COVER STORY

CORROSION MANAGEMENT IN UPSTREAM OIL AND GAS ASSETS

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The world is still a long way from relinquishing oil and gas assets from the global energy mix despite the recent year's significant shift towards renewable energy sources. Fossil fuels remain dominant in the overall global energy mix, with oil and gas demand still growing strongly, particularly in Asia. Hence, effective corrosion management is still pivotal to the successful operation of upstream oil and gas assets. (c.f. Figure 1.) This can not only prolong the life of assets, i.e., structures, facilities, wells, and pipelines, further it can also reduce the uncontrolled release of toxins and harmful by-products into the environment due to loss of containment (LOC).

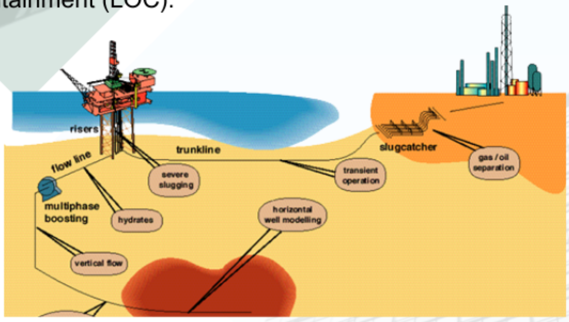

Figure 1: Upstream oil and gas facilities, pipelines and wells.

2. WHY EFFECTIVE CORROSION MANAGEMENT IS ESSENTIAL IN UPSTREAM OIL AND GAS ASSETS

Corrosion can lead to premature failures of oil and gas assets. The resulting loss of containment leading to gas leaks and oil spills can be dangerous to the environment, human health, and potential human fatalities. It can also increase the cost of operating upstream oil and gas assets by requiring frequent inspection, monitoring, repairs and replacement of corroded components and equipment.

Therefore, it is important to implement effective corrosion management strategies to ensure the long-term viability, safe and reliable operation of oil and gas assets. This will earn the "Licence to Operate" for the operators.

3. WHAT CAUSES CORROSION ATTACKS IN UPSTREAM OIL AND GAS ASSETS?

Corrosion in upstream oil and gas assets is caused by a combination of factors, including exposure to harsh hydrocarbon. The main causes of corrosion in these assets is the presence of high concentrations of water, hydrogen sulfide (H_2S), carbon dioxide (CO_2), mercury, High Pressure/High Temperature (HPHT) etc. in the upstream oil and gas assets.

High temperatures can accelerate the corrosion process, particularly in areas where CO_2 is in contact with water or other acids like organic acid which can lead to "Top of Line" (TOL) corrosion in a high temperature and high pressure (HTHP) pipeline. Additionally, high temperatures can cause metal components to expand and contract, which can lead to stress on the materials and accelerate corrosion.

Other factors that can contribute to corrosion in oil and gas assets include exposure to other contaminants, such as sulfur compounds, chlorides, H_2S, mercury, as well as the presence of microorganisms, such as bacteria leading to Microbial Induced Corrosion (MIC) in oil pipelines. Interaction with CO_2, H_2S, and water will create an environment that is corrosive to metal surface. i.e. carbonic acid.

4. EFFECTIVE CORROSION MANAGEMENT STRATEGIES IN UPSTREAM OIL AND GAS ASSETS

Currently, there are several strategies that can be used to manage corrosion in upstream oil and gas assets during operated phase. In project design phase, a proper material selection shall be thoroughly studied and a comprehensive Risk Based Inspection plan shall be established aligned with Corrosion Management Framework (CMF) and Corrosion Management Manual (CMM). Of course, regular inspection/monitoring and maintenance is crucial, as per the established Risk Based Inspection (RBI) plan for the assets.

"Fit For Purpose" Material Selection

Material selection is a crucial aspect of corrosion management in oil and gas assets. The use of corrosion-resistant materials, such as stainless steel, can significantly reduce the risk of corrosion. However, it's important to note that no material is completely immune to corrosion, and other strategies such as coatings/cathodic protection, and corrosion inhibitors should be considered.

Risk-Based Inspection (RBI)

RBI is a methodology used to prioritize inspections of equipment based on risks assessments, it assesses the Probability of Failure (POF) and the Consequences of Failure (COF) to rank equipment for inspection, focusing limited resources on high-risk items with specific corrosion mechanisms while minimizing inspections of low-risk assets. It is a best practice for a new project to deliver a baseline RBI plan to the assets operators as part of the project handover deliverable.

Regular inspection/monitoring and maintenance
Regular inspection/monitoring and maintenance are essential for the early identification and addressing of corrosion threats. This includes visual inspections, conventional and advanced non-destructive testing, and real-time remote monitoring of corrosion rates.

Advanced Non-Destructive Testing (NDT) techniques like phased array ultrasonic testing (PAUT) or advanced eddy current testing (EcT) become essential. The maintenance Planning will anticipate and address potential corrosion issues before they escalate, extending the life of aging assets.

Coatings/Cathodic protection (CP) and corrosion inhibitors. Coatings/CP and corrosion inhibitors can be used to protect metal surfaces from corrosion. Coatings, such as paint or epoxy, can provide a physical barrier to prevent external corrosion.

Inhibitors, such as corrosion inhibitors, can be added to slow down the corrosion process within acceptable limits. Corrosion inhibitors are generally preferred in closed systems where the presence of the inhibitor can be more easily maintained. These are commonly used in oil and gas assets and can be effective in slowing down corrosion, but it's important to note that the selection of the right coating or corrosion inhibitor depends on the specific conditions of the asset. The corrosion inhibitor selection may be subjected to a proper protocol laboratory testing. Regular monitoring and maintenance are still needed from the asset's operator.

