



Process Piping - Corrosion, Insulation and Testing

An Online Continuing Education Course for Engineers

Course Number: M-5023

Credit: 5 Hours / 5 PDH / 5 CPD

Process Piping – Corrosion, Insulation and Testing

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A critical step in ensuring pipe fitness for operational use is the proper diagnosis of the failure resulting from corrosion, leakage or ruptures due to excessive pressures. Corrosion is a natural occurrence that will damage pipeline and leads to pipe leak. A correct choice of material, thickness, coating etc. is essential to prevent the potential failure. Also when to opt for hydro test and when to pneumatic test is a common concern to most piping engineers.

The objective of this 5-hour course is to help readers gain a comprehensive knowledge of corrosion mechanisms, testing, and inspection along with a discussion of the influence of different environmental factors on them. The course is written in a simple format without stretching too much on the mathematical equations.

This course is intended for mechanical and process engineers, piping engineers and designers, loss prevention engineers, operation and maintenance personnel, health and safety personnel, construction personnel, vendors and estimators, personnel in integrity management, operations, and regulatory compliance roles who need to know about piping components and systems. The quick easy format of the course will enable a time-saving means to broaden and update their knowledge of piping.

This course is the 9th module in series of 9 modules, which cover the entire gamut of piping engineering in quick reference. All topics are introduced to readers with no or limited background on the subject. The course is divided into five (5) chapters:

CHAPTER– 1: PIPE CORROSION AND COATINGS

This chapter discusses corrosion basics and the types of corrosion - Galvanic corrosion, Pitting corrosion, Selective Leaching, SS Corrosion, Crevice corrosion, Microbial corrosion, Cavitation and Erosive Corrosion, Chemical Corrosion, High-temperature Corrosion, Stray Current Corrosion, Stress Corrosion Cracking etc. The chapter discusses the different methods of protection from corrosion, material selection, use of inhibitor, cathodic protection (CP), galvanizing, surface treatments etc.

CHAPTER -2: PIPE INSULATION

This chapter discusses the different types of Insulation materials and their applications. It provides the characteristics of common insulating materials such as Mineral Fibre, Cellular materials, Calcium Silicate, Expanded Silica (Perlite), Elastomeric Foam, Foamed Plastic,

Expanded Polystyrene, Polyurethane (PUR). It provides information on the protective coverings and finishes.

CHAPTER -3: PRESSURE AND LEAK TESTING

This chapter discusses the Hydrostatic and Pneumatic Testing methods, their requirements, challenges, pros and cons. It describes when to perform the pressure testing and the applicable test pressures.

CHAPTER -4: INSPECTION AND TESTING

This chapter discusses various destructive and non-destructive testing methods such as Ultrasonic Testing, Eddy-Current Testing, Magnetic Particle Testing, Radiographic (X-Ray) Testing, and Dye- penetrant Test etc. It discusses on the importance of material traceability.

CHAPTER -5: PIPE AND COMPONENT IDENTIFICATION

This chapter discusses the need for marking and colour coding for pipe identification, pipe labelling in plant, component identification, packing and preservation etc.

CHAPTER - 1

PIPE CORROSION AND COATINGS

1. What is Corrosion?

Corrosion can be defined as the tendency of any metal to return to its most stable thermodynamic state. More simply stated, it is a chemical reaction of the metal with the environment to form an oxide, carbonate, sulfate, or other stable compound.

When a metal part fails in service, it is essential to determine the cause of the failure so that the replacement part can be manufactured from the proper alloy to prevent future failure. Many times a failed part is replaced with the same alloy. For example, if a piping system is made from Type 304L stainless steel and it fails by chloride stress corrosion cracking, replacing with the same alloy will assure failure within the same time frame. If a change of alloy is made, say to a 6% Mo stainless steel, the piping may last for the lifetime of the system.

1.1. Corrosion Basics

Corrosion of most pipelines occurs due to an electrochemical reaction in the presence of an electrolyte. The rate of corrosion of a piping system is generally related to external and internal factors.

External factors include a working environment of pipes, soil chemistry and moisture for buried pipes or water chemistry in the case of submerged pipes.

