



CORROSION PROBE, INC.

THE COMPLETE ENGINEERING APPROACH – FROM DETECTION TO CORRECTION

Fitness-for-Service Evaluation of Thinning in Continuous Digesters

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TAPPI PEERS
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Discussion Topics

- Overview of API 579
- Part 4 – General Metal Loss
- Part 5 – Local Metal Loss
- Part 6 - Pitting
- Level 3 Analysis
- Questions/Discussion



Disclaimer

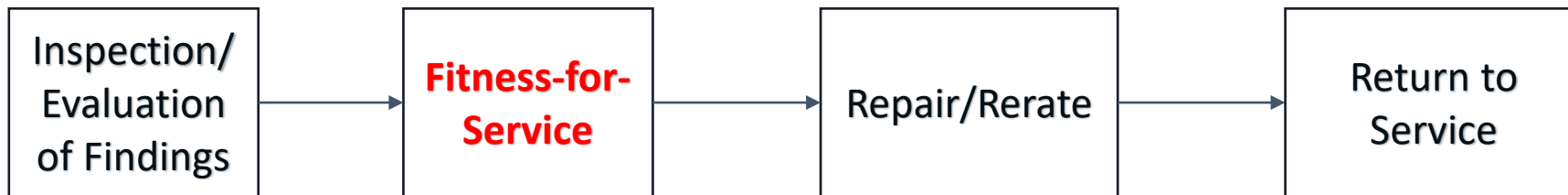
There is no new information contained in this presentation.

FFS methods are poorly utilized throughout the P&P Industry.



Current Industry Practice

- A very important step is omitted in digester inspection.



Overview of API 579/ASME FFS-1

- Originally published in 2000.
- Revised in 2007, 2016, and 2021.
- Supplement to post construction codes (API 510, 653, and NBIC).
- Provides more rigorous approach to evaluation.



Overview of API 579/ASME FFS-1

- Organized into parts based on flaw type.
 - Part 2 - Assessment Procedures
 - Part 3 - Brittle Fracture
 - **Part 4 - General Metal Loss**
 - **Part 5 - Local Metal Loss**
 - **Part 6 - Pitting**
 - Part 7 - Hydrogen Damage
 - Part 8 - Weld Misalignment and Distortion
 - Part 9 - Crack Like Flaws
 - Part 10 - Creep Damage
 - Part 11 - Fire Damage
 - Part 12 - Dents, Gouges, and Combinations
 - Part 13 - Laminations
 - Part 14 - Fatigue Damage



Overview of API 579/ASME FFS-1

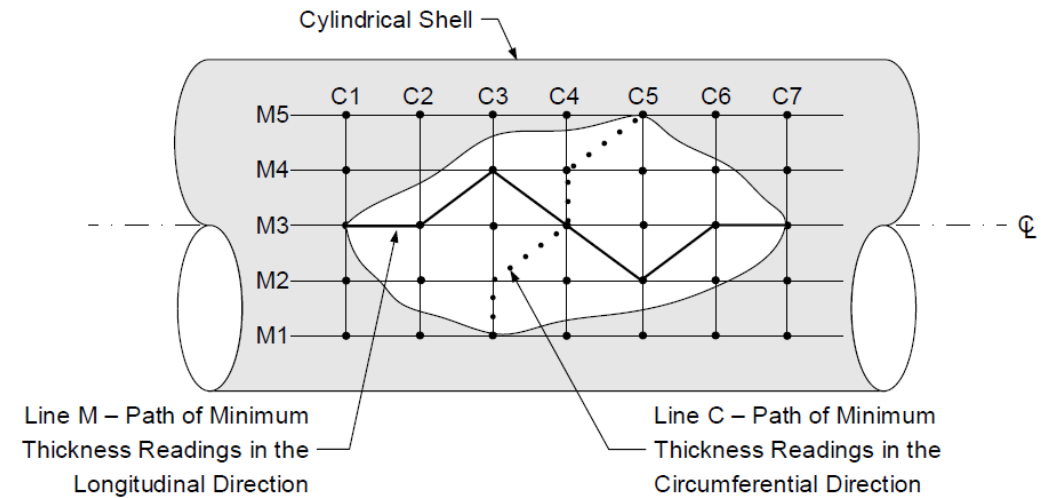
- Each evaluation is based on an assessment level.

