# CORROSION-RELATED EQUIPMENT FAILURES IN NIGERIA OIL/GAS INDUSTRY: A CASE STUDY

**Atanmo, P. N. and Nwankwo, E. I.**
Department of Mechanical Engineering, Chukwuemeka Odumegwu Ojukwu University, P.M.B. 02 Uli. Anambra State. Nigeria.

## ABSTRACT
The focus of this study is to understand the prevalence of corrosion-related failures in Nigeria Oil/Gas Industry and seek ways to arrest the degradation of the facilities. The hash environmental conditions are known to severely affect the equipment integrity i.e., the exposure causes corrosion of the equipment. Events in the industry show that failures of these equipment have occurred due to corrosive action. The failures have led to environmental impacts such as spills and releases to the environment, others have led to production shut-ins with loss of revenue. All these touch the business bottom line which is costs and profits. Different oil/gas facilities in Niger-Delta were studied through site visits, observations, measurements and photographic analysis. The study established that location of the various equipment makes them susceptible to weathering effects. They experience cycles of rains, sunshine and humid ambience. Crevice, galvanic, pitting and “dry corrosion” mechanisms are dominant and, in some, result in uniform corrosion. There were cases of bacteria-related attacks on the internals of some equipment. The average metal thickness loss was established at about 12.5%. Use of more modern corrosion protection measures should be considered including increased deployment of corrosion-resistant alloys. Heavy coatings of the tank roofs under sides with anti-corrosive agents prior erection are required. Welded rather than bolted and riveted connections should be designed to minimize crevices where deep pittings are known to occur. Reinforcements with closed tubular sections are preferred to channel sections to avoid trapping of corrodents.

**Keywords:** Equipment, Corrosion, Insulation, Paint coating, Failure.

## 1.0 INTRODUCTION
Numerous equipment, both static and dynamic are used extensively in the oil and gas industry in Nigeria. Apart from some product evacuation units like pumps and compressors with their associated drivers such as gas engines, turbines and electric motors that have protective roofs over them, the vast majority of other equipment are exposed to hash operating environments where they are in cyclic contact with rains, sunshine, wind, dust and other weather situations. In this group are static and dynamic equipment such as scrubbers, separators, valves (both manually operated, control and relief), pipelines and instrumentation piping, tanks, chemical dose pumps, product transfer pumps, etc. All these are mounted either on steel reinforced concrete or metallic structures. These hash environmental conditions are known to severely affect the equipment integrity i.e., the exposure causes corrosion of the equipment. Events in the industry show that failures of these equipment have occurred due to corrosive action (Pennwell, 1999). The failures have led to environmental impacts, in cases of spills and releases to the environment, others have led to production shut-ins with loss of revenue. All these touch the business bottom line which is costs and profits (Saom, 2002). In November, 2012, a pipeline failure in one of the oil majors crude oil terminals led to oil spills. At this time of writing, the costs on the communities, environments are still being counted. The increasing cases of corrosion-assisted failures (unrelated to vandalisation and community militancy) in the oil/gas business in Nigeria is high enough compared with other African Nations engaged in the same oil/gas activities. (Abemese, 2004). The need to ensure human safety and safeguard the environment calls for serious attention to the incidence of corrosion-assisted failures. As Nigeria is mainly a one-product economy (oil and gas production and export), the failures directly affect the overall

Gross Domestic Product; with social stability fall-outs. This study seeks to understand the prevalence of these corrosion-related failures and find ways to arrest the degradation of the facilities in the industry.

## 2.0 THEORETICAL BASIS

Corrosion is degradation of vital properties in a material or structure owing to reactions of these materials with their environments. In the Nigeria oil/gas industry, millions of Naira is lost each year to corrosion of equipment. Iron and steel being the main materials employed in the business, much of these corrosive impacts are on these materials. A number of measures -including provision of "sacrificial materials" and surface coatings- have been, and are being used to combat this loss, the problem persists (Abemese, 2004). In some metals, the initial corrosion (oxide films) on their surfaces provide the needed protection from further attacks, but the issue with iron and steel is that these oxide films formed by oxidation do not stick to the metal surface, rather they tend to "peel" off and expose fresh surface to the reaction and this continues until the entire material thickness is deteriorated. Eventually, these show up as equipment and structural failures with replacement costs and in some cases with environmental impacts (hydrocarbon could be released).

In the works of Iwuoha and Onyeka (2011) in Nigeria oil/gas industry, corrosion related failures have been reported in:

**Perforation of pipelines:** These have led to crude oil spills. A major case is the Mobil offshore oil spill in 1998 of a 48-inch pipeline evacuating crude from the platforms to the shore terminal.

**Separator vessels and Pump elbows burst:** In the crude oil gathering stations, the separator vessels ripped open due to corrosion.

**Workover rig sub-structure:** In one of the oil majors land rehabilitation wells, the structure for mounting the rig suddenly collapsed. The failure was traced to un-noticed pitting corrosion of the brace members.
Corrosion can also lead to contamination of products being handled, this is very important in sensitive gas supplies. Generally, an electrolytic base, electric current, an anode and a cathode must work together for corrosion to occur. Electrochemical basis of this action is that at the point where current originates or flows (the anode), metal dissolution takes place and at the other point of current drive or reach (i.e., the cathode), no metal dissolution occurs. This metal dissolution is called corrosion. Electrons are lost at the anodic point and the resultant positive ions are free to go into solution (Iwuoha and Onyeka, 2011).

The action in equation form could be written as:

$$FeO \rightarrow Fe^{++} + 2e^{-} \text{ (oxidation)} \qquad (1)$$

Electrons set free migrate through the electrolytic base to the cathode. At the cathode, they are removed from the electrolyte and merge with some ionic group in solution. At this stage, the process is completed. The relation could be written, again, in equation form as:

$$2H^{+} + 2e^{-} \longrightarrow H_2 \text{ (Reduction)} \qquad (2)$$

Essentially, what happens is that the hydrogen released attaches to the cathode and forms an "insulation wrap." This action results in polarization. The polarization opposes the current flow and brings about a slowing down or stoppage of the corrosion process. A complete stoppage is often not possible because oxygen is present in the insulation covering. By the oxygen combining with hydrogen to form water, a reversal or depolarization occurs. The inhibition to current flow is removed, current flows again and the process of corrosion continues. The rate of corrosion come under some influences such as time, concentration of the fluid, temperature and pressure of the medium, presence of depolarizers such as oxygen, flow velocity, medium pH value. (Bosse, C., 2007).

Some common grouping of corrosion are:

1. General Corrosion
2. Pitting Corrosion
3. Crevice Corrosion
4. Galvanic Corrosion
5. Contact Corrosion

General corrosion is where there is a general uniform removal of material, by dissolution, e.g. when steel is used in petrochemical plant containing strong acids. Design in this instance is based on published data to predict the life of the components. Published data document the corrosion rate per year (removal of metal over a year). Kadry (2008) stated that tables of resistance to various chemicals are published by various organizations and a very large collection of charts, list recommendations. Technical papers are available through steel manufacturers and suppliers.

Pitting is very localized corrosion which, if not arrested can lead to perforation of materials. This often occurs under certain conditions, particularly involving high concentrations of chlorides (such as sodium chloride in sea water), moderately high temperatures and aggravated by low pH (i.e. acidic conditions). This is not related to published corrosion data as it is an extremely localized and severe corrosion which can penetrate right through the cross section of the component (Kadry, 2008).

Iwuoha and Onyeka (2011) listed some of the common corrosion monitoring and evaluation means to include:

- Visual Inspection
- Weight-loss Coupons
- Radiography
- Linear Polarization Resistance.
- Dye Penetrant Inspection (DPI)
- Magnetic Particle Inspection (MPI)
- Ultrasonic Thickness Measurement (UTM)
- Acoustic Emission
- Electrical Resistance Probes (ER)

This study focuses on corrosion-related failures in the Nigeria oil/gas industry, seek measures to arrest the related failures. This is very important for an economy like Nigeria which is directly attached to the industry; with all aspects of its national life –social, political, spiritual, etc- revolving around it.

