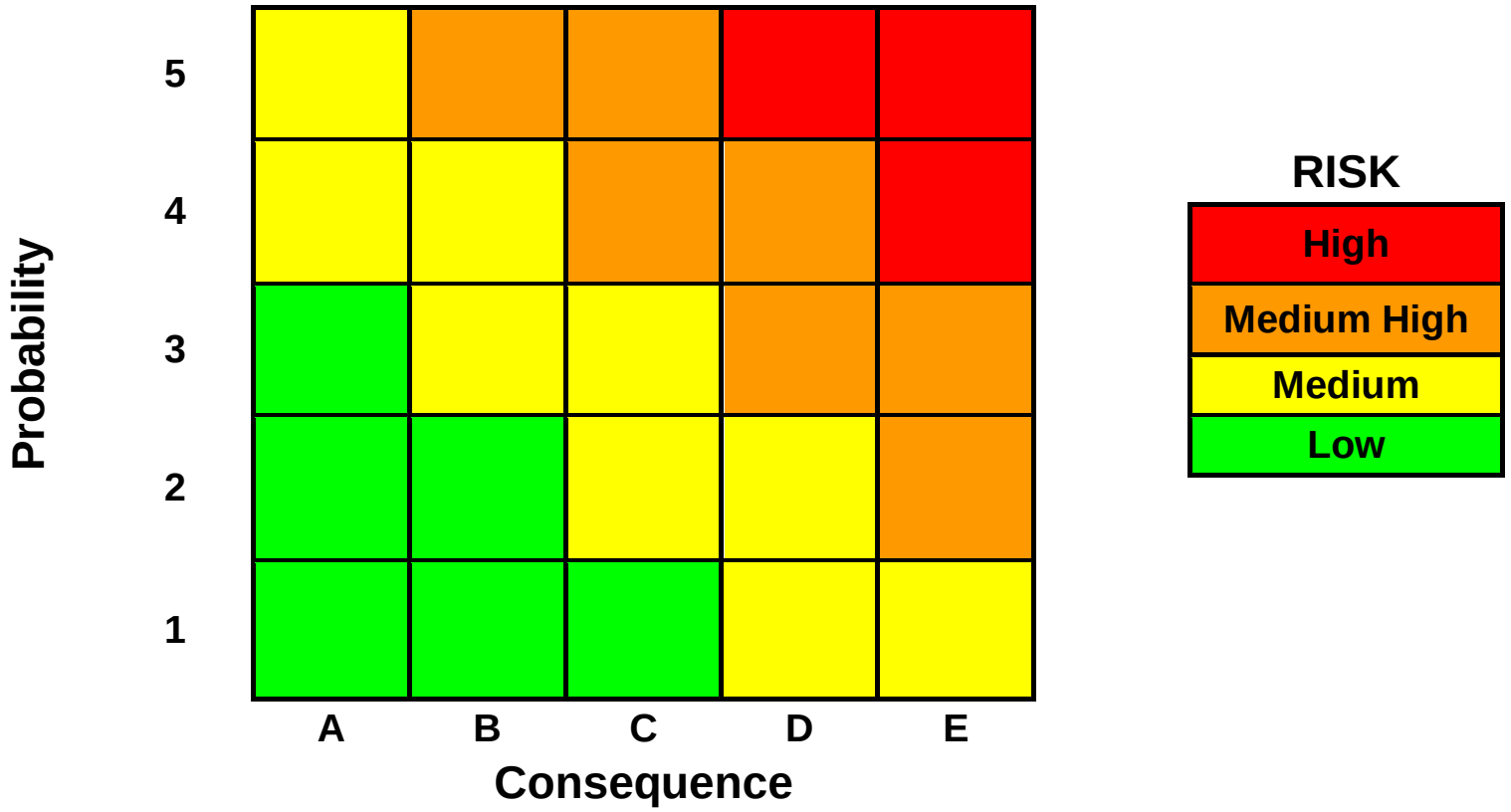


Figure 4.3 – Balanced Risk Matrix

API RP 581 Part 1

- Iso-Risk plots added for Area and Financial Consequences (Figures 4.4 and 4.5)