Evaluation Level	Data Required	Qualifications	Evaluation Type
1	Low	Inspection personnel	Basic equations and acceptance criteria
2	Medium	Plant engineers or specialist	More complex equations, supplemental loads, geometries
3	High	Specialist	Numerical analysis, FEA, Complex acceptance criteria



Overview of API 579/ASME FFS-1

- Data Collection
 - Point Thickness Readings
 - Critical Thickness Profile
- Limitations
- Future Corrosion Allowance



(a) Inspection Planes and the Critical Thickness Profile



Overview of API 579/ASME FFS-1

- **Why?**
- True representation of the acceptability of pressure components.
- Deferment of unplanned repairs
- Minimize repairs



Part 4 – General Metal Loss

- General or Uniform corrosion
- Thickness averaging
- Minimum measured thickness
- Useful at discontinuities



Part 4 – General Metal Loss

- Level 1 analysis
 - Type A component
 - Internal or external pressure
 - PTRs or CTP may be used

Level 1 Assessment Acceptance Criteria
Determine $t_{\min}^C$ using P $t_{am} - FCA_{ml} \geq t_{\min}^C$



Part 4 – General Metal Loss

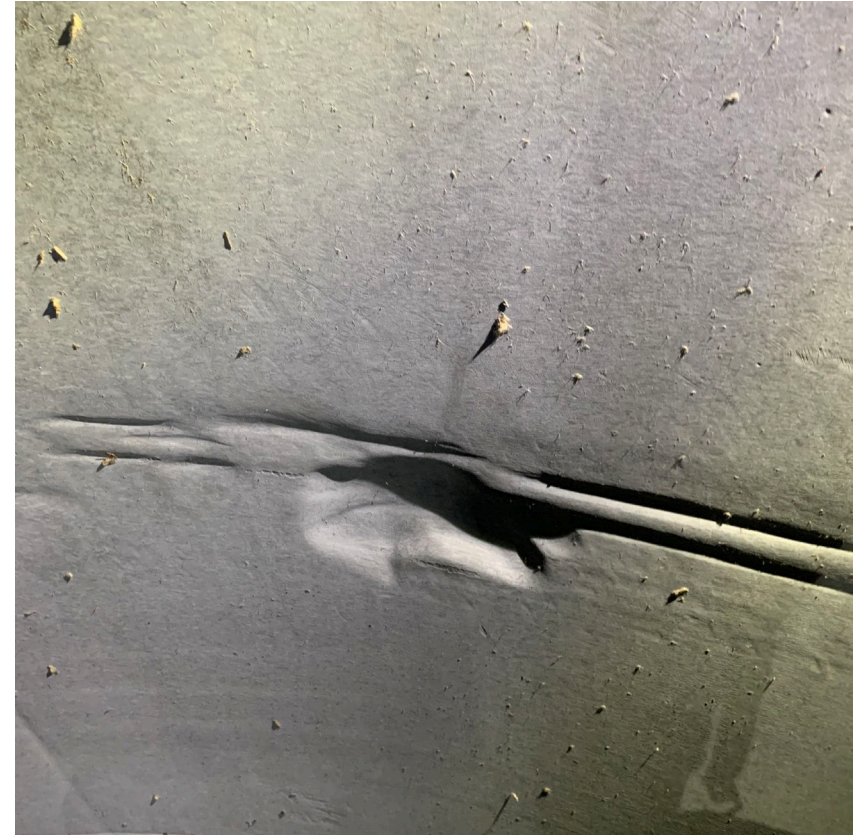
- Level 2 analysis
 - Type A or B component
 - Internal or external pressure
 - Supplemental loads
 - PTRs or CTP may be used
 - Can evaluate structural discontinuities

Level 2 Assessment Acceptance Criteria
Determine t_{min}^C, t_{min}^L using $P \cdot RSF_a$ $t_{am} - FCA_{ml} \geq \max[t_{min}^C, t_{min}^L]$



