FUNDAMENTALS OF CORROSION MITIGATIONS IN OIL INDUSTRY

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ABSTRACT

It is unknown to many of the science of corrosion as old as history, where scientists have the Romans and Greeks like Pliny, Austin, and others, are built the first building blocks of the science of corrosion, through which has knowledge of the most important developments in the science of metals, Through this study determine with any kind of corrosion can be chosen in Oil and Gas industry so that the appropriate corrosion prevention and control measures, or so as to avoid corrosion problems in the future. This study also analyzes the causes that lead to the high volume of corrosivity such as environmental conditions and accompanying crude acids, gases, and production conditions in different stages.

Keywords: Types of Corrosion, Erosion, Corrosive Gases.

1 INTRODUCTION

Corrosion has been known by different names as rust, an undesirable phenomena which destroys the luster and beauty of objects and shortens their life. A Roman philosopher, Pliny (AD 23-79) wrote about the destruction of iron in his essay ‘Ferrum Corruptar’. Corrosion since ancient times has affected not only the quality of daily lives of people, but also their technical progress. There is a historical record of observation of corrosion by several writers, philosophers and scientists, but there was little curiosity regarding the causes and mechanism of corrosion until Robert Boyle wrote his ‘Mechanical Origin of Corrosiveness’. [1]

a. Definition, Corrosion is the destructive attack of a material by reaction with its environment. The serious consequences of the corrosion process have become a problem of worldwide significance. In addition to our everyday encounters with this form of degradation, corrosion causes plant shutdowns, waste of valuable resources, loss or contamination of product, reduction in efficiency, costly maintenance, and expensive overdesign; it also jeopardizes safety and inhibits technological progress. [2]

b. Corrosion in the Petroleum Industry

In oil production plants, many cases of extensive corrosion have occurred in production tubing, valves, and in flow lines
from the wellhead to the processing equipment. The reason for this is that oil and gas from the well contain varying amounts of water, which can be precipitated as a separate phase in contact with the material surface, and that this water contains gases such as CO₂ and possibly H₂S, as well as salts. In most cases of severe corrosion, CO₂ plays a major role. The carbonic acid reacts with steel, and a layer of reaction products, to a large extent FeCO₃, is formed on the steel surface. The deposit is cathodic relative to steel, and when small defects occur in the deposit layer, pitting corrosion is developed. The conditions may be particularly corrosive in the production tubing, which carries the oil/gas up from the well. In production tubing of carbon steel, corrosion rates in excess of 10 mm/year may occur under unfavorable conditions. [3]

2 METHODOLOGY

The methods can be arranged in the following groups:

I. Laboratory testing, comprising accelerated testing, model testing, and special tailor-made investigations in research. Accelerated test methods give measurable attacks after short time, which can be obtained by using a more aggressive environment, higher potential, higher temperature or higher mechanical stress than under the actual service conditions. These methods are suitable only for qualitative comparison and ranking of various materials with respect to specific properties, and for routine control and approval of delivered materials. Accelerated testing cannot answer questions about lifetime without knowing the degree of corrosion acceleration. Model testing aims at realistic conditions. Possible acceleration must be limited to avoid change of the corrosion mechanism. The testing takes longer than the accelerated test dealt with above, and will often require a sensitive measuring technique. For the extrapolation of results to a realistic service period or lifetime, a thorough understanding of the corrosion mechanism and the change of corrosion conditions and rate with time is necessary. New measuring techniques contribute to improvements in this direction. [4]

II. Service (plant) and field testing, including exposure of coupons, test specimens or components in process environments of industrial plants as well as in special natural fields (in seawater, atmospheres, soils etc.)

3. Testing in a pilot plant, which is a true model (up to half scale) of the actual industrial plant. Pilot plant testing is used as a basis for appropriate design and selection of materials in cases where the condition cannot be satisfactorily modeled in laboratory tests. Pilot plants for modeling are suitable for relatively expensive installations, in which the corrosion conditions are complex and aggressive and the consequences of failure are great. [5]

Various factors contribute to the high corrosivity:
1. Water content
2. Salt content
3. High total pressure
4. Considerable concentration (%) of CO₂
5. High temperature,
6. High flow rate,
7. Corrosive Gases,
   A. Acidic gases,
   B. Caustic gases, and
   C. Oxidizing gases

III. Classification of corrosion problems:

1 Uniform Corrosion "30% of failures"

Uniform corrosion, as the name suggests, occurs over the majority of the surface of a metal at a steady and often predictable
rate. Although it is unsightly its predictability facilitates easy control, the most basic method being to make the material thick enough to function for the lifetime of the component.