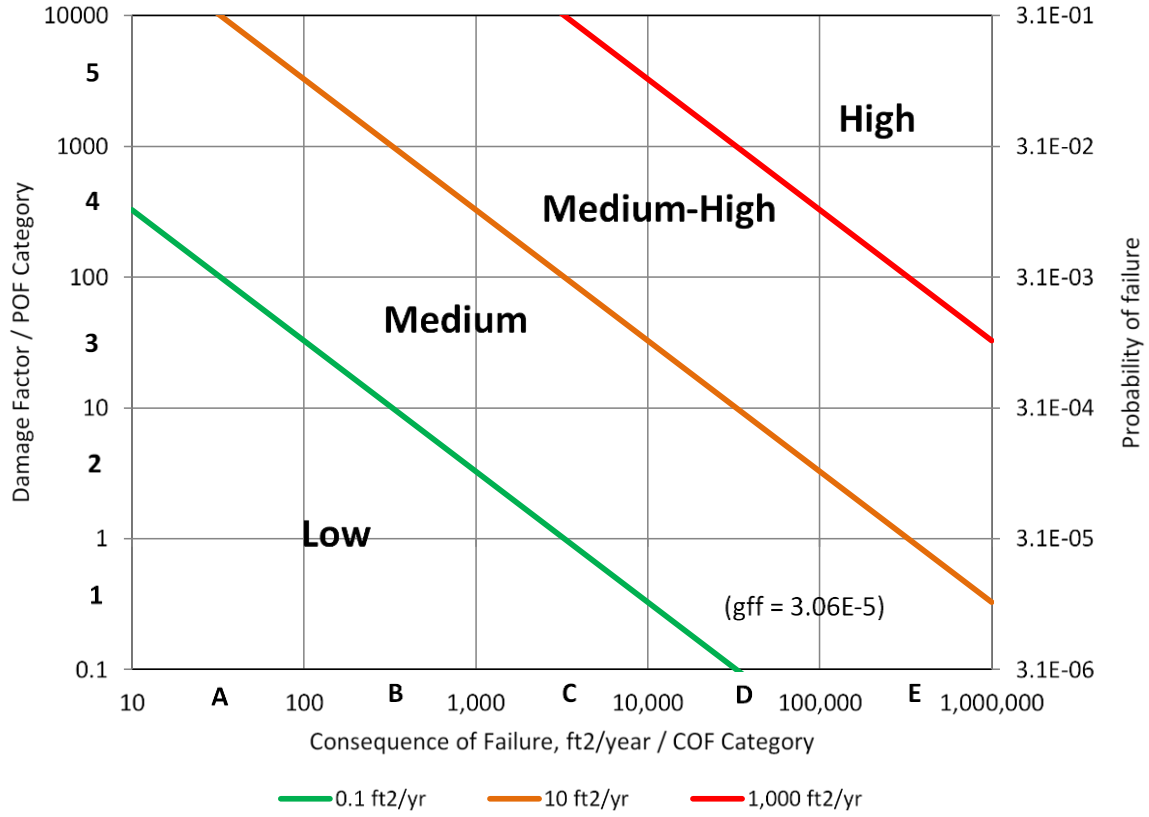


Figure 4.4 – Example Iso-Risk Plot for Area Consequence Area

API RP 581 Part 1

- Guidance for defining targets that trigger action, including inspection (4.4.2):
  - Risk Target
  - POF Target
  - Damage Factor (DF) Target
  - COF Target
  - Thickness Target
  - Maximum Inspection Interval Target
- Defined by user using one or more of targets above

API RP 581 Part 1

- Section 7 – Pressure Relief Devices (PRD)
  - Added Set Pressure Factors for PRD types (Table 7.7)
  - Modified PRD categories of service severity for Fail to Open and Leak cases with examples and typical temperature ranges (Tables 7.4 and 7.11)
- Section 8 – Heat Exchanger Bundles
  - Bundle Material Cost Factors expanded for tube material of construction (Table 8.3)
  - Inspection Effectiveness and Uncertainty revised (Table 8.5)