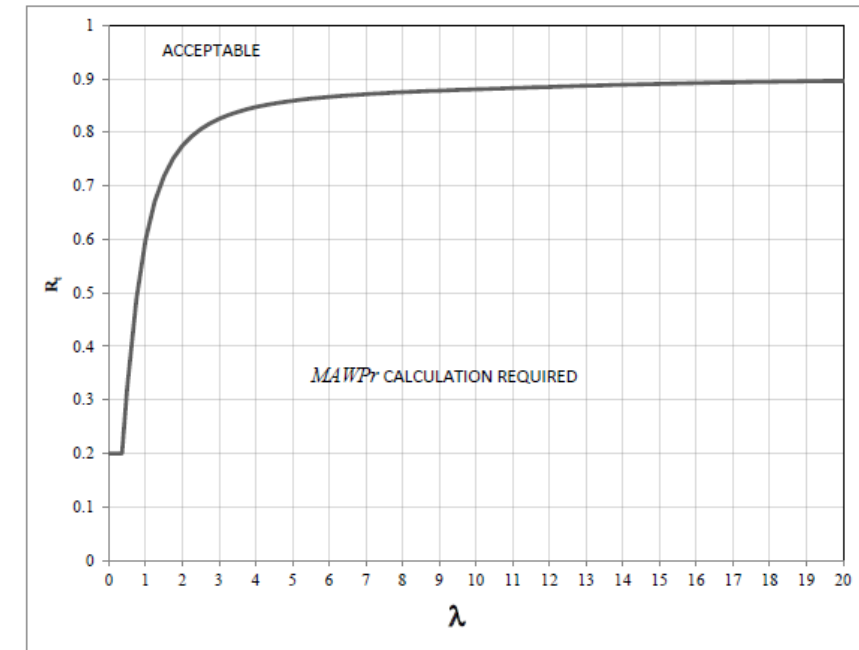
Part 5 – Local Metal Loss

- Local thin areas (LTAs)
- Modified thickness averaging
 - Folias factor



Part 5 – Local Metal Loss

- Level 1 analysis
 - Type A component
 - Internal pressure only
 - CTP must be used.



Note: The allowable remaining strength factor for this curve is $RSF_a = 0.90$. Equations for the curves in this figure are provided below where M_t for a cylindrical shell is determined using [Table 5.2](#).

$$R_s = 0.2 \quad (\text{for } \lambda \leq 0.354) \quad (5.40)$$

$$R_s = \left(RSF_a - \frac{RSF_a}{M_t} \right) \left(1.0 - \frac{RSF_a}{M_t} \right)^{-1} \quad (\text{for } 0.354 < \lambda < 20) \quad (5.41)$$

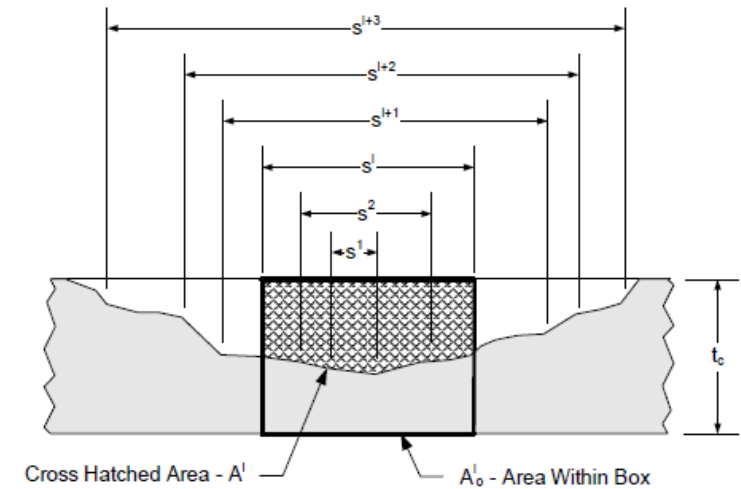
$$R_s = 0.90 \quad (\text{for } \lambda \geq 20) \quad (5.42)$$

Figure 5.6 – Level 1 Screening Criteria for Local Metal Loss in a Cylindrical Shell

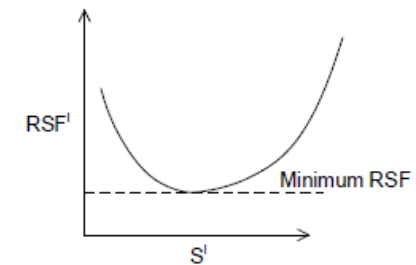


Part 5 – Local Metal Loss

- Level 2 analysis
 - Type A or B (cylindrical) component
 - Internal or external pressure
 - Supplemental loads



