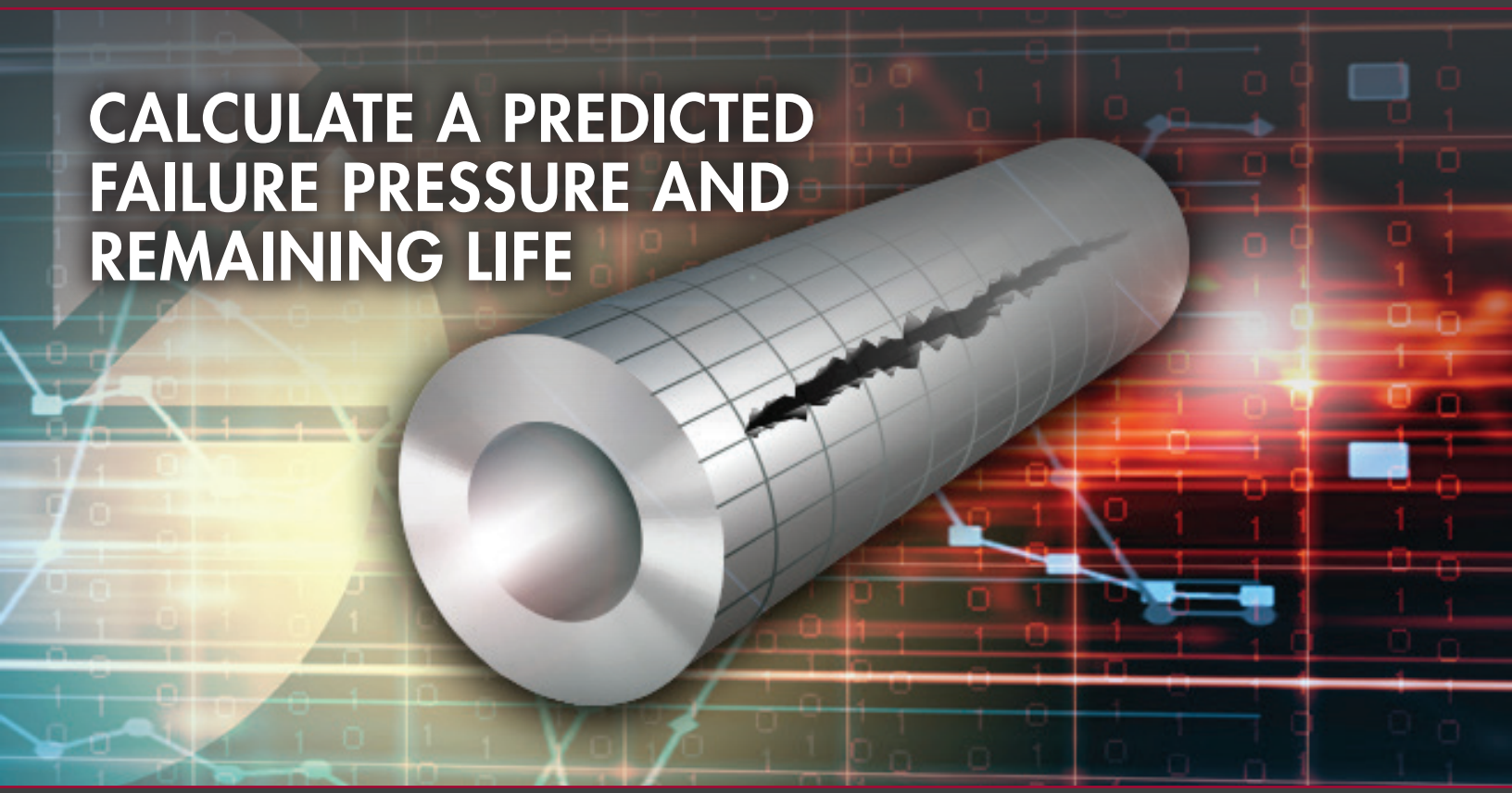
APTITUDE™

CRACK EVALUATION FOR PRESSURIZED CYLINDERS



CALCULATE A PREDICTED FAILURE PRESSURE AND REMAINING LIFE

According to pipeline safety regulation 49 CFR § 192.712 - Analysis of predicted failure pressure, "An operator must determine predicted failure pressure, failure stress pressure, and crack growth using a technically proven fracture mechanics model appropriate to the failure mode (ductile, brittle or both), material properties (pipe and weld properties), and boundary condition used (pressure test, ILI, or other)."

The application of APTITUDE™ combined with Structural Integrity's fracture mechanics expertise, provide pipeline operators an efficient and cost-effective method to complete an Engineering Critical Assessment (ECA) and PFP analysis to meet the pipeline safety regulatory requirements.

APTITUDE calculates a Predicted Failure Pressure (PFP) using multiple industry accepted methods crack and crack-like defects in pipelines.

APTITUDE also determines the optimal re-assessment interval based on criteria defined in updates to the Pipeline Safety Regulation §192.712 .

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Structural Integrity Associates, Inc.®

WHY USE APTITUDE?

An accurate and easy to use application that can analyze cracks and crack-like defects in pressurized steel cylinders is needed to ensure safety, regulatory compliance, and asset optimization.