API RP 581 Part 2 Summary of Changes

- Internal & External Thinning DF summation
- Thinning DF calculation revision
- Modified DF Tables to allow DF < 1
- Various Thinning and Cracking supplement changes for susceptibility

API RP 581 Part 2 – Damage Factors (DF)

- Modified External/Internal thinning DF combination (3.4.2)
  - If external and/or thinning damage are classified as local, damage is unlikely to occur in the same location and the total DF is calculated.

$$D_{f-total} = \max\left[D_{f-gov}^{thin},\ D_{f-gov}^{extd}\right] + D_{f-gov}^{scc} + D_{f}^{htha} + D_{f-gov}^{brit} + D_{f}^{mfat} \qquad (2.2)$$

  - If the external and thinning damage are general, damage is likely to occur at the same location and the total DF is calculated.

$$D_{f-total} = D_{f-gov}^{thin} + D_{f-gov}^{extd} + D_{f-gov}^{scc} + D_{f}^{htha} + D_{f-gov}^{brit} + D_{f}^{mfat} \qquad (2.3)$$

Note: Sum of DFs can be $\leq$ 1.0 so that the component can have a POF < Generic Failure Frequency (Gff)

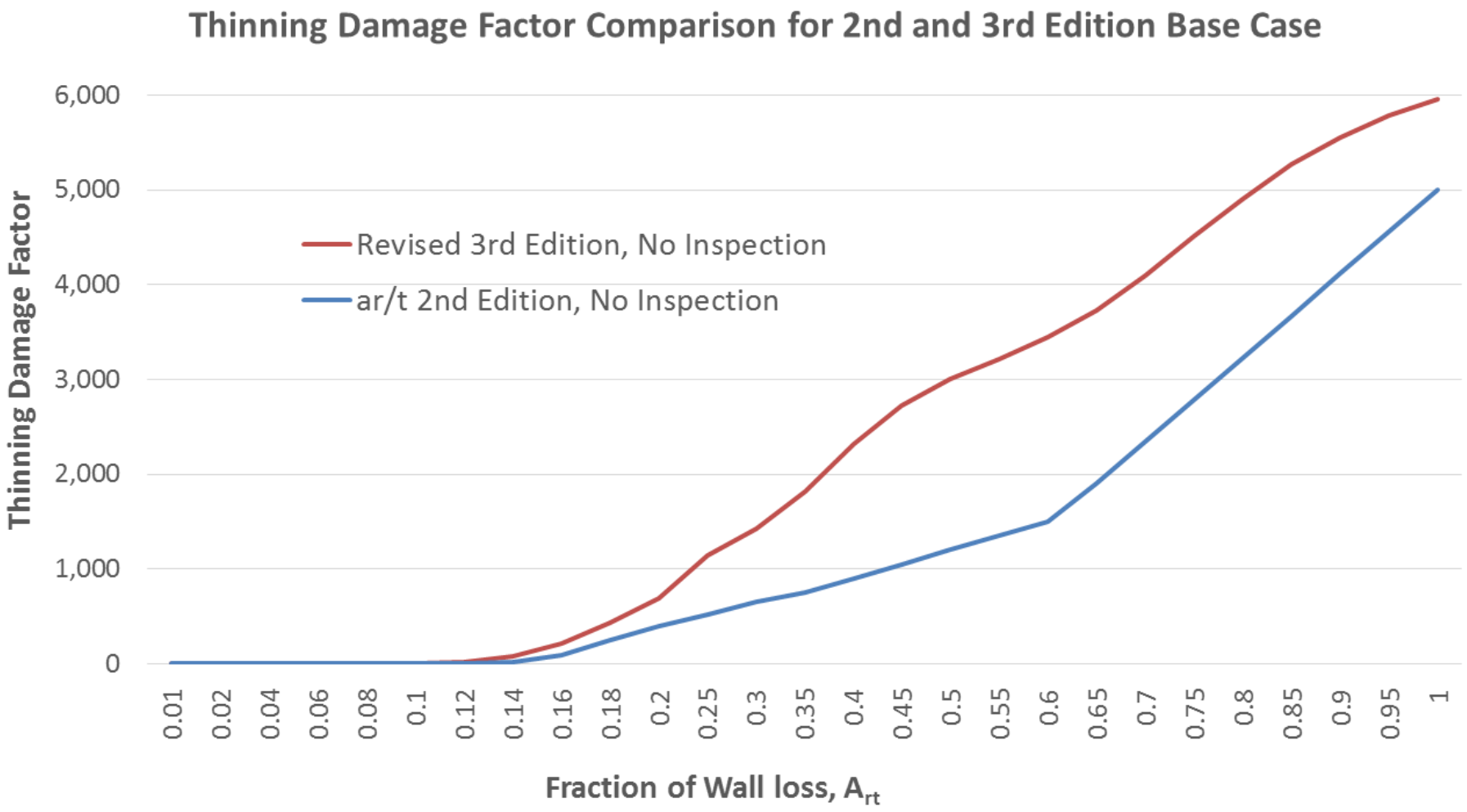
API RP 581 Part 2 – Thinning Damage

- Added user guidance for key variables in Thinning Damage calculation:
  - Corrosion Rate (4.5.2) – Assigning corrosion rates
  - Corrosion Rate Confidence (4.5.3) – Uncertainty and Damage States
  - Thinning Type (4.5.4) – Local and general thinning behavior
  - Thickness and Age (4.5.5) – Selecting thickness and calculating age for POF calculation
  - Inspection Effectiveness (4.5.6) – Grading inspection histories
- Thinning DF calculation (4.5.7)
  - Completely revised using reliability calculation that was the basis for ar/t table values
  - Eliminated ar/t (Table 5.11)

