A Damage Mechanisms Methodology for Refinery Process Units

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Presentation Outline

- Introduction
  - Background of DMR Template Development
  - Show Examples of Templates & Methodology Used

- Case Study – Marathon Petroleum

- Case Study – Chevron

- Summary & Conclusions

- Questions
Background

- Marathon wanted to improve PHA team knowledge & understanding of refinery Damage Mechanisms (DMs)
  - Include more detailed materials & corrosion dialogue in the PHA process

- Subsequent discussions with Chevron indicated generally similar interests
  - Long-term goal to have unit-specific (corrosion) PFDs for each operating unit

- Help prevent loss of containment
Methodology
Damage Mechanisms Review (DMR) Templates

- Generic Damage Mechanisms PFDs
- Process Unit Descriptions & Primary DMs
- Assessment Tools
Starting point was API 571 generic PFDs which include “most likely” Damage Mechanisms.

API 571 PFDs modified to include corrosion “Systems” or “Loops” based on major process sections (e.g., Feed, Reaction, Separation, etc.).

Unit-specific PFDs to be used for some units.

Created new DMs (e.g. deadlegs and mix points).
Hydroprocessing Units - Hydrotreating, Hydrocracking

Key to Damage Mechanisms:
1. Sulfidation
2. Wet H2S Damage (Blistering/HIC/SOHIC/SSC)
3. Creep / Stress Rupture
4. High Temp H2/H2S Corrosion
5. Polytrophic Acid Cracking
6. Naphthenic Acid Corrosion
7. Ammonium Bisulfide
8. Ammonium Chloride Corrosion
9. HCl Corrosion
10. High Temperature Hydrogen Attack
11. Temper Embrittlement
12. Erosion / Erosion–Corrosion
13. Amine Cracking
14. Chloride Stress Corrosion Cracking
15. Hydrogen Embrittlement
16. Short term Overheating – Stress Rupture
17. Brittle Fracture
18. Sigma Phase/ Chi Embrittlement
19. Reheat Cracking
20. Amine Corrosion
21. Corrosion Under Insulation (CUI)
DMR Templates
Process Descriptions & Primary DMs

- Process description of each System/Loop prepared.

- Detailed description of relevant damage mechanisms developed.

- Critical factors/conditions affecting damage in each System / Loop identified. Referred to as “assessment triggers,” (e.g., for sulfidation – 5Cr>600°F with sulfur >3 wt%).
DMR Templates
Assessment Tools

- Questionnaire developed to assist the PHA Team in determining the compatibility of the process stream conditions & materials of construction

- Benefits:
  - Enabled methodical approach to evaluate each area of concern
  - Incorporated assessment triggers
  - Allowed for concise documentation of results
<table>
<thead>
<tr>
<th>PFD Section</th>
<th>Section</th>
<th>Damage Mechanism</th>
<th>571 DM#</th>
<th>Materials Assessment</th>
<th>Y / N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reactor/Heater</td>
<td>CRU Reactor/Heater</td>
<td>High Temperature Hydrogen Attack</td>
<td>10</td>
<td>Are specification break(s) of carbon steel to higher alloys operating at &lt; 450°F? Are hotter materials acceptable per Assessment triggers?</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Stress Rupture or Creep</td>
<td>3</td>
<td>Do heater tubes have a defined maximum tube metal temperature that is based on original API design basis or API 579 Fitness for Service Analysis?</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Carburation/Metal Dusting</td>
<td>24, 59</td>
<td>Does the feed stream have a minimum S level requirement? (either feed S or sulfiding agent)</td>
<td></td>
</tr>
</tbody>
</table>
## Examples of Assessment Questions

<table>
<thead>
<tr>
<th>Y / N</th>
<th>Possible Follow-up</th>
<th>Consequence</th>
<th>Damage Morphology</th>
<th>Recommendation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><strong>Tech</strong>: Evaluate HTHA exposure. (Include non PWHT assessment exposure). <strong>Insp</strong>: HTHA inspections.</td>
<td>Hydrogen, naphtha, reformate</td>
<td>Reduced strength, fissures, cracks, rupture</td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Tech</strong>: Confirm design basis and TMT maximums for heater tubes.</td>
<td>Hydrogen, naphtha, reformate</td>
<td>Reduced strength, bulging and yielding, rupture</td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Tech</strong>: Troubleshoot if S levels too low. <strong>Insp</strong>: Thickness monitoring for metal</td>
<td>Hydrogen, naphtha, reformate</td>
<td>Reduced toughness, crack thinning</td>
<td></td>
</tr>
</tbody>
</table>
Case Study – Marathon Petroleum

Dana Williams
Case Study – Marathon Petroleum

Scope

Develop unit specific guidance documents designed to provide a systematic and conservative set of assessment questions (“triggers”)

To assist Marathon Petroleum Company PHA Teams in identifying potential corrosion and material degradation mechanisms
Guidance Document Deliverables

✓ Provide operating unit descriptions, divided into sections.
✓ The section division consistent with assessment checklist questions.
Guidance Document Deliverables

- Provide operating unit descriptions, divided into sections. The section division consistent with assessment checklist questions.