![Figure 1: Uniform corrosion](image)

This corrosion can be slowed or stopped by using the five basic facts:

1) Slow down or stop the movement of electrons
   a) Coat the surface with a non-conducting medium such as paint, lacquer or oil
   b) Reduce the conductivity of the solution in contact with the metal an extreme case being to keep it dry. Wash away conductive pollutants regularly.
   c) Apply a current to the material (see cathodic protection).

2) Slow down or stop oxygen from reaching the surface. Difficult to do completely but coatings can help.

3) Prevent the metal from giving up electrons by using a more corrosion resistant metal higher in the electrochemical series. Use a sacrificial coating which gives up its electrons more easily than the metal being protected. Apply cathodic protection. Use inhibitors.

4) Select a metal that forms an oxide that is protective and stops the reaction. Control and consideration of environmental and thermal factors is also essential.

![Figure 2.i: Galvanic cell](image)

2 Localized Corrosion "70% of failures"

The consequences of localized corrosion can be a great deal more severe than uniform corrosion generally because the failure occurs without warning and after a surprisingly short period of use or exposure. Application of the five basic facts needs greater thought and insight.

2.1 Galvanic Corrosion, this can occur when two different metals are placed in contact with each other and are caused by the greater willingness of one to give up electrons than the other. Three special features of this mechanism need to operate for corrosion to occur:

- The metals need to be in contact electrically
- One metal needs to be significantly better at giving up electrons than the other
- An additional path for ion and electron movement is necessary.

![Figure 2.ii: Galvanic corrosion](image)
Proposed solutions
Prevention of this problem is based on ensuring that one or more of the three features do not exist.
Break the electrical contact using plastic insulators or coatings between the metals.
Select metals close together in the galvanic series.
Prevent ion movement by coating the junction with an impermeable material, or ensure environment is dry and liquids cannot be trapped.

2.2 Pitting Corrosion, it can occur in materials that have a protective film such as a corrosion product or when a coating breaks down. The exposed metal gives up electrons easily and the reaction initiates tiny pits with localized chemistry supporting rapid attack.

Proposed solutions
Control can be ensured by:
• Selecting a resistant material
• Ensuring a high enough flow velocity of fluids in contact with the material or frequent washing
• Control of the chemistry of fluids and use of inhibitors
• Use of a protective coating
• Maintaining the material’s own protective film.

Note: Pits can be crack initiators in stressed components or those with residual stresses resulting from forming operations. This can lead to stress corrosion cracking.

2.3 Selective Attack, this occurs in alloys such as brass when one component or phase is more susceptible to attack than another and corrodes preferentially leaving a porous material that crumbles.

Figure 4: Selective attack

Proposed solutions
It is best avoided by selection of a resistant material but other means can be effective such as:
• Coating the material
• Reducing the aggressiveness of the environment
• Use of cathodic protection

2.4 Stray Current Corrosion, when a direct current flows through an unintended path and the flow of electrons supports corrosion. This can occur in soils and flowing or stationary fluids.

Proposed solutions
The most effective remedies involve controlling the current by:
• Insulating the structure to be protected or the source of current
• Earthing sources and/or the structure to be protected.
• Applying cathodic protection
• Using sacrificial targets.
2.5 **Microbial Corrosion**, this general class covers the degradation of materials by bacteria, molds and fungi or their by-products. It can occur by a range of actions such as:

- Attack of the metal or protective coating by acid by-products, sulphur, hydrogen sulfide or ammonia
- Direct interaction between the microbes and metal which sustains attack.

**Proposed solutions**

Prevention can be achieved by:

- Selection of resistant materials
- Frequent cleaning
- Control of chemistry of surrounding media and removal of nutrients
- Use of biocides
- Cathodic protection.

2.6 **Intergranular Corrosion**, this is preferential attack of the grain boundaries of the crystals that form the metal. It is caused by the physical and chemical differences between the centers and edges of the grain.

