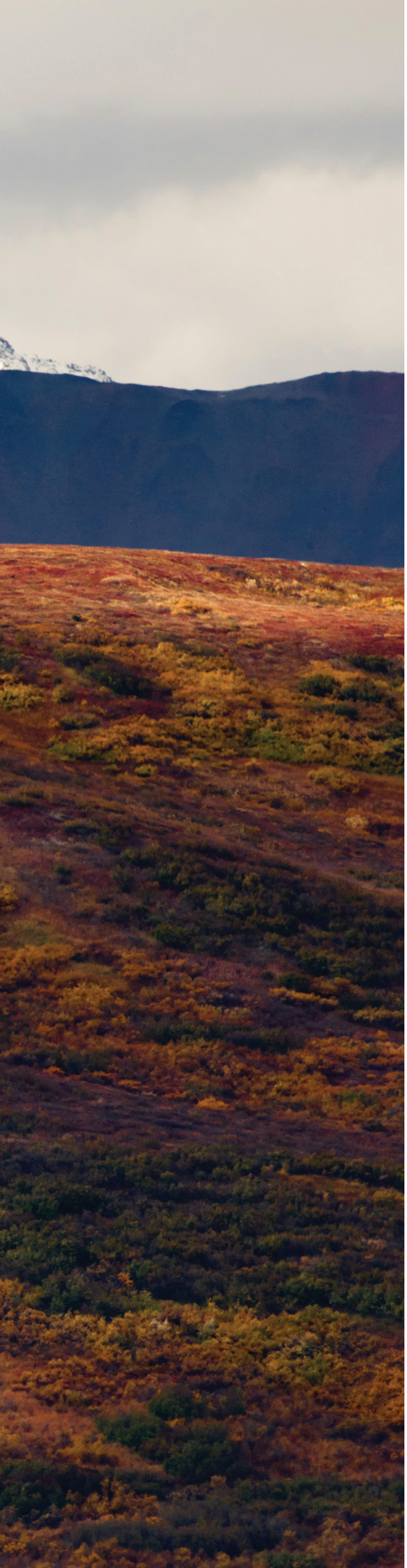
energy API

Companion Guide To

API RP 1176

Assessment and Management of Cracking Pipelines

TABLE OF CONTENTS



ASSESSING AND MANAGING PIPELINE CRACKS

Introduction

Pipelines are responsible for safely transporting petroleum and natural gas over 2.6 million miles. The pipeline systems that are used to transport products must be maintained to prevent against pipeline anomalies, such as cracking. Being able to assess pipelines and manage threats are key elements of an operator's successful integrity management plan.