- Provides common materials degradation summary associated with each operating unit and establishing criteria to assess the potential impact.
Guidance Document Deliverables

- Provide a operating unit descriptions, divided into sections. The section division consistent with assessment checklist questions.

- Provides common materials degradation summary associated with each specific operating unit along with establishing criteria to assess the potential impact.

- Provides assessment checklist organized by unit section. Questions formatted to generate a simple YES or NO response, and a suggested “Issue Follow-up” dependent upon the response.
Utilization

- Refinery A: Pilot (Nov. 2012), LEP, LPVGO, HPVGO, CCR1, CCR2, Gas Con (2), Sat Gas, HF Alkylation
- Refinery B: FCC revalidation, CCR Reformer, NPT, Crude, DHT
- Refinery C: FCC Unit
- Refinery D: Coking, Hydrotreater, Sat Gas

Note: All above completed prior to formalized implementation within standard practice.
User Feedback

☑ Major shift in emphasis on PHA corrosion discussion from a historical perspective.

Reactive  Proactive
User Feedback

✓ Assessment checklist asks the questions in such a way it drives the team to straightforward “Yes” or “No” responses along with the suggested follow-up.
User Feedback

Interaction with diverse group of team members provided discussion forum on how process conditions interacted with materials/corrosion limitations beyond the perceived “pressure & temperature mechanical limits”.
User Feedback

- Questionnaires are self-driven and user friendly
- Doesn’t require highly trained metallurgy / corrosion SME present in the room
- Team resource requires an individual capable of determining materials of construction and process variables
Case Study – Chevron

Orin Wakefield
Deliverable:

- To have a documented discussion conducted by a cross-functional team of plant SMEs that:
  - Considers potential metallurgy/corrosion damage mechanisms at the PFD level for given metallurgy and the plant process conditions
    - E.g. Sulfidation Corrosion, High Temperature H2 Attack (HTHA), Wet H2S Corrosion, etc.
    - Damage mechanisms consistent with API 571 and/or Chevron U.S.A. Inc. programs
Key Functional Requirements:

- Considers mitigations/safeguards in place, such as inspection, process monitoring, procedures
- Identifies concerns and possible recommendations to address concerns
- Finalizes recommendations in conjunction with Business Unit and Fixed Equipment Management
- Documentation allows other teams (PHA, e.g.) to consider damage mechanisms as part of their work processes
Work Process Summary:
- Manufacturing process to be implemented at all US refineries
- Reviews completed prior to scheduled PHA
- Fixed Equipment Integrity leads DMR
- Business Unit Management leads solution development and tracking to resolution in partnership with Reliability Engineer
### Roles and Responsibilities:

<table>
<thead>
<tr>
<th>Key Performer</th>
<th>Key Behavior</th>
</tr>
</thead>
</table>
| Materials Engineer             | • Review Manufacturing template and gather information as appropriate  
                                 | • Schedule and lead DMR pre-work session  
                                 | • Facilitate DMR meeting  
                                 | • Participate in follow-up action plan meetings (Solutions Workshops)                                                                                                                                     |
| Inspector/Analyst              | • Participate in pre-work session as requested  
                                 | • Participate in DMR meeting and associated Solutions Workshops                                                                                                                                               |
| DMR Document Specialist        | • Coordinate DMR documents, schedule, meetings, reports, action items, and metrics  
                                 | • Scribe for DMR and associated Solutions Workshops                                                                                                                                                            |
## Roles and Responsibilities:

<table>
<thead>
<tr>
<th>Key Performer</th>
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</thead>
<tbody>
<tr>
<td>Fixed Equipment Integrity Manager</td>
<td>• Accountable for Damage Mechanism Review schedule</td>
</tr>
<tr>
<td></td>
<td>• Accountable for overall health of system through use of metrics, audits, &amp; behaviors</td>
</tr>
<tr>
<td></td>
<td>• Endorse DMR team recommendations</td>
</tr>
<tr>
<td>Reliability Engineer</td>
<td>• Participate in DMR pre-work session and meeting as requested</td>
</tr>
<tr>
<td></td>
<td>• Schedule and Facilitate Solutions Workshops (in partnership with OA)</td>
</tr>
<tr>
<td></td>
<td>• Enter items into tracking tool with appropriate due dates (in partnership with OA)</td>
</tr>
<tr>
<td>Technical SME</td>
<td>• Participate in DMR meeting and associated Solutions Workshops</td>
</tr>
</tbody>
</table>
### Roles and Responsibilities:

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<tbody>
<tr>
<td>Operations Assistant (OA)</td>
<td>• Assign operator resource to DMR</td>
</tr>
<tr>
<td></td>
<td>• Schedule Solutions Workshops (in partnership with Reliability Engineer)</td>
</tr>
<tr>
<td></td>
<td>• Enter items into tracking tool with appropriate due dates (in partnership with Reliability Engineer)</td>
</tr>
<tr>
<td>Business Unit Manager</td>
<td>• Endorse DMR team recommendations</td>
</tr>
<tr>
<td>M&amp;R, Ops, Refinery Managers</td>
<td>• Proactively champion process through communication and encouraging behaviors.</td>
</tr>
</tbody>
</table>
PREPARATION FOR DMR MEETING

DURATION: 1 MONTH BEFORE

WHO:
- MATERIALS ENGINEER
- INSPECTOR
- PROCESS ENG
- DESIGN ENG
- RELIABILITY ENGINEER
- OPERATIONS

DMR MEETING

DURATION: 2 DAYS MAXIMUM

WHO:
- MATERIALS ENGINEER
- INSPECTOR
- PROCESS ENG
- DESIGN ENG
- RELIABILITY ENGINEER
- OPERATIONS

DMR IMPLEMENTATION/SOLUTIONS WORKSHOPS

DURATION: 1–3 MONTHS

WHO:
- MATERIALS ENGINEER
- INSPECTOR
- PROCESS ENG
- DESIGN ENG
- RELIABILITY ENGINEER
- OPERATIONS
Figure 1. Caustic Scrubber PFD

- Off gases
- Makeup 12% NaOH
- Circulating NaOH
- Treated Gas

98% H2SO4 Neutralized Solution Neutralized Vent Gas

Mix Point
DL Dead Legs
9 HCl Corrosion
18 Caustic SCC
19 Caustic Corrosion
36 Sulfuric Acid Corrosion
## Template Assessment Item:

| CSN 1 | Neutralizer Isometric # or Equipment | Caustic Corrosion / Caustic Stress Corrosion Cracking (CSCC) | 18 | N | We think the plant is old enough that standoffs may not be present per current design standards. |

- All non-PWHT CS in caustic service with the following:
  - Steam tracing used in the in caustic service with no specific standoff controls to prevent point contact.
  - No operating practices to require water wash of non-PWHT CS before steam out exposures.

Is it confirmed that steam tracing is used, are there tracing standoffs to prevent point contact in caustic service?

| Ops | Ensure steam tracing if used is installed with standoffs. |

| Insp | Inspection of piping and dead legs for localized corrosion at locations where hot steam tracing contact is occurring. |

| Perform evaluation of steam tracing in plant to ensure standoffs are in place. Includes the following steps: |

1) Identify all steam traced piping and equipment.

2) Turnover identified lists to inspection.

3) Inspection group to x-ray areas to attempt to identify if standoffs are present.

4) If no standoffs are present, line will need to be uninsulated for inspection of the line to verify integrity. Otherwise, no additional action.
Key Learnings:

- Cross Functional team enhances knowledge of Damage Mechanisms
  - E.g. Operator/Inspector view “deadleg” differently
- Defining “DM sections” of unit on the PFD level can help identify boundaries and mitigations for DMs
- DMRs identified some “refinery-wide” gaps that could be addressed as larger projects instead of within individual units.
- Few real threats; but an opportunity to document safeguards that are already in place
Summary & Conclusions

- Damage Mechanisms Templates can be created for all Refining & Chemical Process Units.

- Can utilize generic PFDs, unit-specific PFDs or P&IDs
Summary & Conclusions

- Templates have been created for over 30 Refinery & Chemical Process units including:
  - Crude / Vacuum
  - Amine
  - Delayed Coker
  - Sulfuric Acid
  - Catalytic Reformer
  - HF Alkylation
  - SRU / TGT
  - Isomerization
  - SWS
  - Caustic Treating
- FCC & LERU
- Hydroprocessing
- Hydrogen Reforming
- Cat Poly
- Solvent De-asphalting
- Caustic Scrubber
- Naphtha Splitter
- Flare system
- Selective Hydrogenation
- LPG storage
- NH3 storage
- Visbreaker
- Hydrogen compression