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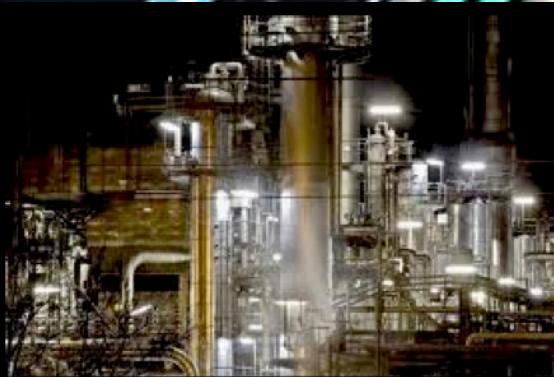
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Cursos Nace International

## CORROSION CONTROL IN THE REFINING INDUSTRY



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

Para más información:

Europea de Ingenieros en Corrosión SAL (*Licenciatarios 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(CarbolicAcid)  
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) .  
WetH2SCracking  
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 (H<sub>2</sub>S Attack) High-Temperature Carburization .

Polythionic Acid Stress Corrosion Cracking CatalystErosion

Feed Nozzle Erosion.

Refractory Damage .

High-Temperature Graphitization.

SigmaPhaseEmbrittlement

885°F (475°C) Embrittlement .

CreepEmbrittlement

High-TemperatureCreep

Thermal Fatigue .

OptionalTeamExercise

### **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  
TowerOverheadCorrosion  
Reboiler Corrosion and Fouling Control .  
Acid Tanks  
Corrosion Control During Unit Shutdowns  
Corrosion Under Insulation (CUI) .  
CorrosionMonitoring  
Inspection.  
Reaction Section  
TreatingSection  
FractionationSection  
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 H<sub>2</sub>S Corrosion – With Hydrogen Present .  
High-Temperature H<sub>2</sub>S 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 H<sub>2</sub>S 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  
Separator Vessels  
Recycle Hydrogen System  
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.  
Naphthenic Acid Corrosion  
High-Temperature Oxidation/Carburization/Sulfidation  
Decoking Heater Tubes  
Erosion-Corrosion  
Aqueous Corrosion  
Corrosion Under Insulation (CUI)  
Thermal Fatigue, and Temper Embrittlement of Cr-Mo Steels  
Inspection of Coking Units  
General Inspection  
Coke Drum Inspection

## **Chapter 10: Amine Treating Units**

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

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

CastIrons

GrayCastIrons

DuctileIrons

High-Silicon Cast Irons

Nickel Cast Irons

Other Metals and Alloys

CopperandItsAlloys

NickelAlloys

Aluminum

Titanium and Its Alloys

Non-Metallic Materials.

Refractories

Plastics

ThermosettingResins

HeatTreatment

Normalization

Annealing

Quenching.

StressRelieving

SolutionHeatTreatment

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 .

WeldingDecisions

WeldingProcesses

ShieldedMetalArcWelding(SMAW)

Gas Metal Arc Welding (GMAW)

GasTungstenArcWelding(GTAW)

SubmergedArcWelding(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 wit

## **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