

CORROSION INHIBITORS IN O&G INDUSTRY: A REVIEW OF CURRENT APPLICATION CHALLENGES AND RESEARCH GAPS

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ABSTRACT

Corrosion continues to be a threat to the petroleum industry. It risks people's lives, assets integrity and the environment. These risks are mitigated by different means such as selection of appropriate materials, chemical treatment, cathodic protection, protective coatings, and process control. One of the most common corrosion control measures is the use of corrosion inhibitors. This is a cost-effective option that can be applied to upstream, mid-stream and downstream facilities. This has driven the research institutes and the chemical manufacturers to invest on developing corrosion inhibitor chemistries for field-specific applications. In spite of all the efforts being put, there are still many important aspects about corrosion inhibition treatment that need to be researched for a better understanding of the chemicals' performance, monitoring, laboratory testing, and field application. This paper highlights knowledge gaps to invite focused research to help bridging the gaps between operators, research institutes and developing companies. These gaps are classified in four main areas: Field Monitoring, Facility Design, Laboratory Testing, and Simulation & Prediction.

Key words: Corrosion Inhibitor, Inhibitor, CI, Chemical Treatment, Corrosion Control, Corrosion Management

INTRODUCTION

Corrosion continues to be a threat to the petroleum industry. It risks people's lives, the environment, and assets integrity, in addition to the financial losses. In fact, the annual global cost of corrosion was estimated in 2013 to be around US\$2.5 trillion (3.2% of 2013 global GDP). Of this amount, approximately 15-35% (i.e. US\$375 to US\$875 billion annually) can be avoided through proper corrosion control management and advanced mitigation technologies [1].

Corrosion risks can be mitigated by different means such as selection of appropriate materials, chemical treatment, cathodic protection, protective coatings, and process control. One of the most common corrosion control measures is the use of corrosion inhibitors. This is a cost-effective option that can be applied to upstream, mid-stream and downstream facilities. This has driven the research institutes and the chemical manufacturers to invest on developing corrosion inhibitor chemistries for field-specific applications. In spite of all the efforts being put, there are still many important aspects about corrosion inhibition treatment that need to be researched for a better understanding of the chemicals' performance, monitoring, laboratory testing, and field application. This paper highlights knowledge gaps in this topic to invite focused research to help bridging the gaps between operators, research institutes and chemicals developing companies. These gaps are classified in four main areas: Field Monitoring, Facility Design, Laboratory Testing, and Simulation & Prediction.

1. FIELD MONITORING

Field monitoring of corrosion progression and effectiveness of applied corrosion control measures ensures effective use and optimization of corrosion inhibitors. Monitoring is very critical for economic and safe operations as it allows adjusting the required inhibition dosage and minimizing the corrosion in oil and gas pipelines and processing equipment. When a corrosion inhibitor is injected, frequent monitoring of chemical tank levels, oil/gas/water production rates, corrosion inhibitor dosage rates can substantially reduce corrosion risks. Corrosion monitoring tools should be integrated in the operation practices to enhance efficiency, and ensure high life expectancy of equipment with optimized operating costs [1].

Despite the technological advancements in corrosion inhibitors development, residual monitoring continues to be a main challenging. Further research is needed to develop online analysis techniques, for continuous residual monitoring to ensure chemical availability in the system for effective protection. Moreover, there is a gap in establishing analysis procedures for measuring residuals in facilities where multiple corrosion inhibitors are used simultaneously. For example, in water supply and injection systems, different inhibitors are injected on surface and subsurface. Interferences between the two chemicals add more complexity to residual analysis. Likewise, additional development efforts are required to address possible interferences between amine-based corrosion inhibitors and amines compounds that are may be present naturally in some oils. Lastly, residual analysis for corrosion inhibitors in gas facilities continues to be a challenge that needs to be addressed particularly in fields where condensed liquids are very low

2. FACILITY DESIGN

Inhibitors are applied for corrosion control throughout the oil and gas production system extending from downhole to transportation pipelines, produced water and injection systems, and O&G processing facilities. Corrosion inhibitors can be applied through different injection methods, including squeeze treatment, continuous injection, and batch inhibition [4].