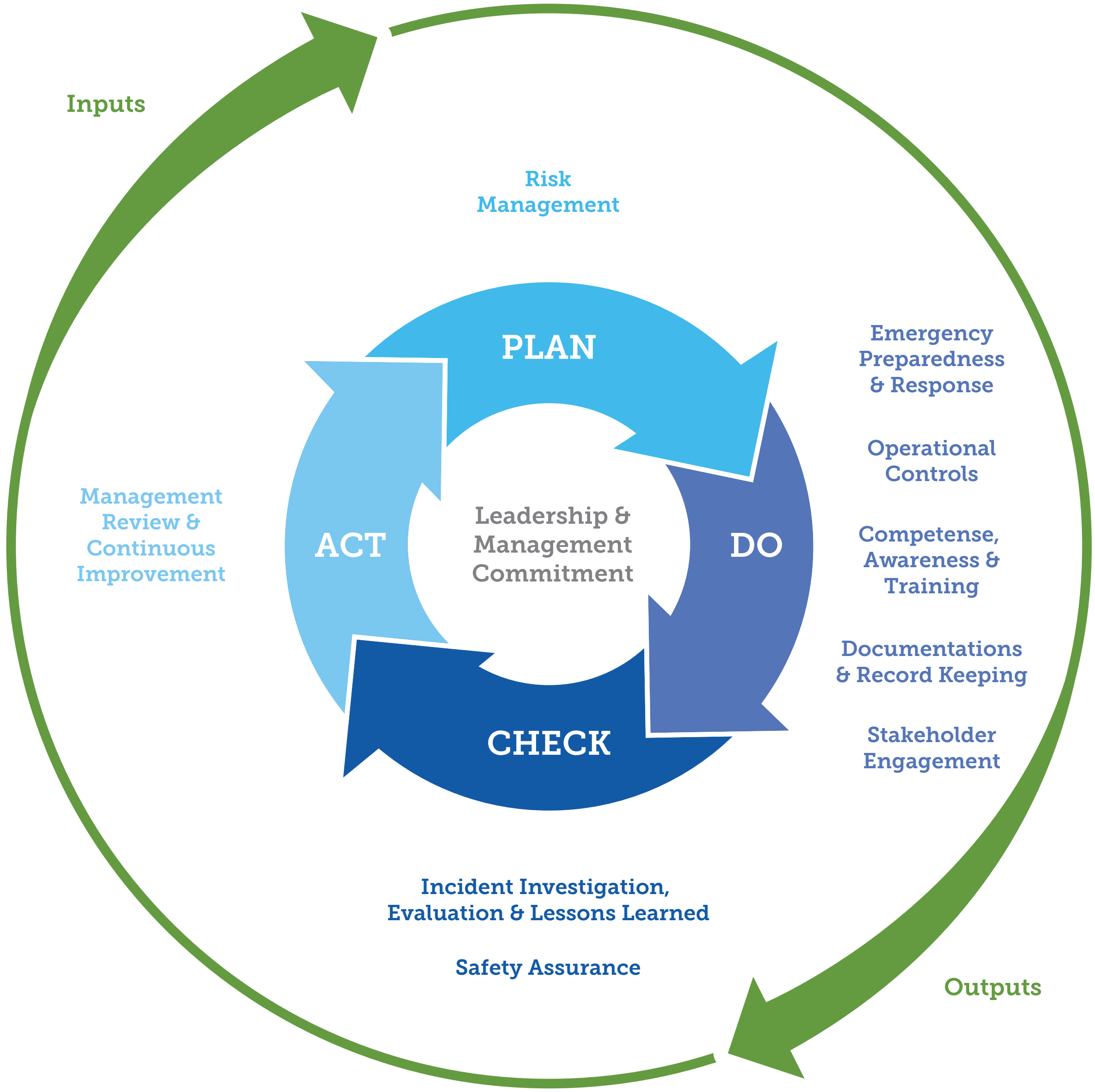
In 2016 API introduced a new recommended practice for crack management programs, API RP 1176. This document is intended to help industry more effectively use API RP 1176 by highlighting pertinent sections and key considerations. Senior leaders can use this document to get an overview, while subject-matter experts (SMEs) are encouraged to read the whole RP in an effort to fully understand implementation.

PLAN-DO-CHECK-ACT CYCLE

The Plan-Do-Check-Act (PDCA) cycle is central to all pipeline processes, including crack management programs. API RP 1173, Pipeline Safety Management Systems, outlines the PDCA process.

Consider one example for instituting PDCA for your crack management program:

PLAN	DO	CHECK	ACT
Identify the extent to which cracking, in any form or due to any cause, could affect pipeline integrity and chart a timely process, prioritized based on risk, to assess, prevent, and mitigate.	If threats are found, execute a plan to mitigate and prevent future crack growth, which includes making any planned repairs by uncovering, repairing appropriately, hydrostatic pressure testing, and putting back in service.	Assess line to ensure all threats are under control and your plan was successful. In other words, did you find what you thought you would find?	If assessment finds more cracks or need to modify the inspection strategy, make the unplanned repairs and update the plan. For instance, if you found cracking you didn't think you had, such as circumferential cracking, make adjustments to account for that through an updated susceptibility analysis.



Inputs
Risk Management
PLAN
Emergency Preparedness & Response
Operational Controls
Management Review & Continuous Improvement
ACT
Leadership & Management Commitment
DO
Competense, Awareness & Training
Documentations & Record Keeping
CHECK
Stakeholder Engagement
Incident Investigation, Evaluation & Lessons Learned
Safety Assurance
Outputs

Susceptibility—What causes pipelines to crack?

Section 6 of API RP 1176 (Threat Mechanisms Associated with Cracking) provides details about the characteristics and susceptibility indicators addressed with the RP.

A susceptibility assessment must be conducted and includes review of pipeline characteristics to determine the potential likelihood and severity of cracking on each segment. This process should be continuously monitored for changes in operation or discoveries of new information, even when an effective in-line inspection (ILI) program is in place.

Remember, there is no perfect material: all commonly used grades of line pipe steel are potentially susceptible.

Be aware that no type of pipe manufacturing process, both past and present, is inherently a defect free process.

