



# NATIONAL UNIVERSITY OF ENGINEERING

## COLLEGE OF CHEMICAL AND TEXTILE ENGINEERING

### CHEMICAL ENGINEERING PROGRAM

---

#### PI515 – CORROSION I

##### I. GENERAL INFORMATION

<b>CODE</b>	: PI515 – Corrosion I
<b>SEMESTER</b>	: 8
<b>CREDITS</b>	: 3
<b>HOURS PER WEEK</b>	: 5 (Theory–Practice)
<b>PREREQUISITES</b>	: PI513 Industrial Materials.
<b>CONDITION</b>	: Compulsory
<b>DEPARTMENT</b>	: Chemical Engineering

##### II. COURSE DESCRIPTION

The course prepares students for the identification, analysis, prevention and correction of corrosion, as well as its technical and economic impact in industry. The course starts presenting the value chain in the petroleum and the natural gas industry in Peru (Upstream, Midstream and Downstream) and analyzes the value of the great installed infrastructure which should be protected against corrosion to avoid potential disruptions, inefficiencies, and their corresponding economic costs. Students analyze the types of corrosion, their causes, and analyze methods for preventing it, as well as for repairing or correcting the damages caused by corrosion.

##### III. COURSE OUTCOMES

At the end of the course, students:

1. Understand the value chain of the oil and natural gas industry in Peru (Upstream, Midstream and Downstream).
2. Determine the direct and indirect economic losses of corrosion in Peru and other countries, related to GDP and data from the National Institute of Statistics INEI.
3. Understand and interpret the different types and forms of corrosion, and classify it depending on its mechanisms.
4. Interpret the concept of dry corrosion or corrosion at high temperature, the different types of growth of oxides, and apply the relationship of Pilling & Bedworth to determine protective oxides.
5. Review the types of furnaces and fuel gas/oil burners, flares and process equipment operating at high temperature.
6. Understand the classical electrochemical corrosion process, apply the Nernst equation, measure potentials with acidic and basic media reference electrodes.
7. Apply isocorrosion (< 20 mpy) curves of metals subjected to inorganic acids, understand acid corrosion in the fields of oil and natural gas by CO<sub>2</sub> and H<sub>2</sub>S (sweet corrosion and sour corrosion) and refineries (HCl, Ac. Naphthenic).

##### IV. LEARNING UNITS

###### 1. THE VALUE CHAIN IN THE OIL AND NATURAL GAS INDUSTRIES IN PERU

Upstream (exploration-production) / Lots of exploration / Off shore and on shore production / Separation of natural gas / Midstream (oil pipelines, gas pipelines and maritime terminals for crude oil and fuels) / Downstream, petroleum refineries.

###### 2. CORROSION, ECONOMIC IMPACT, TYPES AND FORMS OF CORROSION

Definition of corrosion / Magnitude of economic losses due to corrosion in Peru and the world / Types and forms of corrosion in industry / Classification of corrosion according to its shape and media / Uniform and in-plate corrosion / Localized corrosion (corrosion under tension, fatigue corrosion, pitting, corrosion-erosion, corrosion cracks or cracking,

intergranule corrosion) / Galvanic corrosion, embrittlement by hydrogen, blistering by hydrogen.

### **3. DRY CORROSION OR CORROSION AT HIGH TEMPERATURE**

Global reaction of metal oxidation / Gaseous oxidation process / Oxidation kinetics, oxide thickness, speed (linear, parabolic and logarithmic cubic) growth, relationship of Pilling & Bedworth and the thickness of the protective oxide / Corrosion at high temperature in carbon steels stainless steel and non-ferrous metals / Flares and burners field of natural gas / Off-shore / Flares from refineries and natural gas plants / Steam boilers / Turbines for cogeneration / Process furnaces, types of furnaces. / Natural gas and refineries, radiant and convective area. / Types of flares, colors and shapes of flames of natural gas, use of steam boilers. / Materials of pipes and furnaces.

### **4. ELECTROCHEMICAL CORROSION**

Electrochemical corrosion, anode areas, cathode areas, electrolyte and potential difference between the cathodic and anodic area / Electrochemical corrosion by atmospheric moisture in carbon steel, stainless steel, aluminum and copper (plates, pipes and structural beams) / Metallography of carbon steel and electrochemical corrosion / Electrochemical corrosion at sea / Anodic reactions, cathodic reactions between basic and acidic media / Electrochemical corrosion in acids / Nernst equation / Table of normal potential / Reference Cu electrodes / CuSO<sub>4</sub>, Ag. / AgCl and calomel (field and laboratory) / Causes that produce anodic areas and cathodic areas / Heterogeneities of metallic phase, dispersed phases in the metal matrix / Particulate pollutants from surface, segregations, dendrites, crystal beads anisotropy. / Regions of cold, deformed metal. / Heterogeneities of the environment, concentration, differential aeration cell batteries. / Heterogeneities of the physical conditions, variations of temperature, presence of an external electric field (in buried pipelines), under an electric field.

### **5. KINETICS OF CORROSION PHENOMENA OF POLARIZATION**

Determination of corrosion with the Faraday law of speed / Polarization of concentration or diffusion / Activation polarization / Resistance polarization / Evans polarization curves / Control of mixed, anodic, cathodic and resistance corrosion / Effects of temperature and the concentration of chlorides.