Pipeline designers tend to overlook the impact of fluid hydrodynamics and operating conditions on corrosion inhibitor treatment. Principally speaking, it is well known that high wall shear stress in the pipelines can significantly impact the stability of corrosion inhibitor film. However, influence of the operating parameters on the inhibitor film stability, on the pipeline steel's surface, should be further studied to get more understanding of all oil & gas process applications [5]. Many other factors are unexpectedly encountered, nowadays, that might affect the corrosion inhibitors performance and underlying requirements in designing oil and gas facilities. These factors include but not limited to the following:

Wall Shear Stress

It is well known that fluid flow is a critical factor affecting the performance of corrosion inhibitors. In fairly high velocity service or at wall shear stress > 100 Pa, corrosion inhibitors adsorption on metal service is usually questioned. Additionally, it is believed that effective distribution of the corrosion inhibitor can be crucially affected in low velocity services [4]. Therefore, flow velocity limits shall be further researched to ensure effective treatment. For example, the maximum wall shear stress above which the inhibition film may be destroyed, and the minimum flow velocity below which the corrosion inhibitor distribution is not ensured must be defined. Likewise, a methodology is required for calculating the maximum allowable interruption before corrosion inhibitor film is removed.

Number of Injection Points

For offshore oil and gas production pipelines, corrosion inhibitor is required to travel long distance to protect the total length of the pipeline. However, the corrosion inhibitor testing conventionally does not

address the transport ability of the chemicals to ensure protection of the entire length of the pipeline. Normally, corrosion inhibitor is tested in water or water/hydrocarbon small systems where it is required to travel short distances in the test fluids for full system protection. Therefore, further study is required to develop verified guidelines for testing how far corrosion inhibitors can be transported, and accordingly, identifying the optimum number of injection points needed [4]. Currently, a rule-of-thumb is followed in most of the hydrocarbons transmission lines' projects of having an injection point every 50 km.

Oxygen Ingress

Oxygen ingress due to process upset or plant start up can find its way to water supply/injection systems or even produced fluids in the amount of 100-500 ppb [6]. Phosphate esters are claimed to be effective in systems with <1ppm oxygen. However, it was shown that phosphate esters perform significantly less with presence of oxygen compared to systems with no oxygen [7]. Consequently, further efforts will be required to clearly define the threshold limits for oxygen content above which corrosion inhibitor efficiency will be significantly dropped [4].

Uncertainties Related to Inhibition Mechanisms of TLC

Despite the fact that Top of the Line Corrosion (TLC) was initially identified in 1990s, it has only been recently recognized as a serious corrosion threat in oil and gas industry. TLC is now considered as a main pipeline integrity concern and accounted for in any gas field project development. During the past two decades, tremendous efforts were invested toward elucidating TLC underlying mechanism and advancing in the mitigation and prediction tools [1].

Mitigation of TLC has been a challenging area in corrosion engineering since traditional inhibitors do not guarantee protection of the upper section (12 o'clock position) of the pipeline, especially in stratified flow regime. To ensure effective protection against TLC, the inner pipe circumference shall be entirely covered with the inhibition film [1]. Two corrosion inhibition methods being used in mitigating TLC; Batch Corrosion Inhibition (BCI) and Vapor-phase Corrosion Inhibition (VCI).

BCI is applied periodically and jetted, i.e. using v-jet tool, on the upper half of the pipe internal. BCIs are normally oil-soluble, which offer better film persistency compared to water-soluble inhibitors. One concern about BCI that it is considered, in some uncontrolled occasions, to be wasteful and resulting in high concentration of inhibitor remaining in the fluid that might cause stable emulsion and, hence, operation interruptions [4]. Periodic BCI treatment can ensure effective protection against TLC if the proper application frequency is accurately determined. The key to address this concern is better understanding of film persistency, which might be achieved through extensive laboratory testing and field verification [1]. Yet, there is no industrial testing protocol for BCI chemicals including determination of the film thickness and persistency on bare carbon steel and FBE coated pipes, and, as a result, defining accurately the required BCI application frequency.

On the other hand, search of chemicals that has adequate inhibitive properties (held usually by long-chain molecules) and, simultaneously, exert sufficient volatility (held usually by short-chain small molecules) to cover the entire pipe internal surface, is the paramount interest of chemical companies recently [1]. So far, limited success has been proven in the development and use of volatile corrosion inhibitors in field [8]. Volatile components are usually added to the corrosion inhibitor with the intent to be transported through the entire pipeline length with the gas phase, and either neutralize the corrosive acid gases or partition to the condensed water phase, providing the required protection [4]. Although TLC mechanism has been well comprehended by corrosion experts, inhibition efficiency of liquid phase corrosion inhibitors and film formation of VCI are not well understood. This gap in knowledge requires further research to effectively address the TLC challenge.