## 3.0 METHODOLOGY

The following equipment were surveyed in the course of this work: surge vessels, separators, storage tanks, settling tanks, pumps, compressors, valves chemical injection pumps, pipelines, engines, floor gratings, saver pits, heat exchangers, drainages, fans and blowers. The corroded members were visually examined to determine extent and nature of the corrosion. They were photographed for further visual inspection and analysis. Pit gauges were inserted to measure depths of pitted sections of surge vessels, separators, tanks, valves fittings. Vernier calipers were also utilized for accurate measurements. Beyond visual inspections and measurements, Ultrasonic Thickness Measurement (UTM) using IDM2 meter was employed to further analyse the corrosion effects. The UTM is a direct reading thickness meter which ranges from 1 – 300 mm. The error margin is about 1%. It also measures the time taken for the sound pulse to traverse the metal thickness. This limits the errors to the change in echo amplitude on reflection. (Umezuruike, 1995; Iwuoha and Onyeka, 2011). With UTM, the following relation may be used to determine reduction in thickness $\Delta t$ :

$$\Delta t = (t_1 - t)\ t_1 \times 100\% \qquad (3)$$

Where:
$t_1$ = Original thickness or thickness prior to corrosion
$t$ = Thickness upon corrosion

## FINDINGS

Fig. 1: Corroded Re-heater column walls

Fig. 2: Corroded valves, electric motor, pump and elbow

### Re-Heater Columns and Settling Tanks

Figure 1 shows re-heater columns and settling tanks (background) for crude oil storage in Isiope facility, southern Niger-Delta. The walls of the re-heater columns and settling tanks show severe and prominent corrosion attacks. These are clear indications of environment effects. The internals of the vessels were not examined because as at time of inspections, they were in active service. Cycles of rains, sunshine and humidity have combined to produce the corrosion. Condensation initially weakens the protective coating. The coating progressively gives way to fresh metal surface; localized material surface depletion commences and progresses on the bare metal surface. The valves experienced extensive pitting and perforations to about 16 % metal loss.

### Electric Motors, Pumps and Pipe Elbow

Figure 2 shows an integral of vertically-mounted electric motor with a submersible pump. There are also pipeworks and valves. Generally, the equipment were protected by paint coatings. There was not any form of sacrificial corrosion (cathodic protection) material in the “circuit.” Thus the electric motor, surface exposed part of the pump together with the pipes and valves freely corroded on environmentally-induced paint coating removal. Crevice-type of corrosion was very severe and prominent.

**Pipe Spools and Chemical Injection Facility**

In network pipes, valves and chemical dosing stations, the heavy marine grey paints are depleted and bare pipe surfaces exposed. Galvanic corrosion was prominent as the materials in the interconnections of pipe spools were of different grades. The atmospheres in both locations were observed to be pungent. Material thickness loss was as high as 20%. There were also bacteria-induced pittings on the insides of the pipes.

**Metallic Drainage and Valves**

24-inch manual valve in 24-inch pipe line in an associated gas (AG) production station in another oil/gas field at Opuku of Nigeria Niger-delta. The pipeline is "corrosion spared" in this case but the valve is not. Similar cases were observed in other valves in the same facility. Galvanic corrosion was established. It should be noted that in an adjacent facility where cathodic protection method was in use, the equipment within the circuit of the protection process retained their surface integrity. For the 24-inch valve, uniform corrosion attacked the valve and similar valves. The cyclic wetting and drying of the ambient surrounding the valves facilitated this corrosion. Some of the valves in special temperature service were wrapped with insulation and these offered limited protection because trapped water moisture within the insulation also initiated corrosion-related degradation and the "secondary protectiveness" of the insulation wrapping was rendered ineffective.