### **6. METHODS TO PREVENT CORROSION**

Modification of the environment / Dehumidification of medium / Water deoxygenation, addition of inhibitors / Classification of inhibitors: according to the mechanism, anodic, cathodic and absorption. According to its chemical composition: organic and inorganic. According to the application: water (soft, hard), neutral solutions and metals (steel, copper) / Methods based on protective coatings, conversion coating, metallic coating (nickel plating, zinc plating, chrome), organic coatings (paints, plastic coatings, rubber and resins) / Electrochemical methods, anodic protection (passivation zone), cathodic protection (immunity zone), curves of Pourbaix, cathodic protection (sacrificial anodes) galvanic and impressed current (dispersants anodes with and without fill, rectifiers in AC, classification of the aggressiveness of the corrosive medium by the soil resistivity. / Electrical potentials with and without bacteria protection / Cathodic protection by impressed current in an underwater line, a production battery, well and oil tank.

### **7. ACID CORROSION**

Curves of isocorrosion < 20 mpy, HCL, H<sub>2</sub>SO<sub>4</sub>, H<sub>2</sub>SO<sub>4</sub> + HNO<sub>3</sub> / Methods to avoid acid corrosion, (hypalon, fiberglass, PVC and rubber), organic coatings (paints chlorinated rubber, polyurethane and 100% solid composites), if T > 100 ° C use of lining / Clads of stainless steel. / Monitoring and control of corrosion of HCl in refineries stop system (drainage of water and sediments), control of salts of Ca, Mg and Na (PTB), desalted, injection of NaOH, neutralization of HCl with ammonia and amine neutralizing and inhibitors of corrosion on the top of the column / Stainless 13 Cr and monel in the upper part of the column, use of corrosion specimens and analysis of Fe<sup>+2</sup>, Cl<sup>-</sup> and stop water condensate pH / Monitoring and acid corrosion control in oil wells (corrosion by CO<sub>2</sub> - sweet corrosion / Guide to prevent corrosion with the partial pressure of CO<sub>2</sub>, H<sub>2</sub>S - sour corrosion.

## 8. INDUSTRIAL PAINTING

Preparation of surface, washing with industrial liquid soap, cleaning solvent (SSPC-SP-1-63), manual cleaning (SSPC-SP-2-63), mechanical cleaning (SSPC-SP-3-63), commercial blasting (SSPC-SP-6-63), blasting to almost white metal (SSPC-SP-10-63) and blasting white Metal (SSPC-SP-5-63) / Verification of adhesion of painting (ASTM 3359) / Surface preparation / Industrial painting systems: anticorrosive, second layer: intermediate (mid coat) and third layer: finish (top coat) / Systems immersed in the sea required up to 6 layers of painting / Inorganic Zinc or Zinc silicate / Organic Zinc / Zinc inorganic vs. organic / Anticorrosive zinc epoxy / Intermediate painting (mid coat) and finish (top coat) - epoxy HB - epoxy polyamine HB polyamide and polyurethane dry painting performance / Economic cycle of painting / Measurement system of wet and dry film of painting / Defects in paint application.

## 9. MONITORING AND CONTROL OF CORROSION SPEED

Corrosion coupons (different types of coupons and coupons-holder) / Use of test tubes of corrosion / Types, selection and lifetime of measuring items of specimens of corrosion speed / Environmental monitoring conditions / Monitoring of speed corrosion and buried pipelines / Monitoring of corrosion in pipes and equipment with various types of test-tubes of corrosion / Corrosometers and specimens of high resolution / Corrosion in downhole monitoring / Monitoring of corrosion during the injection of inhibitors of normal and accelerated corrosion.

## V. LABORATORY

**Session 1:** Electrodes of Reference.

**Session 2:** Galvanic Corrosion.

**Session 3/4/5:** Piles of Corrosion.

**Session 6:** Corrosion in Acid Media.

**Session 7/8/9:** Corrosion Inhibitors.

**Practical Work 1:** Entrance Test.

**Practical Work 2:** Actualization of Corrosion Costs.

**Practical Work 3:** Analysis of Scientific Articles related to Corrosion.

## VI. METHODOLOGY

The course takes place in theory, practice and laboratory sessions. In theory, faculty present and analyze concepts and methods. In practice sessions, students analyze and solve problems related to corrosion identification, description, kinetics, prevention and monitoring. In laboratory sessions, students perform experimental tests and verify expected outcomes and results. After each laboratory experience, students submit a report describing procedures and summarizing results and conclusions. Student active participation promoted.

## VII. GRADING FORMULA

The Final Grade PF is calculated as follow:

$$PF = (EP + 2*EF + PP) / 4$$

EP: Mid-term Exam

EF: Final Exam

PP: Average of Practical Works

## VIII. BIBLIOGRAPHY

1. OTERO HUERTA, Enrique.  
Corrosion and Degradation of Materials, Sintesis Ed., 2011.
2. PEABODY, A.W.  
Control of Pipeline Corrosion, Second Edition, NACE International, 2001.