Corrosion Control Documents Revisited - An essential element of a mechanical integrity and risk-based inspection program

by David Hendrix
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  - Professional Engineer in the State of Texas
  - Past Chair of the Houston chapter of NACE International
  - Past Chair of the Houston chapter of ASM International
  - API 653 Aboveground Storage Tank Inspector
  - API 580 Supplemental Inspection Certification in Risk-based Inspection
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- President of The Hendrix Group, Inc., a metallurgical engineering consulting company
  - Corrosion investigations
  - API 580 Risk-based inspection implementation
  - Failure analysis
  - API 579 fitness-for-service assessments
  - Metallurgical and mechanical testing
Purpose of Presentation

- To acquaint audience with corrosion control documents and their importance in mechanical integrity and inspection programs

  - Training
  - RBI programs
  - Inspection planning
  - Operating windows
  - Inspection technique selection
  - Inspection location selection
Elements of a CCD

Corrosion Control Document

- A document that summarizes:
  - Unit process description
  - Rationale for materials of construction
  - Discusses damage mechanisms
  - Defines corrosion circuits
  - Defines damage mechanisms in each circuit:
    - Includes critical locations
    - Start up and shut down influences
    - Includes predicted (or actual) corrosion rates and environmental cracking tendencies
The CCD Includes:

MOC diagram

CC diagram
CCD Inputs

- Process descriptions
- Hazops
- PFD’s
- P&ID’s
- Material and Heat Balance (H&MB)
- Equipment design
- Piping specifications
- Inspection and maintenance history
CCD Team Members

- Subject matter expert (SME)
- Operations
- Process
- Inspection
- RBI specialist (optional)
- Owner RBI focal point (optional)
- Licensor representative
How is a CDD Used?

- As a training tool
- TML and CML placement tool
- Input into RBI inspection programs
- Inspection Planning
- Optimizing inspection techniques
- Establish integrity operating windows
Corrosion Circuit Definition

- Fixed equipment and piping in a process with:
  - Same stream composition
  - Similar operating pressure and temperature
    < 25F (~13C) difference
    < 50 (~4 Barg) psig difference
  - Same materials of construction
  - Same phase, (liquid, vapor, etc.)
Attributes of a corrosion circuit

- Circuit numbering system (legend)
- Circuit description
- Materials of construction
- Stream composition
- OP/OT/Phase information
- Corrosion precursors
- Operational upsets influencing corrosion
Attributes of a corrosion circuit

- Damage mechanisms
- Corrosion rates (predicted or actual)
- Critical areas
- Operating envelopes
- Startup and shutdown considerations
Corrosion Circuit No.  11-001-09

Legend:     

Circuit Description
15-R-1101A/B Reactor outlet

Materials and Process

<table>
<thead>
<tr>
<th>Streams</th>
<th>Pipe</th>
<th>PV</th>
<th>V/L</th>
<th>OP</th>
<th>OT</th>
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<td>316LSS</td>
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Stream Components

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<tr>
<th>HAC</th>
<th>H2O</th>
<th>VAC</th>
<th>MEAC</th>
<th>ETAC</th>
<th>ACETALD</th>
<th>C2H4</th>
<th>CO2</th>
<th>N2</th>
<th>O2</th>
<th>AR</th>
<th>PBQ</th>
<th>EGDI</th>
<th>ACET</th>
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Corrosion Precursors
- HAc, H2O, CO2

Operational Upsets influencing corrosion
- none

Damage Mechanisms

<table>
<thead>
<tr>
<th>Damage mechanisms</th>
<th>CR, I.D./O.D. (mpy)</th>
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</thead>
<tbody>
<tr>
<td>Normal</td>
<td>Upset</td>
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<td>69</td>
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<td>Startup/Shutdown</td>
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<tr>
<td>Normal</td>
<td>Upset</td>
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</table>