**Proposed solutions**

It can be avoided by:

- Avoiding sharp corners and designing out stagnant areas
- Use of sealants
- Use welds instead of bolts or rivets
- Selection of resistant materials

2.7 **Concentration Cell Corrosion (Crevice)**, if two areas of a component in close proximity differ in the amount of reactive constituent available the reaction in one of the areas is speeded up. An example of this is crevice corrosion which occurs when oxygen cannot penetrate a crevice and a differential aeration cell is set up. Corrosion occurs rapidly in the area with less oxygen.

**Proposed solutions**

The potential for crevice corrosion can be reduced by:

- Avoiding sharp corners and designing out stagnant areas
- Use of sealants
- Use welds instead of bolts or rivets
- Selection of resistant materials

2.8 **Thermo-galvanic Corrosion**, temperature changes can alter the corrosion rate of a material and a good rule of thumb is that 10°C rise doubles the corrosion rate. If one part of component is hotter than another the difference in the corrosion rate is accentuated by the thermal gradient and local attack occurs in a...
zone between the maximum and minimum temperatures.

**Figure 8: thermo galvanic corrosion**

**Proposed solutions**
The best method of prevention is to design out the thermal gradient or supply a coolant to even out the difference.

2.9 Corrosion Caused by Combined Actions, this is corrosion accelerated by the action of fluid flow sometimes with the added pressure of abrasive particles in the stream. The protective layers and corrosion products of the metal are continually removed exposing fresh metal to corrosion.

**Figure 9: corrosion caused by combined action**

**Proposed solutions**
Prevention can be achieved by:
• Reducing the flow rate and turbulence
• Use of replaceable or robust linings in susceptible areas
• Avoiding sudden changes of direction

**Figure 10: corrosion fatigue**

2.10 Corrosion Fatigue, the combined action of cyclic stresses and a corrosive environment reduce the life of components below that expected by the action of fatigue alone.

**Proposed solutions**
This can be reduced or prevented by:
• Coating the material
• Good design that reduces stress concentration
• Avoiding sudden changes of section
• Removing or isolating sources of cyclic stress

2.11 Fretting Corrosion, relative motion between two surfaces in contact by a stick-slip action causing breakdown of protective films or welding of the contact areas allowing other corrosion mechanisms to operate
**Proposed solutions**

Prevention is possible by:
- Designing out vibrations
- Lubrication of metal surfaces
- Increasing the load between the surfaces to stop the motion
- Surface treatments to reduce wear and increase friction coefficient.

**2.12 Stress Corrosion Cracking (SCC),** the combined action of a static tensile stress and corrosion which forms cracks and eventually catastrophic failure of the component

This is specific to a metal material paired with a specific environment.

**Proposed solutions**

Prevention can be achieved by:
- Reducing the overall stress level and designing out stress concentrations
- Selection of a suitable material not susceptible to the environment
- Design to minimize thermal and residual stresses
- Developing compressive stresses in the surface of the material
- Use of a suitable protective coating

**2.13 Hydrogen Damage,** a surprising fact is that hydrogen atoms are very small and hydrogen ions even smaller and can penetrate most metals. Hydrogen, by various mechanisms, embrittles a metal especially in areas of high hardness causing blistering or cracking especially in the presence of tensile stresses.
Figure 13.ii: Caustic Corrosion

Proposed solutions
This Problem can be prevented by:
- Using a resistant or hydrogen free material
- Avoiding sources of hydrogen such as cathodic protection, pickling processes and certain welding processes.
- Removal of hydrogen in the metal by baking.

3 EXPECTED RESULTS
3.1 Reducing operating Costs, which include:
   a. Direct (Money Spent)
      A. Replacement
      B. Installation
      C. Maintenance
      D. Clean up of spillages
   b. Indirect (Money Not Saved)
      A. Unplanned shutdowns
      B. Loss of product (oil or gas)
- Over design (“corrosion allowances”), Loss of efficiency (e.g. thermal efficiency of corroded heat exchangers) and Bad publicity.

It's nearly cost about 67% for repairs, 33% in lost production

3.2 Health & Safety, releasing:
I. Leaks, Can release hydrocarbons/other chemicals risk of injury from fire, explosion, and risk of exposure to hazardous materials. Can cause equipment malfunction risk of injury to personnel
II. Mechanical failure, can control, Process upsets risk of injury from operating outside normal envelope, Catastrophically risk of injury.

3.3 Environmental Impact, can be avoided:
1. Pollution of environment from corrosion leaks.
2. Depletion of non-renewable resources.
3. Adverse political and social relations.

REFERENCES: