

Optimization of Internal Corrosion Assessments in Crude Oil Pipelines with an Internal Corrosion Predictive Model

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ABSTRACT

This paper explores optimized approaches used to assess the internal corrosion condition of several crude oil pipeline segments with the support of a robust internal corrosion predictive model (ICPM). Proven ICPMs can predict internal corrosion wall loss within $\pm 10\%$ of the actual wall loss confirmed by inline inspection (ILI) or non-destructive techniques. In addition, the ICPM can accurately predict water and solid accumulations for the entire pipeline, enabling operators to proactively pinpoint susceptible locations and develop prevention and mitigation plans. Operators can also realize significant savings on inspecting and managing transmission pipelines, especially for non-piggable pipelines where ILI and/or hydrostatic testing is not practical. The results of this holistic assessment with ICPM were validated with ILI, and the comparison showed promising results. Lessons learnt and real-life case studies are presented to substantiate the presented arguments.

Key Words: ICPM, ILI, Direct Assessment, Crude Oil, Data Analysis and Integration, Pipeline Integrity, Internal Corrosion, Internal Corrosion Mechanisms, Validations.

INTRODUCTION

Oil and gas pipelines may suffer internal corrosion if they are exposed to corrosive conductive environments in the presence of conductive water. The corrosivity is dependent on several factors such as the temperature, total pressure, partial pressures of CO₂ and H₂S in the gas, oxygen content, water cut, flow rate / histories, pH of water, flow conditions, presence of microbial organisms, use of inhibiting chemicals, etc. It has been reported¹ that pipeline failures caused by internal corrosion have always been a major issue for pipeline operators and the general public. Reports from the US Department of Transportation and the Pipeline and Hazardous Materials Safety Administration indicate that internal corrosion accounts for approximately 60% of all pipeline incidents caused by corrosion and during the 5-year period of 2013-2017, approximately 12% of incidents on gas transmission, gas gathering, and hazardous liquid pipelines were caused by internal corrosion¹⁻⁴.

To prevent internal corrosion and / or assess the integrity of pipelines, industry-wide accepted pipeline integrity assessment techniques are employed by inline inspection (ILI), direct assessment and pressure testing or other equivalent technologies. However, conducting comprehensive integrity assessments on all pipelines in numerous networks may not be practically feasible due to logistics / timing, interruptions in operation due to the intrusive nature of the inspection type, cost, limitations in applying some integrity assessment techniques (e.g. ILI for difficult-to-pig pipelines), third-party involvements, weather, etc.

For crude oil pipelines that are easy to pig, most operators normally rely on ILI to detect internal corrosion defects. In addition to ILI, internal corrosion direct assessment (ICDA) programs with concurrent internal corrosion predictive modelling (ICPM) can be supplemented with ILI to ensure the holistic integrity assessment of crude oil pipelines. ICPM predicts not only the estimated internal corrosion rate but also the locations most susceptible to internal corrosion based on water and solid accumulations. For instance, the assessment of internal corrosion susceptibility on multi-phase pipelines requires the review of comprehensive inspections, historical pipeline data, and operational information including gas analysis, water analysis and solid analysis. This helps establish not only the trend but also expected internal corrosion damage mechanisms with a high level of confidence. With ICPM, operators are able to identify potential internal corrosion initiation behaviour that is not normally reported when ILI reported wall-losses are <10%. Once the exact corrosion and / or damage mechanism is identified, associated monitoring and mitigation actions can easily be established. This is an effective way to optimize internal corrosion assessments on crude oil pipeline segments⁵.

Liquid water is necessary for internal corrosion to initiate and determining the existence of water in a crude oil pipeline with ICPM is vital to the success of any ICDA inspection program. In crude oil petroleum pipelines, the internal corrosion threat assumes that internal corrosion only occurs when water drops out of the hydrocarbon phase and wets the steel surface of the pipe. Internal corrosion in locations in which water accumulates may also be significantly exacerbated by organic or inorganic solids that may co-precipitate from the liquid, grow on the pipeline surface, or both. Liquid petroleum (LP-ICDA) allows water and solid accumulation locations to be confidently predicted with ICPM. With these predictions, operators can proactively address internal corrosion concerns. This showcases how internal corrosion issues can be optimized by ICPM.

