



Material Selection, Design & Failure Analysis

Course Objective

To provide participants with a comprehensive understanding of material selection philosophy, corrosion resistance, mechanical behavior, refinery material applications, and structured failure analysis techniques, enabling safe design, life-cycle optimization, and prevention of premature equipment failures.

Day 1 – Fundamentals of Material Selection & Failure Analysis

Module 1: Introduction to Material Selection

- Purpose of material selection in equipment and piping
- Role of process and mechanical designers
- Life-cycle cost concept
- Maintainability, safety, and replacement considerations

Module 2: General Aspects of Material Selection

- Environmental compatibility
- Aqueous corrosion
- High-temperature attack (oxidation, sulfidation, hydrogen damage)
- Metallurgical degradation (phase precipitation, spheroidising, hydrogen embrittlement, temper embrittlement)

- Mechanical and physical property requirements

Module 3: Introduction to Failure Analysis

- Objectives of failure analysis
 - Consequences of failure (People, Environment, Asset, Reputation)
 - Principles of failure analysis
 - Qualities of an analyst
 - Failure analysis tasks (Prioritize – Analyze – Recommend)
 - First principle: *Observe – Do Not Touch*
 - Importance of visual examination and operating conditions
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Day 2 – Mechanical Properties, Corrosion & Failure Modes

Module 4: Mechanical Properties of Engineering Materials

- Tensile strength
- Toughness
- Hardness
- Fatigue
- Creep
- Effects of high temperature
- Effects of low temperature (Charpy impact testing)
- Influence of alloying elements

Module 5: Corrosion Resistance Considerations

- Temperature, pressure and pH effects
- Impurities and stress corrosion
- Aeration and erosion-corrosion
- Heat transfer influence

Module 6: Types and Modes of Failure

- Types of failures: ductile, brittle, fatigue, deformation, embrittlement
- Failure modes:
 - Permanent distortion
 - Fracture (ductile, brittle, fatigue, creep, SCC, hydrogen embrittlement)
 - Surface damage (wear, fretting, cavitation, thermal fatigue, corrosion)

Module 7: Causes of Failure

- Design errors
- Improper materials and heat treatment
- Manufacturing defects
- Assembly and maintenance errors
- Environmental effects
- Unforeseen operating conditions

Day 3 – Material Grades, Design Codes & Failure Investigation Methods

Module 8: Material Types and Grades

- Carbon steels
- Stainless steels:
 - Austenitic
 - Ferritic
 - Duplex
 - Martensitic
 - Precipitation hardening (17-4 PH)
- Low alloy steels and HSLA steels
- Nickel alloys (Monel, Inconel, Hastelloy)
- Aluminium alloys
- Plastics (thermoplastic & thermosetting)
- Refractory materials

Module 9: Refinery Design References

- Iron–Carbon phase diagram
- Design curves and standards:
 - McConomy curves
 - Couper–Gourman curve
 - NACE MR0175 / MR0103
 - Nelson Curve (API 941)
 - ASME UCS-66
 - API 945

Module 10: Failure Analysis Methodology

- Practical inspection issues
 - Steps and stages of failure analysis
 - Sample preparation
 - Data collection techniques
 - Visual examination rules
 - Materials analysis:
 - Chemical analysis
 - Metallography
 - Fractography & SEM
 - Mechanical testing
 - Surface evaluation
 - Finite Element Analysis and simulation
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Day 4 – Refinery Applications, Degradation Mechanisms & Prevention

Module 11: Refinery Equipment Material Applications

- Crude Distillation Unit
- Vacuum Distillation Unit
- FCCU
- Hydrocracker
- General refinery process flow

Module 12: Degradation Mechanisms in Refineries

- Sulfidation
- High-temperature hydrogen attack
- Creep
- Polythionic acid SCC
- Amine SCC
- Wet H₂S damage
- Ammonium bisulfide corrosion
- HCl corrosion
- Naphthenic acid corrosion
- Sour water corrosion
- Sulfuric acid corrosion

Module 13: Corrosion Control & Failure Prevention

- Material selection
- Design improvement
- Heat treatment
- Metallic cladding and lining
- Corrosion inhibitors
- Cathodic protection
- Coatings

Module 14: Failure Prevention & Reporting

- Prevention through design, materials, processing, and service control
- Failure analysis report structure
- Case histories and failure examples

- Objectives of material selection
- Design philosophy:
 - Minimum investment design
 - Minimum maintenance design
 - Economic design