Key factors to consider for susceptibility:

- Pipe manufacturer (industry experience) and vintage
- In–service failure history
- Operational history (pressure cycling severity and maximum operating pressures, or MOP)
- Coating and other environmental factors, including cathodic protection (CP) performance
- Previous hydrostatic testing results, including failures and maximum test pressures
- Results of ILI and historical excavation nondestructive examination (NDE)

Annex A provides susceptibility information for stress corrosion cracking (SCC), and Annex B provides a prioritization flowchart for electric–resistance welded (ERW) pipe, electric fusion welded (EFW) pipe, and lap–welded pipe. Note that both low–frequency and high–frequency ERW are susceptible to similar manufacturing flaws so manufacturing date should not be used in isolation to determine susceptibility (i.e. pre–1970 ERW). While Annex B does not specifically reference submerged arc weld (SAW)/double submerged arc weld (DSAW) seam welds, they too can be susceptible to manufacturing flaws, although not typically as frequent or severe as low-frequency ERW seams.

INTEGRITY ASSESSMENTS

Section 10 of API RP 1176 provides guidance for considering different methods to complete an integrity assessment for cracking on a pipeline.

When determining the appropriate integrity assessment method for cracking, careful consideration of the benefits and limitations is critical.

Types of integrity assessments that can be completed on a cracking pipeline include:

- ILI
- Hydrostatic testing
- Direct assessment, for stress corrosion cracking (SCC) only
- Or a combination of methods, such as multiple ILI or combination of ILI and hydrostatic testing

Key considerations for ILI are:

Typical threats to probability of detection (POD) and probability of identification (POI) (Section 11.1)

- Line cleanliness
- Tool speed and potential for tool stoppages during inspection
- Technology limitations (not the right tool for the threats)
- Performance in diameters less than 10–12" and in wall thicknesses below 0.250" may be lower than typically experienced
- Can be conservative or non–conservativ e uncertainty in POI and POS
- Different flaws may provide similar response to ILI

Photo courtesy of Colonial Pipeline Company

Additional considerations for ILI include:

- Need a performance measurement system
- POD, POI, and POS can be used to measure vendor-specified performance but can still miss a defect
- Need additional measures to understand program performance, which includes performance of ILI and response criteria
- Need to understand what additional activities (such as pressure management or hydrostatic test) may be required if performance is judged not to be adequate

Understanding the benefits and limitations of common crack ILI technologies (Section 11.2)

- Liquid–Coupled Angle Beam Ultrasonic (UTCD)
- Electromagnetic acoustic transducer (EMAT)
- Circumferential magnetic flux leakage (CMFL)

Key considerations for hydrostatic testing are:

- Minimum-strength test pressure is 125 % MOP and 110 % MOP for a leak test
- Spike testing may provide increased reassessment intervals, but there are situations where it may be inadvisable (Section 12.4.2.4)
- Pressure reversals may occur and can cause the failure pressure of the largest remaining flaw(s) to be lower than the experienced test pressure

DETERMINING FITNESS-FOR-SERVICE OF PIPELINES

Burst Pressure Assessment of Crack–like Flaws

There are several acceptable assessment methods to assess crack–like flaws in pipelines including:

- Battelle Model (Modified Log–Secant)
- CorLAS™
- API 579 Part 9

There are also other models and published industry studies are available to demonstrate the performance of each method. The critical consideration for use of any method is to understand potential uncertainty associated with inputs and possible model errors.

Due to uncertainty in the inputs, conservative values should be selected for deterministic assessments. Note that for different types of analysis, the same assumption could either be conservative or non-conservative.

In some cases, it may be appropriate to include residual stresses or local bending stresses (Section 7.2.6) and API 579 is the only method that can incorporate these effects.

Section 7 of API RP 1176 (Fitness–for–Service of Crack–like Flaws) provides a list of considerations for inputs for crack burst pressure modeling, and Annex D and Annex E provide additional guidance for material strength and toughness inputs.

Photo courtesy of Colonial Pipeline Company

Photo courtesy of
Marathon Pipe Line

USING DATA TO PREVENT FUTURE CRACKS

Photo courtesy of TransCanada

Data Integration and Threat Interaction

Section 9.2 of API RP 1176 (Data Integration and Threat Interaction) are important to all threat management programs and should be completed in the case of crack management programs, as well.

If available, crack ILI data should be compared to geometry and metal loss ILI results to identify potential interacting threats, such as dents with cracks or metal loss with cracks. Ultrasonic crack ILI tools may often report corrosion as crack–field or crack–like features (i.e., seam weld, Feature B, weld anomaly, manufacturing anomaly, etc.), which may result in a significant number of false positives being reported. A thorough validation program and experience with each pipeline can support decision-making in these cases.

Crack ILI performance can be degraded in areas of deformation, particularly if the deformation is sharp or narrow. Section 6.4 of API RP 1176 discusses different types of mechanical damage and deformation, including susceptibility to forming cracking. Mechanical damage with gouging or cracking should always be targeted for excavation.

