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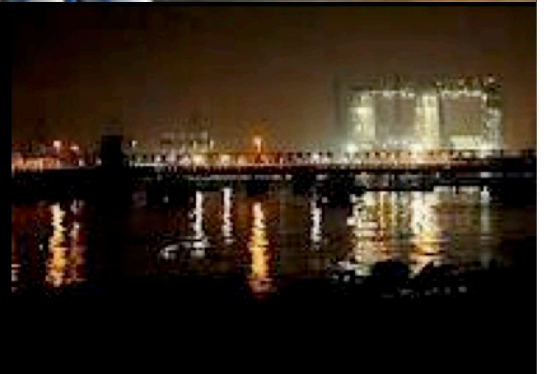
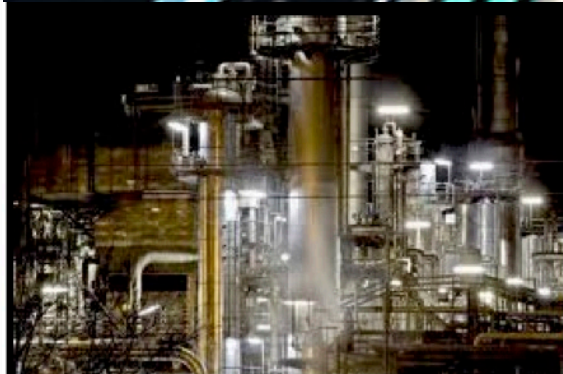
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CORROSION CONTROL IN THE REFINING INDUSTRY



**Nace internacional y
Europea de Ingenieros en
corrosión SAL**

Para más información:

Europea de Ingenieros en Corrosión SAL (*Licenciarios de Nace en España*)

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Course Topics

The following topics are included in *Corrosion Control in the Refining Industry*:

- Corrosion and Other Failures
- Crude Distillation and Desalting
- Fluid Catalytic Cracking Unit
- Cracked Light Ends Recovery (CLER) Units
- Hydrofluoric Acid Alkylation Units
- Sulfuric Acid Alkylation Units
- Corrosion in Hydroprocessing Units
- Catalytic Reforming Units
- Delayed Coking Units
- Amine Treating Units
- Sulfur Recovery Units
- Process Additives and Corrosion Control
- Corrosion Monitoring Methods in Refineries
- Refinery Injection Systems
- Materials of Construction for Refinery Applications
- Refinery Operations and Overview
- Failure Analysis in Refineries

Chapter 1: Corrosion and Other Failures

Introduction .

Low-Temperature Refinery Corrosion

Low-Temperature Corrosion Principles

Corrosion Rates and Polarization

Temperature and Concentration

Low-Temperature Conditions.

High-Temperature Refinery Corrosion

High-Temperature Corrosion Principles.

Linear Rate Law

Parabolic Rate Law .

High-Temperature Conditions .

Corrosion/Failure Mechanisms .
Metal Loss—General and/or Localized Corrosion.
GalvanicCorrosion
Pitting .
CreviceCorrosion
Intergranular Attack .
Erosion-Corrosion .
Hydrogen Chloride .
Ammonium Bisulfide (NH₄HS) Carbon Dioxide .
Process Chemicals .
Organic Chlorides
Aluminum Chloride .
SulfuricAcid
Hydrofluoric Acid .
Phosphoric Acid.
Phenol(CarboicAcid)
Amines .
Atmospheric (External) Corrosion.
Corrosion Under Insulation (CUI)
High-Temperature Sulfide Corrosion (Without Hydrogen Present)
High-Temperature Sulfide Corrosion (With Hydrogen)
Naphthenic Acid Corrosion .
High-Temperature Oxidation.
StressCorrosionCracking(SCC)
Chloride Stress Corrosion Cracking (CISCC) .
Alkaline Stress Corrosion Cracking (ASCC) .
CarbonicAcid(WetCO₂)
PolythionicAcidStressCorrosionCracking(PTASCC)
Ammonia Stress Corrosion Cracking (NH₃ SCC) .
WetH₂S cracking
Hydrogen Blistering .
SulfideStressCracking(SSC)
HydrogenInducedCracking(HIC)
Stress Oriented Hydrogen Induced Cracking (SOHIC) .
HydrogenCyanide(HCN)
SCC Prevention.
Inspecting for Wet H₂S Damage .
High-Temperature Hydrogen Attack (HTHA) .
MetallurgicalFailures .
GrainGrowth
Graphitization
Hardening
Sensitization .
Sigma Phase .