APTITUDE is not only accurate and easy to use, it also addresses a wide range of material properties (yield strength, flow stress, fracture toughness) and pipe and flaw geometries (diameter, wall thickness, thru-wall or surface crack, crack length, depth, and orientation). APTITUDE employs various approved methodologies to calculate the most applicable predicted failure pressure (from reference standards), determine crack categories, and establish re-assessment intervals since each methodology has limitations, boundary conditions, and conservatisms.

APTITUDE DETAILS

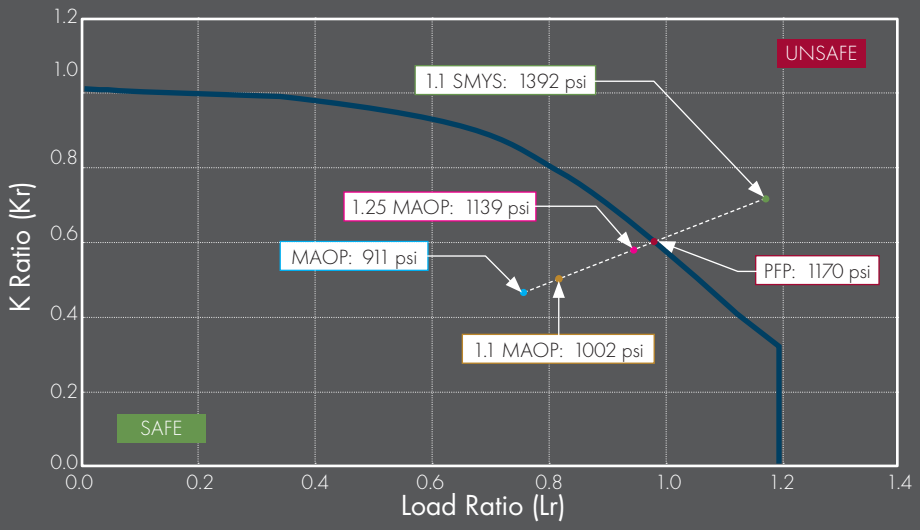
APTITUDE, was designed to evaluate crack and crack-like defects using the following commonly employed methodologies:

- Modified Ln Secant
- Failure Assessment Diagram (API-579 Level or the MAT-8 methods)
- Finite Element Based Limit Load Approach (Limit Load)

APTITUDE also incorporates the ability to use different Charpy V-Notch (CVN) to fracture toughness correlations, multiple crack geometries, different flow stress approximations, and, if available, measured material properties such as material fracture toughness, yield strength, and ultimate tensile strength.

Lastly, APTITUDE incorporates advanced fracture mechanics logic that recommends one method among the various options, the optimal calculation approach which accounts for methodological limitations and boundary conditions, based on the specified set of pipe / flaw geometries and material properties.

Failure Assessment Diagram (FAD)



A FAD is a versatile approach to evaluate crack defects as it applies to a wide range of material behavior from brittle fracture under linear elastic fracture mechanics conditions to ductile overload in the fully plastic regime.

The x-axis represents a Load ratio (Lr) or the ratio of the reference (applied) stress to the yield strength of the material. The y-axis represents a K ratio (Kr) or the ratio of the applied stress intensity within the crack (KI) to the fracture toughness of the material (Kmat).

These two parameters, Lr and Kr, provide an assessment point on the FAD that is a function of material properties, crack dimensions and operating pressure. As the pressure increases, the point moves up and to the left on the FAD. Also plotted on the FAD is a failure curve. If the point falls below the failure curve, the component is considered stable or "safe" for operation. The predicted failure pressure can be determined by the pressure at which the point falls on the failure curve for a given flaw and set of material properties.

USER APPLICATIONS

APITTUDE has been used by several major pipeline operators in the United States to address crack and crack-like defects discovered in their pipeline systems. Some of the common applications include:

- Evaluate the predicted failure pressure of pipeline cracks and crack-like defects to meet the pipeline safety regulatory requirements (§192.712) – capabilities include
  - Analysis of cracks defects with different root causes such as SCC and Electric Resistance Welded (ERW) Long Seam Weld defects
  - Application of fracture mechanics methods appropriate for the applicable failure mode (ductile, brittle, or mixed).
- Calculate the failure pressure ratio for flaws identified by in-line inspection (ILI) and/or NDE to help guide appropriate remediation steps in accordance with a pipeline operator's PFP procedure and crack management plan(s).
- Analyze In Line Inspection (ILI) crack tool results to prioritize indications and evaluate against regulatory required response criteria.
- Establish re-evaluation periods and re-assessment intervals through a remaining life analysis using various models such as SCC bathtub curve, fatigue, and linear crack growth
- Support MAOP reconfirmation activities when applying an Engineering Critical Assessment (ECA).

The application of APTITUDE combined with Structural Integrity's fracture mechanics expertise, provide pipeline operators an efficient and cost-effective method to complete an Engineering Critical Assessment (ECA) and PFP analysis to meet the pipeline safety regulatory requirements.

APTITUDE is currently being used in a Joint Industry Project to evaluate crack and crack-like defects in hydrogen blending environments.