Crack Growth and Reassessment Interval Determination

Section 8 of API RP 1176 (Crack Growth) provides detailed guidance for crack growth modeling.

A wide range of results is possible depending on the input assumptions, so careful consideration of inputs is required.

Pressure cycle monitoring and pressure cycle counting

- Increasing the frequency of pressure sampling increases the accuracy of the remaining-life calculation. In addition, the longer the time frame over which pressure data is collected, the more accurate the remaining-life calculation will be because seasonal changes or other operational changes are more likely to be sampled.
- Pressure cycling should be monitored on a regular basis to check for changes that were not previously predicted or considered. Pressure cycle management is important to reduce growth, particularly on liquids pipelines.
- Rainflow cycle counting can be used to simplify complicated pressure cycling information into data that is more easily used for growth modeling, as discussed in Section 8.1.4.

Starting Flaw – Hydrostatic Testing

- When generating starting flaws from hydrostatic test results, it is more conservative to use higher values for strength and toughness for the analysis because higher strength and toughness could result in a larger starting flaw surviving the hydrostatic test pressure. Mill test data is the most accurate way of determining appropriate material properties. The RP provides possible material properties in Annex D and E for use when mill test data is not available. In some cases, the wall thickness input assumption may have a non–conservative effect, particularly if the wall thickness is much thicker than used for the assessment.
- Remaining life calculations using a flaw that just survives a hydrostatic test may be overly conservative if the input assumptions are too conservative.

Starting Flaw Size – ILI Results

- When generating starting flaws from ILI results, it is more conservative to use lower values for strength and toughness for the analysis because a smaller flaw could be critical in an area with lower properties. When determining a starting flaw size, vendor measurement uncertainties and field NDE results should be considered. In some cases, the wall thickness input assumption may have a non-conservative effect, particularly if the actual wall thickness is much thinner than the assumptions used for the assessment.

Growth Model

- Different growth mechanisms are typically modeled in different ways. The RP provides guidance for fatigue, SCC, and corrosion fatigue growth modeling.


INTEGRITY MANAGEMENT
"WE WILL"
2014
TRAINING
DO THE RIGHT THING
2014
2015
EVERY DAY


Photo courtesy of Colonial Pipeline Company

HOW TO RESPOND TO PIPELINE CRACKS

CRACK IN-LINE INSPECTION RESPONSE CRITERIA

Key considerations are listed here:

Section 11 of API RP 1176 (In–line Inspection Tool Types) provides a comprehensive review of crack ILI technologies and response criteria.

Perform data integration and analysis (Section 11.6.3)

- Integrate susceptibility factors, previous ILI experience on the line, and the current ILI results

Section 11.6 of API RP 1176 (Crack Tool Response Methodology) discusses the crack tool response methodology in detail.

Determine likelihood classifications (Section 11.6.4)

- Likely crack — an indication from the ILI results that in the operator's previous experience correlates to a crack–like defect with high certainty
- Possible crack — an indication from the ILI results that, in the operator's previous experience, has a reduced likelihood of being, or rarely been, an actual crack
- Unlikely crack — an indication from the ILI results that in the operator's previous experience has a high certainty to correlate to a non–crack–like feature or imperfection
- Limited previous inspection results, NDE, or other verification results should trigger the operator to use more conservative classifications for at least the first phase of the response

Determine Time Dependency (Section 11.6.5)

- Time–Dependent, potentially time–dependent, non–time–dependent
- Determine potential crack growth mechanisms to apply to reported features that may be time dependent
- Limited previous inspection results, NDE, or other verification results should trigger the operator to use more conservative classifications for at least the first phase of the response

Apply response criteria (Section 11.6.7)

- May require different or additional criteria to account for ILI limitations or pipeline–specific experience to maximize effectiveness
- Statistically relevant number of verification points to have confidence in the results

Verify initial selection based on NDE results or other verification methods such as cutouts

May require multiple phases of digs based on results of first phases to have confidence in the program

IN-THE-DITCH ASSESSMENT

Section 14 of API RP 1176 covers in–the–ditch assessment methods that are used to "detect, identify type, and size anomalies identified as possibly being cracks by ILI."

The two primary methods of in–the–ditch crack sizing are grind–removal and a variety of methods based on ultrasonic techniques. Magnetic Particle Inspection (MPI) is used to locate external cracks and can be used to measure the total length of surface-breaking anomalies.