885°F (475°C) Embrittlement.
Temper Embrittlement
Liquid Metal Embrittlement (LME) .
Carburization
Metal Dusting
Decarburization
Selective Leaching
Mechanical Failures.
Incorrect or Defective Materials
Mechanical Fatigue . .
Corrosion Fatigue
Cavitation Damage .
 Mechanical Damage
Overloading
Overpressuring .
Brittle Fracture
Creep.
Stress Rupture .
Thermal Shock .
Thermal Fatigue .
Other Forms of Corrosion .
Boiler Feed Water Corrosion
Steam Condensate Corrosion .
Cooling Water Corrosion .
Fuel Ash Corrosion.

Chapter 2: Crude Distillation and Desalting

Introduction .
Sources of Crude Oil.
Composition of Crude Oil .
 . Remaining Constraints
More about Crude Oil Composition Crude Oil Pretreatment .
Desalting .
Preflash
Crude Distillation Unit .
Operation of a Crude Distillation Unit Corrosion in Crude Distillation Units .
Columns . .
 Exchangers and Piping .
 . Fired Heaters.
Other Corrosion Combating Measures Blending .
Desalting .
Caustic Addition .
Overhead pH Control .
 Corrosion Inhibitor .
Water Washing .

Corrosion Monitoring in Crude Units . Water Analysis (Overhead Corrosion Control)
Hydrocarbon Analysis
Corrosion Rate Measurement .
On-Stream, Non-Destructive Examination
Optional Team Exercise

Chapter 3: Fluid Catalytic Cracking Units

Introduction .
Hardware .
Riser/Reactor
Regenerator .
Flue Gas System.
Fractionator
Corrosion Control in FCC Units
Materials of Construction
Damage Mechanisms and Suitable Materials
Reactors
Regenerators.
Catalyst Transfer Piping System .
Reaction Mix Line, Main Fractionator, and Bottoms Piping .
Flue Gas Systems .
Inspection and Control Considerations
High-Temperature Oxidation
High-Temperature Sulfidation (H₂S Attack) High-Temperature Carburization .
Polythionic Acid Stress Corrosion Cracking Catalyst Erosion
Feed Nozzle Erosion.
Refractory Damage .
High-Temperature Graphitization.
Sigma Phase Embrittlement
885°F (475°C) Embrittlement .
Creep Embrittlement
High-Temperature Creep
Thermal Fatigue .
Optional Team Exercise

Chapter 4: Cracked Light Ends Recovery Units

CLER Process Description
Materials of Construction
Columns
Exchangers
Corrosion Problems
Corrosion
Hydrogen Induced Damage
Inspection Techniques for Hydrogen-Induced Damage
Prevention and Repair Techniques . Ammonia Stress Corrosion Cracking
Carbonate Stress Corrosion Cracking. . Fouling/Corrosion of Reboiler Circuits

Corrosion Control Measures

. Water Washing

Polysulfide Injection

Corrosion Inhibitors .

Corrosion Monitoring

Hydrogen-Activity Probes .

Chemical Tests .

Corrosion Probes.

Chapter 5: Hydrofluoric Acid Alkylation Units

Introduction .

HF Alky Process Description Materials of Construction . . .

Columns .

Exchangers .

Piping .

Bolting

Corrosion Problems

Corrosion

Hydrogen Induced Damage .

Inspection and Mitigation

Corrosion Control Measures .

Corrosion Monitoring .

Corrosion Probes.

Chapter 6: Sulfuric Acid Alkylation Units

Introduction

Process Description .

Reaction Section

Treating Section

Fractionation Section

Refrigeration Section Materials of Construction .

Materials and Corrosion Problems .

Sulfuric Acid Corrosion .

Acid Concentration .

Acid Temperature and Velocity.

Acid Dilution .

Hydrogen Grooving .

Feed Contaminants .

Acid and Neutral Esters

Acid Esters

Neutral Esters.

Acid Carryover .

Corrosion Under Insulation .

Fouling Problems

Corrosion Control Measures

Reactor Section Corrosion
Tower Overhead Corrosion
Reboiler Corrosion and Fouling Control .
Acid Tanks
Corrosion Control During Unit Shutdowns
Corrosion Under Insulation (CUI) .
Corrosion Monitoring
Inspection.
Reaction Section
Treating Section
Fractionation Section
Refrigeration Equipment.
Acid Tank .

