Using Risk-Based Approaches to Define and Adjust Condition Monitoring Locations, Inspection Techniques and Intervals

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- Materials/Corrosion and Risk Management Engineer
- 30+ Years Refining, Petrochemical and Midstream Gas Processing Experience
- 10 years owner/user plant metallurgist/corrosion and corporate engineer
- 20+ years consulting with plant management, engineering and inspection departments:
  - Risk-Based technology (RBI) development leader
  - Development of implementation work process for plant application
  - Member of API committees for development of API 580 and API 581 recommended practices
- Project Manager of API RBI Project from 1996-2009
- Master Editor for API 581
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• Mechanical/Inspection and Reliability Engineer
• 30 Years Refining, Petrochemical and Oil and Gas Experience in Maintenance, Inspection and Reliability
• 20+ years owner/user inspection engineer, inspection program manager, reliability manager
• Extensive experience in working with existing inspection organizations and developing practical strategies for program improvement
• Actively involved in the API RBI development project and implementation of API RBI programs in a number of plants as an owner/user and as a consultant
• Master Editor for API 585
Purpose

• Purpose of the Presentation
  – Develop a process for using risk-based results to define methods, extent and frequency of inspection for piping
  – Present a way to optimize CML’s
  – Present an inspection prioritization method to be used with or without quantitative RBI

• Sources
  – API 570
  – API 510
  – API 580
  – API 581
Outline

• Defining piping circuit CML’s
• Maintaining CML’s
• Guidance from the API Codes
• A Risk Based Process to guide CML placement
• Example – Piping Circuitization
• Example – Crude Preheat Piping CML placement
• Example – Coker LSR Reflux Piping CML placement
• Conclusion/Summary
Piping Circuit CML’s

• How many CMLs are needed to monitor for General Thinning only?
• How many CMLs are needed to monitor for Localized Thinning?
• Is more thickness data better?
Setting Up CML’s

• Identify locations on drawings and pipe
• Set up equipment, component and circuits in database
• Identify applicable specifications, material of construction and design pressure & temperature
• Document starting thickness and service start date
• Identify minimum thickness and/or alert thickness
Maintaining CML’s

- Conduct Inspection
  - Access to location
  - Calibrate properly
  - Take measurements
  - Record measurement
- Input readings in database
- Perform calculations
- Evaluate corrosion rate and Remaining Life
- Schedule next inspection
API 570 Guidance (5.6.3)

- A decision on the type, number and location of the CML’s should consider results from previous inspections, the patterns of corrosion and damage that are expected and the potential consequence of loss of containment.
- In theory, a circuit subject to perfectly uniform corrosion could be adequately monitored with a single CML.
API 570 Guidance (5.6.3)

• Inspectors must use their knowledge of the process unit to optimize the CML selection for each circuit, balancing the effort of collecting the data with the benefits provided by the data.
API 570 Guidance (5.6.3)

• More CML’s should be selected for piping systems with any of the following characteristics:
  – a) higher potential for creating a safety or environmental emergency in the event of a leak;
  – b) higher expected or experienced corrosion rates;
  – c) higher potential for localized corrosion;
  – d) more complexity in terms of fittings, branches, deadlegs, injection points, and other similar items;
  – e) higher potential for CUI.

• Fewer CML’s can be selected for piping systems with any of the following three characteristics:
  – a) low potential for creating a safety or environmental emergency in the event of a leak;
  – b) relatively noncorrosive piping systems;
  – c) long, straight-run piping systems.
Risk Based Inspection Codes

• RBI may be used to determine inspection interval, type and extent of future inspection/examinations (API 570)
• API 580 provides no guidance on specific type and extent of inspection based on risk levels
• API 581 provides examples of various types of inspection for various damage types, coverage and extent
Risk Based Inspection

• Any RBI methodology requires:
  – POF – COF used in a matrix and generates a risk category
  – Credible corrosion/materials review for current operating conditions
  – Understanding of process operation including normal operation, upsets and start-up/shutdown
  – Review and consistent credit for historical inspection
  – Does not require quantitative, highly technical approach to be credible

Note: Use of a qualitative approach requires more expertise and qualified practitioners.
Risk Based Inspection

• Corrosion System must be properly defined:
  – Corrosion Systems defined as equipment controlled together
  – In similar operating service
  – Expect similar corrosion mechanisms and rates
  – Share Integrity Operating Window (IOW) criteria alerts and alarms

• Corrosion Circuit must be properly defined:
  – Equipment with the same expected corrosion mechanisms and rates
  – Same material of construction
  – Same or very similar operating conditions
  – Equipment thickness measurements and calculated corrosion rates should be manageable as a group

• IOW set by weakest link of circuit per corrosion system
Corrosion System HGO Stripper Pumparound
Corrosion System HGO Stripper Pumparound

5 Cr – ½ Mo

Carbon Steel
CS-5Cr Spec Break
Possible Deadleg
Valve NC

1.8 Avg. 3.2% max. Sulfur
5Cr- ½ Mo @ 465F 2.2 mpy
Carbon Steel @ 465F is 5.5 mpy; @ 440F is 2.0 mpy

IOW based on total Sulfur & Operating Temperature with notice of accelerated CS corrosion rates if bypass valve open during normal operation.
Risk-Based Methodology

• Define the risk based criteria for assigning inspection methods and extent
• Damage assessment
  – Damage Type (Thinning (general, local), cracking, etc.
• Define POF for each damage mechanism
• Define COF based on process fluid and operating conditions
• POF and COF defines the risk using matrix location
• Risk and type of damage expected defines CML approach
Inspection Planning Options

• ½ Life Inspection – performed on or before equipment reaches ½ life based $T_{\text{min}}$ and corrosion rate (condition-based) or max interval

• Risk Target – Risk escalates with time requiring inspection on or before the date the risk target is reached

• Frequency – performed on or before a maximum frequency as determined by risk based matrix location (often the shorter of risk max date and ½ life)

• Frequency Adjustment Factor - performed on or before a remaining life adjusted interval, determined by risk based matrix location
Risk-Based Inspection Planning

Consequence of Failure

Probability of Failure

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<td>MediumHigh</td>
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</table>
Example 1 – Crude Feed Preheat

• Risk Category: Low (POF 2 – COF 2)
• 12-inch carbon steel piping
• Thinning mechanism is general, aqueous corrosion
• Measured (RCR) corrosion rate: 3.4 mpy
• Process Fluid is C_{17}-C_{25} liquid
• Recommended inspection date January 2022
Example 1 – Existing

Existing CML’s
34 Total CMLs
7 on Straight pipe
11 on fittings
16 on deadlegs
Example 1 – Recommended

Recommended CML’s
12 Total CMLs
4 on straight pipe
6 on fittings
2 on deadlegs
Next Inspection Jan 2022
Example 1 – Existing, All Data
Example 1 – Recommended

![Graph showing Corrosion Rate MPY vs Individual TMLs]

- **LONGRATE**
- **SHORTRATE**

Corrosion Rate MPY

Individual TMLs
Example 2 – Coker Fractionation LSR Reflux

- Risk Category: High (POF 4 – COF 3)
- 6-inch Carbon Steel & 9 Cr – 1 Mo piping
- Carbon Steel
  - Damage Mechanism for the carbon steel is localized thinning
  - Measured corrosion rate: 14.4 mpy
- 9 Cr – 1 Mo
  - Damage Mechanism for the 9 Cr – 1 Mo is localized thinning
  - Expected corrosion rate: 1 mpy
- Fluid is liquid C₆-C₈ liquid
- Circuit includes vacuum resid start-up line, resid bypass line and a condensate line
- Recommended inspection date August 2013
Example 2 – Existing

Existing Drawing
28 Total CMLs
10 on Straight pipe
8 on fittings
10 on deadlegs

Carbon Steel Section
18 Total CMLs
8 on Straight pipe
7 on fittings
3 on deadlegs
Example 2 – Recommended

Recommended CML’s on Carbon Steel
11 Total CMLs
4 on straight pipe
6 on fittings
1 on deadlegs
Next Inspection Aug 2013
Example 2 – Existing, All Data
Example 2 – Carbon Steel
UT and RT Methods

Corrosion Rate (MPY)

Individual TMLs

LONGRATE

SHORTRATE
Example 2 – Carbon Steel
UT Method TMLs Only
Example 2 – Recommendations

• Additional Recommendations:
  – Separate isometric piping into 5 circuits
  – Evaluate POF and COF for each circuit separately
  – Define CML’s per each new circuit based on damage types and expected or measured rates

• Evaluate practice of combining UT and RT inspection data for measured thicknesses to determine corrosion rates

• Evaluate practice of combining straight run and fitting CMLs in the same circuit
## Examples Summary

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<tr>
<th>Example 1</th>
<th>Circuit Data</th>
<th>Current</th>
<th>Recommended</th>
<th>Minimum</th>
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<td>Straight Run</td>
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<td>7</td>
<td>4</td>
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<td>Fittings</td>
<td>27</td>
<td>11</td>
<td>6</td>
<td>1</td>
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<td>Deadlegs</td>
<td>16</td>
<td>16</td>
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<td>1 (5%)</td>
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<td>Total CML</td>
<td>34</td>
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<table>
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<th>Circuit Data</th>
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<tr>
<td>Fittings</td>
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<td>7</td>
<td>6 RT or UT scan</td>
<td>3</td>
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<tr>
<td>Deadlegs</td>
<td>1</td>
<td>3</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Total CML</td>
<td>18</td>
<td>11</td>
<td>5</td>
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</table>
Summary/Conclusions

Unless piping inspection programs are based on:

- Inspection by CML types (straight runs, fittings, deadlegs, injection/mix points, heads, etc.)
- Inspection methods types & measurement error (such as UT, RT)
- Extended frequency/interval of measurements for low COF services
- Circuitization of equipment, specifically piping, with same materials of construction and expected corrosion rates
- Less but higher quality inspection data combined with circuit level analysis and inspection planning

....difficult to break the cycle of chasing ½ life inspection of CML’s
Questions?

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