Internal factors that contribute to corrosion may include:

- The oxygen content or reactivity of liquids and gases carried
- The use of dissimilar metals within the piping system
- The temperature, flow rate and pressure of the fluids and gases

1.2. Major Causes of Corrosion

- Salt water (excellent electrolyte and can carry charged particles)
- H₂S (acid gas with iron sulfide the by-product)
- CO₂ (Major cause of produced gas corrosion)
- O₂ (key player, reduce any way possible)
- Bacteria (by products, acid produced)

Other Factors

- pH (aggravated by low pH)
- Chlorides (influences corrosion inhibitor solubility)

- Temperature (Increase usually increases corrosion)
- Pressures (CO₂ and H₂S more soluble in H₂O)
- Velocity - important in stripping films, even for sweet systems
- Wear/Abrasion (accelerates corrosion)
- Solids – strips film and erodes metal

1.3. Types of Corrosion

1.3.1. General or Uniform Corrosion

Uniform corrosion occurs over large areas of the metal surface and is the most common form of corrosion with steel and copper. This is the only form of corrosion that may be accurately calculated for lifetime before failure and the only corrosion mechanism in which increased section thickness gives longer life. This type of corrosion is measured by corrosion rate, usually reported as mpy (mils per year), mm/y (millimeters per year), ipm (inches per month), or mg/sdm/yr (milligrams per square decimeter per year). This type of corrosion may be minimized in the active metals by painting the surface, and unexpected failures can be avoided by periodic inspections.

Acid cleaning of metals is an exaggerated example of general corrosion. Every time a copper or carbon steel surface is acid cleaned, the metal walls are thinned due to uniform corrosion. Stainless steel is subject to general corrosion in many acids and some salt solutions. They are not subject to general corrosion in normal water.

Uniform corrosion can be reduced or even prevented by proper selection of materials that are resistant to the corrosive environment. Certain elements make the alloy more resistant to different media. For example:

- High chromium content imparts oxidation resistance. Therefore, look for high chromium for use with nitric acid, the higher the better. High chromium is useful for high temperature oxidation resistance; so, any stainless steel is better than carbon steel in elevated temperature applications.
- High copper content in stainless steel imparts resistance to sulfuric acid.
- High nickel content gives resistance to reducing acids and produces a tightly adhering oxide film in high temperature oxidation.

1.3.2. Galvanic Corrosion

Galvanic corrosion occurs when dissimilar alloys or metals of different corrosion potentials are connected and are immersed in an electrically conductive solution. In this case, the more active metal (the anode) corrodes at an accelerated rate and the more noble metal (the cathode) corrodes at a

retarded rate. However, there is another factor called "area relationship"; if the anode is very large, such as a vessel wall, and the cathode is small like a bolt head, the galvanic action is slight. But, if the anode is small and the cathode is large, the anode will corrode very rapidly.

Galvanic corrosion is of major interest to the marine industry and also anywhere water, containing salts, contacts pipes or metal structures.

If galvanic corrosion is likely to occur, there are the following methods to mitigate it:

- Using a combination of metals that are closer in the galvanic series.
- Apply electrical insulation of dissimilar metals. Possible electrical connection via pipe supports, deck and earthing cables must be considered.
- Install a distance between dissimilar metals. They will be separated by at least 10 pipe diameters. A solid electrically non-conducting material or a layer of a solid electrically non-conducting material should be placed between the dissimilar metals. The coating should be the most noble of the two metals.
- Apply a non-conducting coating to the metals. The coating shall extend at least 1 inch beyond the joint.
- Apply corrosion allowance to the systems.
- Install internal sacrificial anodes, e.g. resistor controlled cathodic protection system. The anode should be in contact with a conductive liquid and special precautions are required.

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1.3.3. Pitting Corrosion

Pitting corrosion is a form of galvanic corrosion in which the passive layer of an alloy is dissolved at few critical points leaving only the corrosion prone surface.

For example, acid chlorides are the most common cause of pitting in stainless steel. Chlorides react with chromium to form the very soluble chromium chloride (CrCl_3). Thus, chromium is removed from the passive layer leaving only the active iron. As the chromium is dissolved, the electrically driven chlorides bore into the stainless steel creating a spherical, smooth wall pit.

In an attempt to quantify the effect of alloying elements, a relationship of the various elements responsible for corrosion resistance was developed. The resulting equation is called the Pitting Resistance Equivalent Number, or PREN.

$$\text{PREN} = \%Cr + 3.3(\%Mo) + 16(\%N)$$