Grinding is the most accurate way to complete crack sizing if completed correctly (Sections 14.2.3 and 14.4.3)

The proper way to remove a crack through grinding is to watch the tips of the crack move in and disappear. Through this process - and marking off where the tips move to - a proper crack grind profile can be generated. A more simple approach is to remove the crack fully by grinding, and measure the remaining wall thickness along the removed area. This typically generates a less-accurate, but conservative, result. Detection of indications prior to grinding using ultrasonic techniques is covered in Sections 14.2.2 and 14.4.2.

Grinding is destructive testing, and requires a detailed, formal procedure prior to commencing. For example, an operator may define certain limits in depth and/or length or restrictions based on the location of the crack. Ultrasonic inspection prior to grinding is required to check the estimated depth and length on mid–wall or internal cracks or other discontinuities.

There are many ultrasonic techniques (UT) available commercially, as detailed in Annex K in the RP. While the accuracy and precision of each method may vary, measurement uncertainty of UT methods is most likely similar to that of UTCD or EMAT tools. If grinding can be completed on at least a portion of the feature population, measuring the feature with UT and grinding may help define the uncertainty in the field UT measurements.

Photo courtesy of Colonial Pipeline Company

Quality of NDE data collection is critical to the successful implementation of an ILI–based crack threat assessment. Confidence in the in–the–ditch data must be high to allow verification of the classifications and response criteria used in previous phases of the program. Key considerations for successful collection of high-quality in–the–ditch data collection are:

- Have detailed procedures for collection of in–the–ditch inspection results to improve consistency and quality of the data collected
- Collect profiles or longest interlinked lengths rather than only peak depth and total length
- At a minimum, identify portions of cracks that fall below the detection threshold of the inspection tool to allow a consistent comparison
- When assessing in–the–ditch field data, use the same input assumptions for strength and toughness as used for assessment of the ILI results for consistency
- Collect accurate information about morphology and type that may be useful for classifying anomalies reported by future inspections and improving response criteria
- Have a robust process to take action in case ILI and in-the-ditch results do not match prior to closing the excavation, to learn from outliers

Photo courtesy of Colonial Pipeline Company

Repair Methods

Acceptable repair methods for cracking are described within ASME B31.4 and 31.8, as well as other industry publications from organizations such as API and the Pipeline Research Council International (PRCI).

Section 15 of API RP 1176 (Repair Methods) summarizes the benefits and limitations of different repair strategies with respect to repairing cracks.

Table 2, Acceptable Crack Repair Methods, summarizes repair strategies demonstrated to be acceptable for a range of different crack types. Grinding, pipe replacement, and pressure–containing full encirclement sleeves are the most widely acceptable methods for most types of anomalies. Potential repair methods are not limited to those described, but the operator should validate repair approaches if they are different from more common industry approaches.

Remember, grind repair is a destructive method and operators should have robust procedures in place to facilitate grind repairs.

If in–service welding is required, proper weld procedures and testing must be in place before in–service welding is completed.

Prevention and Mitigation

Section 16 of API RP 1176 (Preventative and Mitigative) briefly reviews some preventative measures operators should take to reduce the likelihood of crack initiation and growth and reduce uncertainty

- Mitigating transit fatigue
- Pressure cycle management
- Frequent updates to pressure cycle analysis
- Reducing likelihood of SCC

REVIEW CRACK MANAGEMENT PROGRAM SUCCESS

Crack Management Program Performance Evaluation

Section 17 of API RP 1176 (Crack Management Program Performance Evaluation) contains suggestions for how and what to consider for performance measurement.

Performance evaluation is a key part of all threat management programs. By doing the performance evaluation, operators will be able to show what has been achieved and how it was achieved. The performance measures should consider the activities identified to assess the crack threat, operational factors that affect the integrity of the pipeline related to the crack initiation and growth, and measures used to mitigate the crack threat.

Example measures to consider are:

The performance of the operator's integrity management process

- Leading indicators for this category are tied to the planning aspect of how the operator will deal with the hazard. Lagging indicators are those actionable items of the plan, such as hydrostatic testing two segments of pipe in the first year.

The performance of the operations integrity management activities

- Leading indicators for this category are tied to the "do" aspect of integrity actions, such as recoating 20 miles of pipe, whereas lagging indicators would be spot-checking areas that have shown no disbondment for 10 years.

The improvement in integrity achieved as a result of the integrity assessment, remediation, and mitigation activities

- Leading indicators for this section are broad general statements, such as having a goal of zero leaks before next hydrostatic test, whereas a lagging indicator would be not having leaks through five years, or spot-checking areas that have shown no disbondment for 10 years.

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