Chapter 7: Hydroprocessing Units

Introduction
Hydroprocessing
Hydrotreating
Hydrocracking
Variations on Hydroprocessing
Types of Corrosion Common in Hydroprocessing Units
High-Temperature Hydrogen Attack
High-Temperature H₂S Corrosion – With Hydrogen Present .
High-Temperature H₂S Corrosion – With Little or No Hydrogen Present
Naphthenic Acid Corrosion
Ammonium Bisulfide Corrosion
Chloride Stress Corrosion Cracking (SCC)
Failures Often Happen After Startup
Additional Considerations with Stainless Steel
Polythionic Acid (PTA) Stress Corrosion Cracking
Stainless Steels Used to Prevent PTA
Other Methods to Prevent PTA SCC
Wet H₂S Cracking
Sulfide Stress Cracking (SSC)
Hydrogen Induced Cracking (HIC) and Stress-Oriented Hydrogen Induced Cracking (SOHIC)
Material Property Degradation Mechanisms
Temper Embrittlement
Hydrogen Embrittlement
Selection of Materials
Reactor Loop – General
Reactor Feed System
Reactor Feed Furnaces
Reactors
Reactor Effluent System
Reactor Effluent – Distillation Feed Exchangers

Effluent Air Coolers
Effluent Air Cooler Inlet and Outlet Piping
SeparatorVessels
RecycleHydrogenSystem
Distillation Section

Chapter 8: Catalytic Reforming Units

Introduction
Octane Number (RON)
Catalyst
Catalytic Reforming Processes
Catalytic Reformer, Semi-Regenerative
Reactor Design
Corrosion Phenomena in Catalytic Reformers
High Temperature Hydrogen Attack (HTHA)
Stress Corrosion Cracking
Materials of Construction
Reactors
Exchangers and Piping
Fired Heaters and Other Equipment
Corrosion Control
Corrosion Monitoring
Inspection in Catalytic Reformers

Chapter 9: Delayed Coking Units

Introduction
Equipment and Operation of the Delayed Coking Unit
Corrosion and Other Problems in Delayed Coking Units
High-Temperature Sulfur Corrosion.
NaphthenicAcidCorrosion
High-Temperature Oxidation/Carburization/Sulfidation
Decoking Heater Tubes
Erosion-Corrosion
Aqueous Corrosion
CorrosionUnderInsulation(CUI)
Thermal Fatigue, and Temper Embrittlement of Cr-Mo Steels
InspectionofCokingUnits
GeneralInspection
CokeDrumInspection

Chapter 10: Amine Treating Units

Introduction
Types of Amines Used
Refinery Amine Process Description
Tail Gas Units
Corrosion Phenomena
CorrosiveSpecies

Amine Degradation
Cracking Phenomena
Corrosion Inhibitors.
Materials of Construction
Corrosion Monitoring
Corrosion Control Measures

Chapter 11: Sulfur Recovery Units

Introduction
Sulfur Recovery Units
Sulfur Chemical Reactions
Sulfur Recovery Process.
Tail Gas Treating Unit
Incinerator
Cold Bed Adsorption (CBA) Unit
Corrosion Mechanisms
Sulfidation of Carbon Steels
Sour Environment Corrosion
Weak Acid Corrosion
Corrosion of Claus Units by System
Feed Gas System.
Corrosion Concerns
Mitigation of Corrosion
Reaction Furnace and Waste Heat Exchanger Systems
Corrosion Concerns
Mitigation of Corrosion
Inspections in the Reaction Furnace and Waste Heat Exchanger System
Claus Reactors, Condensers, and Reheat System
Corrosion Concerns
Mitigation of Corrosion
Inspections in the Claus Reactors, Condensers, and Reheat System
Liquid Sulfur Rundown Lines and Storage System
Corrosion Concerns
Mitigation of Corrosion
Inspections in Liquid Sulfur Rundown Lines and Storage System
Corrosion of CBA Units
Corrosion Concerns
Mitigation of Corrosion
Inspection of CBA Reactors, Condensers, and Piping
Corrosion of Tail Gas Treating Units
Burner and Mixing Chamber .
Tail Gas Reactor and Waste Heat Exchanger
Water Quench and Recirculation Blower System
H₂S Adsorption System
Corrosion in the Incinerator System

Chapter 12: Refinery Injection Systems

Introduction
Definitions
Injection Point
Injection System
InjectionSystemDesign
InjectionSystemDesignParameters
EngineeringPractices
ProcessDesign
Materials Selection Considerations
Inspection of Injection Point Locations
Location of Injection Point
Co-Injectants
Injection System Hardware.
Chemical Storage Tanks
Chemical Injection Pumps
Additive Control Systems
PipingSystems
Injector .