Comparing earlier works of Iwuoha and Onyeka (2011), the overall mean material thickness loss stood at 12.5% compared with theirs of 11%.

## 4.0 DISCUSSION OF FINDINGS

The study assessed the failure of equipment in the oil/gas industry in Nigeria environment. The study sought to understand the common mechanism(s) associated with corrosion-induced metal and alloy degradation. Different oil/gas facilities were visited and their equipment inspected for corrosion. Comparison was made between facilities and common equipment. Equipment inspected were mainly land and swamp based and the findings extrapolated to the offshore environments.

The study established mostly uniform corrosion of equipment due to the harsh ambient to which they were exposed. It is noted that the atmospheres were highly humid, with cyclic rains and sunshine weathering on them. This corrosion-induced failure led to material thickness loss; as the equipment material thickness gets thinned down, they fail to meet the service requirements and failures result. The compromise has consequences on safety, performance efficiency, total life cycle and the environment. In some cases, the corrosion was on the inside of the equipment and the corrosion was traced to bacteria-related attacks. The product stream provided "safe haven" for these bacteria multiplication and the various products of their metabolism added to the corrosivity of the internal environment. The general chemical spills in the operations increased the index of corrosivity of the corrodents and faster degradations were registered. The use of rivets and bolted is thought to be responsible for crevice corrosion observed. The design provided hidden ends that trap high humidity and oxygen density which is mainly responsible for oxidation of metals and alloys.

Common dryness exposed the metals and alloys to a type of corrosion termed dry corrosion. (Farmoss and Hendrix, 2009). Being exposed to high oxygen content ambient, nucleus of metallic oxides quickly forms, especially in spots of metal impurity and material dissimilarity. In cases like this, pitting is the first form of corrosion which eventually spreads to other areas as the kinetic of elemental molecular diffusion within the matrix causes alkalinity. Alkaline environments are known for producing severe corrosion. Metallurgically, the formation of oxides and the density depends on the orientation of crystals on the surface. Lateral spread of the film proceeds thereafter until the entire surface is enveloped. Galvanic corrosion type was observed in areas of metal dissimilarity and one serves as the anode and the other as the cathode. Electrons flow through the electrolyte and one of the metals suffers sacrificial corrosion. The rate depends on which of the ions is more mobile (Bosse, 2007).

The findings were extrapolated to offshore environments. This is particularly interesting as harsher ambient envelops every equipment. He following factors are known to assist initiation and aggravation of corrosion viz: saltiness, heavy humidity, weathering cycles of hot and cold, weathering cycles of rains and sunshine (Kii, 2002). The offshore environments have all these in "abundance." The corrosion is expected to be rapid because it is believed, from experience gathered in this study, that the same level of protection applies. Without increased adequacy of protection, the degradation is accelerated. Near sea-water-level mounted equipment suffer both abrasion, erosion, cavitation and pitting attacks. The sea waves, with particles and water bubbles continuously impinge on the same spots, the surfaces are abraded and eroded.

## CONCLUSION

Location of the various equipment makes them susceptible to weathering effects. They experience cycles of rains, sunshine and humid ambience. Crevice, galvanic, pitting and "dry corrosion" mechanisms are dominant and, in some, result in uniform corrosion. There were cases of bacteria-related attacks on the internals of some equipment. The average metal thickness loss was established at about 12.5%. This is over a period of about nine years since installation. This is quite high and suggests that if the situation is not arrested, in six more years the various equipment must have thinned down so much that they either fail completely or become vulnerable. Their failures results in environmental impacts, operating safety concerns, equipment down time, process compromise. All these are related to financial cost. A nation like Nigeria depending almost solely on revenues from oil/gas business will suffer economic set backs. The social, political and psychological incidences are better prevented than experienced. Use of more modern corrosion protection measures should be considered including increased deployment of corrosion-resistant alloys.

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