(a) Subdivision Process for Determining the RSF

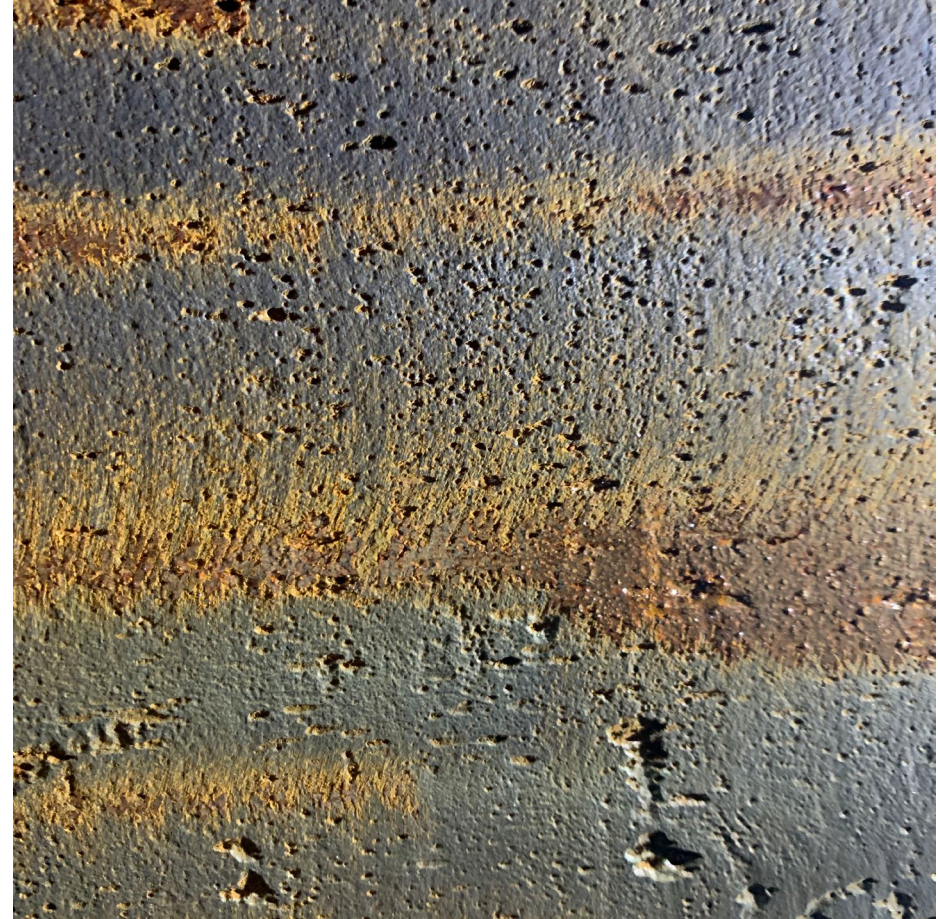


(b) Determining the Minimum RSF Value



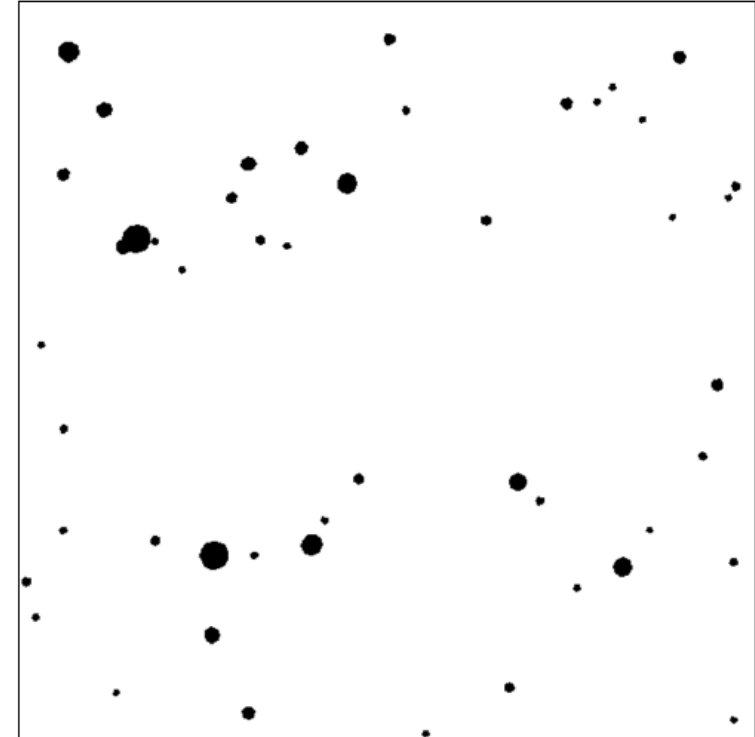
Part 6 – Pitting

- Types of pitting damage:
 - Widely scattered pitting
 - An LTA within a region of pitting
 - Localized regions of pitting
 - Pitting confined to an LTA.



Part 6 – Pitting

- Level 1 analysis
 - Type A components under internal pressure
 - Widespread pitting
- Primarily a visual evaluation.



Note: The scale of this figure is 150 mm by 150 mm (6 in. by 6 in.).

R_{wt}	Level 1 <i>RSF</i>	
	Cylinder	Sphere
0.8	0.98	0.97
0.6	0.97	0.95
0.4	0.96	0.92
0.2	0.94	0.90



Part 6 – Pitting

- Level 2 analysis
 - Can be used for all four types of pitting.
 - Uses the concept of a pit-couple.



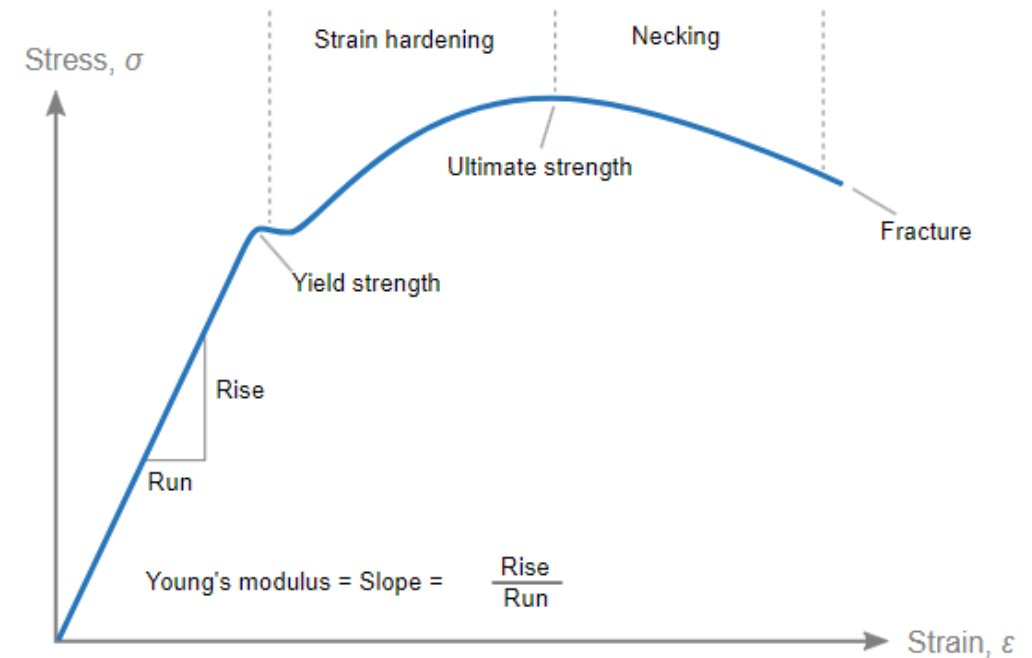
Level 3 Analysis

- Generally, numerical analysis is required - often FEA.
- The rules of ASME Sect. VIII, Div. 2 Part 5 are often utilized.
- Protection against failure modes
 - **Plastic collapse**
 - Local failure
 - Buckling
 - Ratcheting
 - Fatigue



Level 3 Analysis

- Three methods are given for evaluation:
 - Elastic stress
 - Limit load
 - Elastic-plastic



Summary

- Overview of API 579
- Three types of thinning damage and the evaluation technique.
- Advanced Analysis



Questions?