Critical Areas
- none

Operating Envelope
- none

Startup and shutdown Considerations
- none
# Damage Mechanisms

Based on API 571

<table>
<thead>
<tr>
<th>Damage Mechanism No.</th>
<th>Description</th>
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<tbody>
<tr>
<td>1</td>
<td>Sulfidation</td>
</tr>
<tr>
<td>2</td>
<td>Wet H2S Damage (Blistering/HIC/SOHIC/SSC)</td>
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<tr>
<td>3</td>
<td>Creep / Stress Rupture</td>
</tr>
<tr>
<td>4</td>
<td>High temp H2S Corrosion</td>
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<tr>
<td>5</td>
<td>Polythionic Acid Cracking</td>
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<td>6</td>
<td>Naphthenic Acid Corrosion</td>
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<td>7</td>
<td>Ammonium Bisulfide Corrosion</td>
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<td>8</td>
<td>Ammonium Chloride Corrosion</td>
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<td>9</td>
<td>HCl Corrosion</td>
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<td>10</td>
<td>High Temperature Hydrogen Attack</td>
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<td>11</td>
<td>Oxidation</td>
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<td>12</td>
<td>Thermal Fatigue</td>
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<td>13</td>
<td>Sour Water Corrosion (acidic)</td>
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<td>14</td>
<td>Refractory Damage</td>
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<td>15</td>
<td>Graphitization</td>
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<td>Temper Embrittlement</td>
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<td>Decarburization</td>
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<td>Caustic Cracking</td>
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<td>Caustic Corrosion</td>
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<td>20</td>
<td>Erosion / Erosion-Corrosion</td>
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<td>21</td>
<td>Carbonate SCC</td>
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<td>22</td>
<td>Amine Cracking</td>
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<td>23</td>
<td>Chloride Stress Corrosion Cracking</td>
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<td>24</td>
<td>Carburetion</td>
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<td>25</td>
<td>Hydrogen Embrittlement</td>
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<td>27</td>
<td>Thermal Shock</td>
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<td>28</td>
<td>Cavitation</td>
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<td>Graphitic Corrosion (see Dealloying)</td>
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<td>30</td>
<td>Short term Overheating - Stress Rupture</td>
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<td>31</td>
<td>Brittle Fracture</td>
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<tr>
<td>32</td>
<td>Sigma Phase/Chi Embrittlement</td>
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<tr>
<td>33</td>
<td>885oF (475oC) Embrittlement</td>
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<td>34</td>
<td>Softening (Spheroidization)</td>
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<tr>
<td>35</td>
<td>Reheat Cracking</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Damage Mechanism No.</th>
<th>Description</th>
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<tbody>
<tr>
<td>36</td>
<td>Sulfuric Acid Corrosion</td>
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<td>37</td>
<td>Hydrofluoric Acid Corrosion</td>
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<td>38</td>
<td>Flue Gas Dew Point Corrosion</td>
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<tr>
<td>39</td>
<td>Dissimilar Metal Weld (DMW) Cracking</td>
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<td>40</td>
<td>Hydrogen Stress Cracking in HF</td>
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<td>41</td>
<td>Dealloying (Dezincification/ Denickellification)</td>
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<td>42</td>
<td>CO2 Corrosion</td>
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<td>43</td>
<td>Corrosion Fatigue</td>
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<td>Fuel Ash Corrosion</td>
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<td>45</td>
<td>Amine Corrosion</td>
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<td>46</td>
<td>Corrosion Under Insulation (CUI)</td>
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<td>47</td>
<td>Atmospheric Corrosion</td>
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<td>48</td>
<td>Ammonia Stress Corrosion Cracking</td>
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<td>49</td>
<td>Cooling Water Corrosion</td>
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<td>50</td>
<td>Boiler Water / Condensate Corrosion</td>
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<td>51</td>
<td>Microbiologically Induced Corrosion (MIC)</td>
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<td>52</td>
<td>Liquid Metal Embrittlement</td>
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<td>53</td>
<td>Galvanic Corrosion</td>
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<td>54</td>
<td>Mechanical Fatigue</td>
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<td>55</td>
<td>Nitriding</td>
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<td>56</td>
<td>Vibration-Induced Fatigue</td>
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<td>57</td>
<td>Titanium Hydriding</td>
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<td>58</td>
<td>Soil Corrosion</td>
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<td>59</td>
<td>Metal Dusting</td>
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<td>60</td>
<td>Strain Aging</td>
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<td>61</td>
<td>Steam Blanketing</td>
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<td>62</td>
<td>Phosphoric Acid Corrosion</td>
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<td>63</td>
<td>Phenol (carbolic acid) Corrosion</td>
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<td>Uniform Corrosion</td>
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<td>65</td>
<td>Pitting</td>
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<td>66</td>
<td>Underdeposit Corrosion</td>
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<tr>
<td>67</td>
<td>None</td>
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<tr>
<td>68</td>
<td>Intergranular Corrosion</td>
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<tr>
<td>69</td>
<td>Acetic Acid/Anhydride Corrosion</td>
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</tbody>
</table>
Stream Composition

- Typically obtained from H&MB
- Difficult to obtain in refining units
- Small amounts of corrosives might not be listed:
  - Chlorides
  - Injected chemicals
  - Process contaminants or upset OP
- Should review with owner process eng.
Corrosion Precursors

- Examples of stream constituents that can influence or accelerate corrosion:
  - CO₂
  - H₂S
  - Chlorides
  - Acids
  - Oxygen
  - cyanides
Operational upsets

- Chemical injection interruption
- Undersized separators
- Flooded towers
- Condensing in vapor lines
Critical Areas

- Location depends on damage mechanism
  - CO$_2$ – High velocity lines, elbows, etc.
  - Chlorides – Condensing, wet-dry, stagnant area, dead legs, etc.
  - Amine SCC – weld HAZ’s
- Up to unit inspector to locate specific areas in circuit on P&ID
Integrity Operating Windows

![Diagram](image)

Courtesy of Shell Global Solutions – Establishing Integrity Operating Windows, Inspector Summit. January 27, 2006 Galveston, TX/
Integrity Operating Windows

- Fall into two categories
  - Physical
    - limits on pressures and temperatures, partial pressures, dew points, delta P, etc.
  - Chemical
    - pH, water content, oxygen content, CO2 content, sulfur levels, injected chemicals, anhydride formation, acid strength, etc.

- Can be used as input into a MOC review.
Conclusions

Inputs to inspection planning/RBI

- Design data
- Operating data
- Inspection data
- Stream data
- Damage mechanisms (CCD)
Conclusions

Failure to properly execute any one of the three activities items can result lead to wasted money and equipment failures!
Summary

- What does this mean to the unit inspector?
  - If you don’t know the damage mechanism, you can’t inspect for it!
  - Inspection execution is where the rubber hits the road!
  - Inattention to any detail in the inspection planning process can waste money and lead to failures.
Questions?

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