5. HOW DOES CORROSION ATTACKS OCCUR IN UPSTREAM OIL AND GAS ASSETS?

The corrosion of different materials used in upstream oil and gas assets can occur in different ways, depending on the specific properties of the materials used and the environmental conditions.
The common types of corrosion found in upstream Oil and Gas assets are as follows:

Uniform Corrosion
This is the most common type, occurring evenly across the metal surface, often due to chemical or electrochemical reactions. e.g. atmospheric corrosion on valves, tubular, equipment, etc. stored in open storage yard without preservation.

Intergranular Corrosion (IGC)
IGC is a type of corrosion that occurs along the boundaries of metal grain, rather than on the surface. It is often associated with local differences in compositions such as the precipitation of chromium carbides in stainless steels. This depletion creates anodic zones that are more susceptible to corrosion.

Sulfide Stress Cracking (SSC)
SSC is a form of hydrogen embrittlement that occurs in metals when exposed to H_2S and other sulfide ions in humid environments and cracks under stress. In recent years, many new recovered fields in Malaysia have high contaminants of H_2S which poses technical challenges in their field development.

Hydrogen Induced Cracking (HIC)
HIC is a form of material degradation that occurs when atomic hydrogen diffuses into a metal or alloy, often in an environment with hydrogen or H_2S. This process can lead to the formation of hydrogen molecules within the metal's crystal lattices, causing internal pressure build-up and cracking. This occurs when the hydrogen atoms diffuse into steel, leading to internal cracking.

Stress Corrosion Cracking (SCC)
Cracking under tensile stress in corrosive environment. e.g. stainless steel. SCC is difficult to detect early and can lead to catastrophic failures.

Pitting corrosion is the localized corrosion of a metal surface, resulting in small holes or pits. In upstream oil and gas assets, pitting corrosion can occur in pipelines, valves, and other components that come into contact with CO_2, especially in areas where the CO_2 is in contact with water or other liquids.

Crevice corrosion is a form of localized corrosion that occurs in tight spaces or crevices, such as the area between a gasket and a pipe flange. In upstream oil and gas assets, crevice corrosion can occur in joints and connections, such as pipe support contact points, flanges and gaskets, etc.

Galvanic corrosion is a type of corrosion that occurs when two dissimilar metals are in contact with an electrolyte, such as water or CO_2.. In upstream oil and gas assets, galvanic corrosion can occur in joints and connections where dissimilar metals, such as steel and aluminium, are used. This process accelerates the corrosion of the anodic metal (aluminium) and protects the cathodic metal (carbon steel).

Microbiologically influenced Corrosion (MIC)
MIC is perhaps the least understood corrosion phenomenon. It is a huge threat to oil and gas installation especially the pipeline assets. Sulphate Reducing Bacteria (SRB) are the best know corrosion causing microbes. It affects systems with traces of water and it is predominantly manifested in the form of localized corrosion pitting. MIC occurs when sessile microorganisms alter the physiochemical conditions on the metal internal surface of a carbon steel pipeline.

For example, carbon steel is a commonly used material in upstream oil and gas assets due to its lower costs and availability, but it is also highly susceptible to pitting, crevice and other types of corrosion in the presence of CO_2, H_2S, and water. Corrosion-resistant alloys (CRAs) such as Stainless steel, on the other hand, is more resistant to corrosion but can still be affected by high temperatures and the presence of other corrosive agents. e.g. H_2S and chlorides.

6. THE FUTURE OF CORROSION MANAGEMENT IN UPSTREAM OIL AND GAS ASSETS

Managing corrosion in upstream oil and gas assets requires a multi-faceted and multi-disciplined approach, and the best strategy for a specific asset will depend on the specific conditions and materials used. For example:

- Material selection can significantly reduce the risk of corrosion, but it’s important to note that no material is completely immune to corrosion. The challenge for the Materials and Corrosion Engineer is to select a “Fit For Purpose” material as a new project viability is based on its CAPEX costs and not on life cycle costs.
- Regular inspection and maintenance are essential for identifying and addressing corrosion threats early on, but they can be costly and time-consuming. Hence, Risk Based Inspection (RBI) plan shall be put in place prior to oil and gas assets actual production to prioritize risks.
- The maintenance Planning will anticipate and address potential corrosion issues before they escalate, extending the life of aging assets.
- Coatings and corrosion inhibitors can be effective in slowing down corrosion, but they can also be costly and require regular monitoring and maintenance.

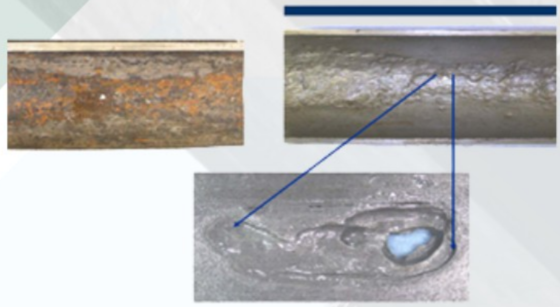

Figure 2: MIC corrosion of carbon steel pipeline.

Corrosion can lead to unsafe operation of upstream oil and gas assets, as well as increasing the cost of operating offshore assets by requiring frequent inspection/monitoring, repairs and replacement of corroded components and equipment.

While current corrosion management strategies are effective at controlling corrosion at upstream oil and gas assets, it is important to continue to research, experiment, and develop innovative techniques/new technologies for enhanced corrosion management. As the technologies and conditions in oil and gas assets evolve, the strategies used to manage corrosion must be adapted in the coming years.

Every improvement that we can make will improve the viability and safety of our oil and gas assets. The Institute of Materials, Malaysia (IMM) is in the perfect position to help industry and academia deliver these improvements.

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