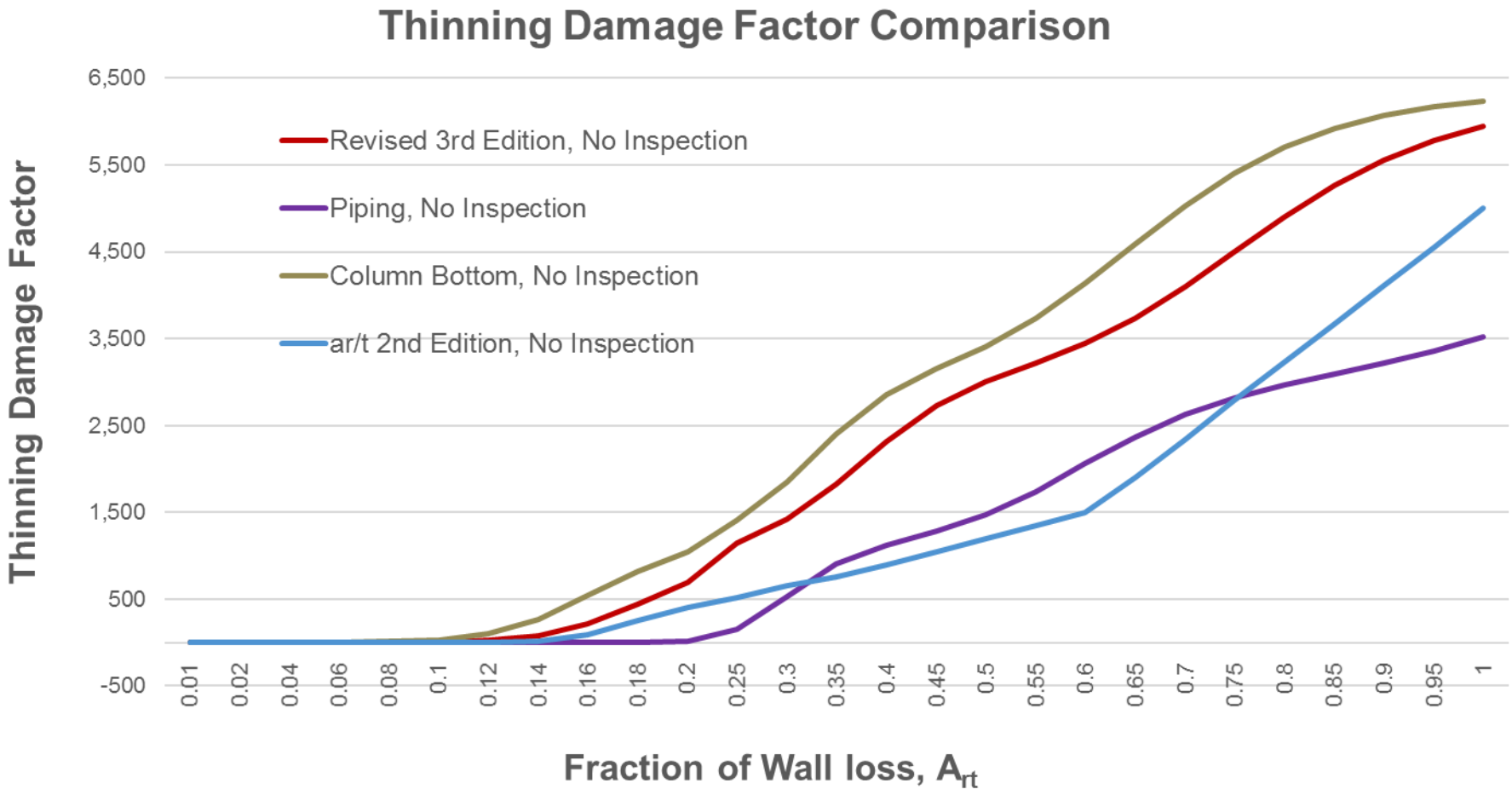
API RP 581 Part 2 – Thinning Damage

- Thinning calculations are based on the actual component information rather than a base case set of data
- DF's applicable for specific components design and operating data
- Set minimum DF to 0.1 (order of magnitude < Gff)
- Streamlined approach to include use of tmin
- The COV for thinning factor changed from 0.10 to 0.20 for smoothing in low inspection cases
- Transparency of calculations that were the basis for the ar/t table
- User flexibility in calculations for corrosion rate confidence, damage state, COV's, if desired

API RP 581 Part 2 – Thinning Damage



API RP 581 Part 2 – Thinning Damage



API RP 581 Part 2

- HTHA
  - Carbon & Low Alloy steel susceptibility based on CSB report findings
  - Changed to proximity to curve basis for all alloys
- Low Temperature Embrittlement calculation procedure updated for consistency with API 579-1/ASME FFS-1
- Low Alloy Embrittlement calculation procedure updated for consistency with API 579-1/ASME FFS-1
- New Annex 2.C
  - Contains all Inspection Effectiveness table examples
  - Discussion for customization of tables by user

API RP 581 Part 3 Summary of Changes

- Removed 10,000 ft^2 area limit from Level 1 and 2 COF
- Significant AST revisions for clarity and corrections for shell course and bottom analysis procedures

API RP 581 Part 3 – Consequence Area

- A 10,000 ft^2 area limit was recommended for pool fire spread due to a liquid release
- Intended to reduce unrealistically large affected areas by flammable liquid releases
- Level 1 COF uses simplified equations based on various release types and release effects
- Pool fire limitation has not been implemented as intended, results in unintended artificial limits

API RP 581 Part 3 – Area Limit Results

Hole Size	**¼"**	1"	4"	Rupture
AINL Consequence (Instantaneous), ft²	3,734.98	10,000.00	10,000.00	10,000.00
AINL Consequence (Continuous) , ft²	277.01	3,267.15	10,000.00	10,000.00
AIL Consequence (Instantaneous), ft²	6,676.97	10,000.00	10,000.00	10,000.00
AIL Consequence (Continuous) , ft²	822.03	10,000.00	10,000.00	10,000.00
Energy efficiency (Instantaneous only)	1	4.16	7.41	7.41
AINL Equipment Consequence Area (Instantaneous)	3,734.98	2,405.44	1,349.69	1,349.69
AINL Personnel Consequence Area (Instantaneous)	10,904.43	7,022.79	3,940.47	3,940.47
AINL Equipment Consequence Area (Continuous)	277.01	3,267.15	10,000.00	10,000.00
AINL Personnel Consequence Area (Continuous)	785.38	9,262.91	28,351.65	28,351.65
AIL Equipment Consequence Area (Instantaneous)	6,676.97	2,405.44	1,349.69	1,349.69
AIL Personnel Consequence Area (Instantaneous)	24,062.45	8,605.30	4,828.42	4,828.42
AIL Equipment Consequence Area (Continuous)	822.03	10,000.00	10,000.00	10,000.00
AIL Personnel Consequence Area (Continuous)	2,030.05	22,821.83	22,821.83	22,821.83
Final Equipment Consequence Area, ft²	**3,354.20**			
Final Injury Consequence Area, ft²	**8,865.86**			

API RP 581 Part 3 – No Area Limit Results

Hole Size	**¼”**	**1”**	**4”**	**Rupture**
AINL Consequence (Instantaneous), ft²	3,734.98	23,667.42	101,921.40	101,921.40
AINL Consequence (Continuous) , ft²	277.01	3,267.15	38,533.27	454,467.34
AIL Consequence (Instantaneous), ft²	6,676.97	24,546.82	68,726.98	68,726.98
AIL Consequence (Continuous) , ft²	822.03	11,449.93	159,483.93	2,221,421.16
Energy efficiency (Instantaneous only)	1	4.16	7.41	7.41
AINL Equipment Consequence Area (Instantaneous)	3,734.98	5,693.06	13,756.23	13,756.23
AINL Personnel Consequence Area (Instantaneous)	10,904.43	16,621.12	40,161.87	40,161.87
AINL Equipment Consequence Area (Continuous)	277.01	3,267.15	38,533.27	454,467.34
AINL Personnel Consequence Area (Continuous)	785.38	9,262.91	109,248.18	1,288,489.82
AIL Equipment Consequence Area (Instantaneous)	6,676.97	5,904.60	9,276.01	9,276.01
AIL Personnel Consequence Area (Instantaneous)	24,062.45	20,781.18	32,041.42	32,041.42
AIL Equipment Consequence Area (Continuous)	822.03	11,449.93	159,483.93	2,221,421.16
AIL Personnel Consequence Area (Continuous)	2,030.05	26,019.35	333,493.07	4,274,420.04
Final Equipment Consequence Area, ft²	**5,496.46**			
Final Injury Consequence Area, ft²	**15,406.45**			

Fourth Edition Planned Revisions

- Approximately 200 action items remaining from 3rd Edition
- Revisions will concentrate on:
  - Focus on necessary updates to thinning and cracking modules
  - Improved handling of clad/weld overlay, liners and coatings
  - Improve documentation of inspection planning methodology
  - Further clarification and simplifying calculation procedures
- Planned Releases:
  - Third Edition, 1st Addendum – Fall 2017
  - Third Edition, 2nd Addendum – Fall 2019
  - Fourth Edition – Fall 2021

Fourth Edition – Document Restructure

- Part 1 – Introduction to Risk-Based Analysis
- Part 2 – Probability of Failure Methodology
- Part 3 – Consequence of Failure Methodology
- Part 4 – Inspection Planning Using Risk-Based Analysis
- Part 5 – Risk-Based Analysis for Specific Equipment Types
- Part 6 – Examples Manual

Summary and Conclusions

- Third Edition represents significant technology changes to the RBI calculations
  - Risk graphics and reporting allows user customization for corporate risk continuity
  - Thinning (internal & external) DFs will increase, particularly when ar/t > 0.70
  - COF areas for Level 1 & Level 2 approaches will increase for liquid releases
  - Risk targets may require adjustments based on Third Edition results
- Third Edition changes should provide the user with a clearer understanding of the methodologies
- Task Group work is ongoing

Questions?

Thank you for your time