PIPELINE INTEGRITY
AXIAL CRACK THREAT ASSESSMENT

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1. INTRODUCTION

Within the Crack Management Plan, a comprehensive crack threat assessment is completed if the susceptibility assessment and mitigation plan determine that one is required. The comprehensive crack threat assessment confirms if critical cracking exists on the pipeline system and may identify other important conditions such as the population of cracking, the type of cracking mechanism present, and whether or not in-service growth has been present. The primary forms of comprehensive crack threat assessment include crack inline inspection, pressure test, and direct assessment programs.

The Crack Threat Assessment Guideline document provides guidance on choosing an assessment methodology. Determining the most appropriate method requires consideration of numerous variables including pipeline characteristics, operating conditions, and past failure history. Each pipeline segment is analyzed on a case-by-case basis as a single method would not adequately consider all situations.

2. CRACK ASSESSMENT METHODOLOGIES

2.1. Crack In-Line Inspection ("ILI")

Typical crack ILI for liquids pipelines use ultrasonic technology to find and size cracks. This is the most common comprehensive crack threat assessment method currently used by Enbridge. Crack ILI is the most informative form of crack threat assessment in that a successful crack ILI run provides detailed information about the crack-like features in the pipeline. Predicted failure pressures and fitness-for-service can be determined from this data. This information allows Enbridge to understand the pipeline condition, plan for short and long term remediation activities, and schedule future assessments.

Advanced analytic or reliability assessment strategies are utilized as a technique to manage integrity program uncertainty due to measured ILI program performance. This performance can be specific to a given defect type or overall precision and accuracy. These assessment strategies can include:

- complete a follow-up ILI program with the same or complementary technology;
- complete an independent reanalysis of the raw ILI data (this can be performed by the ILI vendor or a third party);
- impose a discharge pressure restriction or lower the maximum operating pressure ("MOP") on the pipeline; and
- conduct a hydrostatic pressure test.

2.2. Benefits Of Crack In-Line Inspection ("ILI")

2.2.1.

- Provides detailed information about feature type, location, and size.
- Along with a field validation program allows accurate re-assessment interval determination.
- Tool reporting threshold often identifies features smaller than what would fail at hydrotest pressures, allowing for an increased understanding of pipeline safety and theoretically allowing for longer re-assessment intervals.
- May find cracking threat(s) that were previously unknown and allow management of those threat(s) before failure.
- Pipeline can be inspected while in operation, saving time and cost.

2.2.2. Limitations

- Smaller outside diameter and thinner wall thickness pipe may require reduced reporting threshold for depth.
- Limited to axial features.
- Assessment of ILI data needs to consider that there is a low probability of a flaw being incorrectly identified.
- ILI tools rely on correct positioning of the transducer and therefore have limited ability to identify cracks within surface deformations, such as dents.

2.3. Hydrostatic Pressure Test

Enbridge considers hydrostatic pressure testing as an alternative pipeline integrity condition monitoring method, suitable as a comprehensive crack threat assessment. By testing to at least 1.25 times the MOP of the pipeline, axially aligned defects that would be expected to fail at MOP should be removed from the line by failure during the test. The pressure test is not specific to crack features; it would force a failure of all flaws with a failure pressure below the hydrotest pressure regardless of the cause. A post failure metallurgical analysis would be required to verify the failure mechanism and would be the source of information to verify if a cracking condition existed.

The application of hydrostatic pressure testing within the Enbridge integrity program is considered in the following circumstances.

- When an increase of the maximum operating pressure of the pipeline is planned or required.
- An effective ILI tool is not available that can assess the pipeline for anticipated integrity threats and pressure testing can be shown to provide assessment benefits. This can occur when an ultrasonic tool is required and a liquid couplant is not available.

- The pipeline is not capable of being inspected with ILI tools. This can be the case if a pipeline has tight bends, restrictive valves or other such physical impediments.
- Where, after the completion of a high resolution crack ILI program, the post-program assessment has demonstrated high uncertainty stemming from any of the following:
  - The repair program encounters false negatives (defects not detected by ILI) and the root-cause analysis shows that certain defect types cannot be managed through ILI. Review of the defect type must be completed as well to ensure that pressure test would be an effective method.
  - Probabilistic model results indicate high probability of failure due to false negatives (i.e. probability of detection for defects near MOP threshold is low).
  - Probabilistic/deterministic program trending shows unmanageable non-conservative sizing bias (i.e. probability of sizing for defects near MOP threshold is low)

The post-program assessment is completed using subject matter experts evaluating ILI program results, direct assessment results (false negatives), past failure history, operating context, and other factors that contribute to the understanding of the condition of the pipeline.

The following are the benefits and limitations of utilizing a pressure testing mitigation strategy, several of which are drawn from API 1160 - *Managing System Integrity for Hazardous Liquid Pipelines*.

2.3.1. Benefits

- Detects, by failure, all crack defects if their critical pressure is below the test pressure. This manages uncertainty for defects that are critical below the test pressure at the time of the test.
- Available for small diameter pipe.

2.3.2. Limitations

- Due to the nature of a pressure test, little to no information about the remaining defect severity and locations can be determined, although a maximum just surviving flaw can be estimated.
- The margin of safety provided by the test diminishes over time.
- Successive cycles of test pressure may cause other anomalies to grow such that successive failures can occur at pressure levels below that of a prior pressurization (pressure reversal) which increases the risk of a non-conservative re-assessment interval.
- Crack initiation or growth at locations of otherwise non-injurious defects and / or re-initiating otherwise dormant stress corrosion cracking colonies can occur.
- Short deep flaws could go undetected.

- Depending on test pressure, much larger features may be left in the pipeline than if a crack ILI had been used for a baseline.
- Pressure testing of a pipeline that has been in service is complicated by the need to interrupt liquid transportation service and by the difficulties in acquiring water for testing and in disposing of the water once it has become contaminated.
- Lastly, pressure testing is not a sustainable method for monitoring a pipeline system given that it cannot be applied continuously system wide, unlike ILI that can be utilized widely and frequently. Wide reliance on hydrotesting would also represent a resource distraction from continuously improving the more sustainable method of ILI.

2.4. Direct Assessment Programs

Direct assessment is an acceptable crack threat assessment method for pipelines if the target threat is stress corrosion cracking ("SCC").[1] Direct assessment requires gathering and analysis of dig results from sites that are specifically chosen for assessment as likely sites for SCC. In addition, other excavations completed on the segment must also record the presence and severity of SCC found by field non-destructive examination ("NDE").

It should be noted that all cases of SCC found on the Enbridge system are recorded in the NDE report independent of the actual reason for excavation.

3. REFERENCE DOCUMENTS

OPS TT05, Low Frequency ERW and Lap Welded Longitudinal Seam Evaluation, Revision 3, April 2004

CEPA, Stress Corrosion Cracking, Recommended Practices, 2nd Edition, December 2007

CFR 49, Parts 192 and 195, October 2011

[1] 49 CFR 192.921 (3)