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Damage Mechanisms Affecting Fixed Equipment in the Refining Industry (API 579-1ASME FFS-1RP 571) Training program

Introduction:

Over the past two decades, API has developed two major technologies to improve fixed equipment reliability in refining. They cover Fitness-For-Service (API 579-1/ASME FFS-1) and Risk-Based Inspection (RP 580/581). There are several common factors in both of these integral technologies, including:

- Identification of the operative damage mechanisms
- Assessment of future damage progression rates
- Selection of appropriate Non-Destructive Evaluation (NDE) techniques for detecting/characterizing equipment damage

API RP 571 was created to help link these technologies and to provide access to information in one concise source covering damage mechanisms. This Recommended Practice also aids in understanding damage inspected for in API 510/570 and API 653.

Understanding damage mechanisms and the effect of process conditions is important for several reasons:

- Setting up effective inspection plans requires an in-depth understanding of what kind of damage to look for and how to identify it.
- Methodologies for Risk-Based Inspection (RBI) and Fitness-For-Service (FFS) depend on the accurate prediction and determination of active mechanisms.
- An effective Management of Change (MOC) process needs to consider the effect of proposed changes on future degradation.

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Many problems can be prevented or eliminated if the precursors to damage are observed and monitored so that any potential damage is mitigated. Appropriate inspection and testing can achieve a proper balance between cost and effectiveness for the relevant mechanisms.

Who Should Attend?

Engineers, inspectors, designers, and experienced maintenance personnel who are involved in designing, operating, maintaining, repairing, inspecting and analyzing pressure vessels, piping, tanks and pipelines for safe operations in the refining, petrochemical and other related industries

Course Objectives:

By the end of this course delegates will be able to:

- Improve safety, reliability, and minimize liability of fixed equipment by learning common damage mechanisms in the refining and petrochemical industry as covered in API 571 are the primary objectives
- Learn the roles of the engineer and inspector in identifying affected materials and equipment, critical factors, appearance of damage, prevention and mitigation, inspection and monitoring
- Be introduced to the concepts of service-induced deterioration and failure modes
- Gain a fundamental understanding of damage mechanisms in metals
- Have an overview of basic metallurgy applicable to refinery construction materials
- Describe common refining processes on the Process Flow Diagram level, highlighting where various damage mechanisms are usually observed

- Discuss typical NDE methods and their ability to detect and characterize equipment damage
- Fully discuss the damage mechanisms that are found in refineries covered by RP 571
- Go through examples of equipment damage and failures

Course Outline:

Introduction to Carbon and Alloy Steel Metallurgy

- Basic carbon steel metallurgy: using the Fe-Fe3C phase diagram in practical terms
- Basic alloy steel metallurgy for high and low temperature service
- Common heat treatments for carbon and alloy steels

Introduction to Stainless Steel Metallurgy

- Types and classification of stainless steels
- General corrosion resistance of stainless steels (advantages and disadvantages)
- General introduction to the weldability of stainless steels and affect welding on corrosion resistance

Base Metal and Filler Metal Specifications - ASME Section II Parts A and C

- Classification of steels - UNS, SAE, ASTM, ASME
- ASME SA-105, SA-53, SA-106, SA-333, SA-516, SA-240
- AWS/ASME classification of filler metals, SFA No., F No., and A No
- Material test reports and what they really mean

Welding Metallurgy of Carbon and Alloy Steels

- Weldment and metallurgical heat affected zones using fundamental principles of welding metallurgy
- Use of carbon equivalence to predict weldability
- Hydrogen assisted cracking related to welding (toe cracking, cold cracking, delayed cracking, HAZ cracking, and underbead cracking)
- Preheating and postweld heat treat in practical terms to avoid cracking, improve weldability, and resist weld related failures

General Damage Mechanisms as Described in API 571

Mechanical and Metallurgical Failure Mechanisms

- Graphitization and Softening (Spheroidization)
- Temper Embrittlement
- Strain Aging
- 885°F Embrittlement
- Sigma Phase Embrittlement
- Brittle Fracture
- Creep/Stress Rupture
- Short Term Overheating—Stress Rupture
- Steam Blanketing
- Dissimilar Metal Weld (DMW) Cracking
- Thermal Shock
- Erosion/Erosion-Corrosion
- Cavitation
- Mechanical, Thermal and Vibration-Induced Fatigue
- Refractory Degradation
- Reheat Cracking

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Uniform or Localized Loss of Thickness

- Galvanic Corrosion, Atmospheric Corrosion
- Corrosion Under Insulation (CUI)
- Cooling Water Corrosion, Boiler Water Condensate Corrosion
- CO2 Corrosion
- Flue Gas Dew Point Corrosion
- Microbiologically Induced Corrosion (MIC)
- Soil Corrosion
- Caustic Corrosion
- Dealloying
- Graphitic Corrosion

High Temperature Corrosion, 400°F (204°C)

- Oxidation, Sulfidation, Carburization, Decarburization
- Metal Dusting, Fuel Ash Corrosion
- Nitriding

Environment-Assisted Cracking

- Chloride Stress Corrosion Cracking (Cl-SCC)
- Corrosion Fatigue
- Caustic Stress Corrosion Cracking (Caustic Embrittlement)
- Ammonia Stress Corrosion Cracking
- Liquid Metal Embrittlement (LME)
- Hydrogen Embrittlement (HE)

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Refining Industry Damage Mechanisms as Described in API 571

Uniform or Localized Loss in Thickness Phenomena

- Amine Corrosion
- Ammonium Bisulfide Corrosion (Alkaline Sour Water)
- Ammonium Chloride Corrosion
- Hydrochloric Acid (HCl) Corrosion
- High Temp H2/H2S Corrosion
- Hydrofluoric (HF) Acid Corrosion
- Naphthenic Acid Corrosion (NAC)
- Phenol (Carbonic Acid) Corrosion
- Phosphoric Acid Corrosion
- Sour Water Corrosion (Acidic)
- Sulfuric Acid Corrosion

Environment-Assisted Cracking

- Polythionic Acid Stress Corrosion Cracking (PASCC)
- Amine Stress Corrosion Cracking
- Wet H2S Damage (Blistering/HIC/SOHIC/SCC)
- Hydrogen Stress Cracking—HF
- Carbonate Stress Corrosion Cracking

Other Mechanisms

- High Temperature Hydrogen Attack (HTHA) and Titanium Hydriding