Chapter 13: Process Additives and Corrosion Control

Introduction
Factors Affecting Corrosion
Acids
Temperature
Pressure.
Flow
Turbulence
Material Selection
Methods to Mitigate Corrosion
Desalting and Caustic Injection
Water Washing
. Acid Neutralization.
Barrier between Metal and Environment Chemicals Used to Combat Corrosion .
FilmingAmines
Filmer Formulation
FilmerApplication
TreatRates
Monitoring Filmer Performance
Neutralizing Amines
Polysulfides
Naphthenic Acid Corrosion Inhibitors .
Application of Corrosion Inhibitors

Chapter 14: Corrosion Monitoring in Refineries

Introduction
Uses of Corrosion Monitoring

Corrosion Monitoring Techniques.
Corrosion Coupons
Electrical Resistance Monitoring
Electrochemical Corrosion Monitoring Linear Polarization Resistance
Potential Monitoring
Zero Resistance Ammetry (ZRA
. Electrical Impedance Spectroscopy (EIS)
Electrochemical Noise (EN)
Hydrogen Flux Monitoring.
A Comprehensive Corrosion Monitoring Program
Corrosion Monitoring Sites
Corrosion Monitoring in Specific Process Units
Atmospheric Distillation Unit (ADU)
Vacuum Distillation Unit (VDU)
Fluid Catalytic Cracking Unit (FCCU) Amine Treating Unit (ATU)
Sour Water Stripper Units (SWSU)
Sulfuric Acid Alkylation Unit (SAU) .
Automated On-Line Monitoring.

Chapter 15: Materials of Construction for Refinery Applications

The Role of the Corrosion Engineer Problem Definition
Corrosion Failures
Corrosion Testing Methods
Materials Selection Approach
Using Professional Consultants . Specifying Materials
National Standards
Company Standards
What the Designer Should Remember When Writing Specifications
Questions the Designer Should Ask to Control Quality
Fitness for Service
Refinery Materials of Construction
Introduction
Killed Steel
Steels.
Carbon Steel
C-Mo Steels
Low-Alloy Steels
Cr-Mo Steels
Nickel Steels
Stainless Steels
Martensitic Stainless Steels
Ferritic Stainless Steels
Austenitic Stainless Steels
Precipitation Hardening Stainless Steels
Duplex Stainless Steels

Specialty Stainless Steels

Cast Irons

Gray Cast Irons

Ductile Irons

High-Silicon Cast Irons

Nickel Cast Irons

Other Metals and Alloys

Copper and Its Alloys

Nickel Alloys

Aluminum

Titanium and Its Alloys

Non-Metallic Materials.

Refractories

Plastics

Thermosetting Resins

Heat Treatment

Normalization

Annealing

Quenching.

Stress Relieving

Solution Heat Treatment

Specialized Heat Treatments

What the Designer Should Know About Heat Treatments.

Heat Treatment Verification .

Heat Treatment for Welds.

Preheat

Postweld Heat Treatment.

Normalizing

Welding

The Nature of Welding .

Welding Decisions

Welding Processes

Shielded Metal Arc Welding (SMAW)

Gas Metal Arc Welding (GMAW)

Gas Tungsten Arc Welding (GTAW)

Submerged Arc Welding (SAW)

Welding Procedures and Welder Qualification

Inspection of Welding Electrodes and Filler Metal

Chapter 16: Refinery Operations and Overview

Introduction

Refinery Operating Objectives

Refining Process Overview

Process Interactions with

Chapter 17: Failure Analysis in Refineries

Introduction
Procedural Approach and Test Methods
Background Information
Initial Examination
Nondestructive Testing.
Surface Deposit Analysis
FieldMetallographicReplication(FMR)
HardnessTesting
ChemicalAnalysis
Magnetic Particle Inspection (MPI)
Wet Method .
Dry Method
Dye Penetrant Testing (PT)
Sectioning.
Macroscopic Examination of Fracture Surfaces.
Microscopic Examination
Fracture Appearance
DuctileFracture
BrittleFracture
FatigueFractures
h Corrosion
Stress Corrosion Cracking
Creep Rupture Failures
Additional Testing and Analysis.
Mechanical Testing
Application of Fracture Mechanics Root Cause Analysis.
Recommendations