Internal corrosion assessments on crude oil pipelines have been proven to be optimized when ILI and supplementary ICDA methodologies are employed. When ILI has identified internal corrosion metal loss, ICDA can be supplemented to identify the root cause of the problem. ICPM is one of the tools that supports the root-cause analysis. When corrosion mechanisms are identified using direct assessment (DA) methodologies, root-cause analysis must be done to plan for mitigative and preventative actions. To evaluate the likelihood of internal corrosion on crude oil pipelines, comprehensive historical and operational pipeline parameters are assessed to identify possible corrosion mechanisms.

In this instance, ICPM is used to assess the severity of internal corrosion by identifying the locations or sites where internal corrosion is most / least likely to have occurred. With ICPM, the internal corrosion initiation behaviour not normally reported by ILI can be easily identified. From a corrosion control standpoint, once the exact corrosion and / or damage mechanism is identified, associated monitoring and mitigation actions can readily be established⁵.

OPTIMIZATION OF INTERNAL CORROSION ASSESSMENTS

When practically possible, combining ILI with ICDA (supported by ICPM) is an effective way of managing pipeline integrity. ICPM has been proven to optimize internal corrosion assessments. This is because ICPM can predict critical parameters that can be combined with ILI data to holistically assess internal corrosion concerns. Proper ICPM accurately predicts water, solid accumulations and associated internal corrosion rates for the entire pipeline; therefore, operators are able to leverage ICPM during risk assessments to proactively employ measures to enhance their internal corrosion management strategies. Assessment of internal corrosion likelihood with proper ICPM would require information on temperature, total pressure, partial pressures of CO₂ and H₂S in the gas, oxygen content, water cut, flow rate / histories, pH of water, flow conditions, presence of microbial organisms, use of inhibiting chemicals, and pipeline inclination profiles.

When ICPM is employed to support the internal corrosion assessments on crude oil pipelines, all required input data is needed. The required input parameters are documented in Table 1 of NACE SP0208 Standard Practice⁶. Generally the input data should include pipeline elevation profile, process data (operating temperature, pressure, gas compositions), flow data (flow rate, density, viscosity, pipeline details, water properties details, solid properties details), operational parameters (pipe wall thickness, time in service, inhibition details), water analysis (chlorides, bicarbonates, acetate, oxygen, ionic strength).

The ability to accurately predict water and/or solid accumulations and internal corrosion rates with robust ICPM software helps operators proactively determine mitigative internal corrosion measures and precisely deploy corrosion monitoring probes and coupons for internal corrosion management. Operators can also expect to realize significant savings in inspecting and managing transmission pipelines, especially for non-piggable pipelines where ILI and/or hydrostatic testing is not practical. The optimization of internal corrosion assessments with ICPM can help operators implement proactive internal corrosion management systems to prioritize pipeline segments and prevent potential failures along their pipeline networks.

When ICPM is used to assess the integrity of difficult-to-pig crude oil pipelines per NACE SP0208-2008⁶, ICDA can be optimized:

- On crude oil pipelines, the assumption is that internal corrosion occurs when water wets the pipeline wall. Robust ICPM is able to predict whether the pipeline wall is likely to be wetted with oil, water and / or both wetted with oil and water depending on operating conditions. The wettability can be used to assess the likelihood of internal corrosion (together with other governing factors).
- ICPM can accurately predict water, solid accumulation locations and internal corrosion rates for the entire pipeline.
 - o Depending on the water and solid accumulations, general and localized internal corrosion attack can occur on crude oil pipelines, and this can be easily predicted with robust ICPMs.