RCA Framework for Gas Distribution Piping Assets

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Abstract

A critical component of pipeline integrity management is understanding and fully characterizing the risks in the pipeline network. While integrity management efforts seek to avoid them, when pipeline releases do occur, they represent a valuable opportunity to further understanding and characterization of these risks in the pipeline. For gas distribution pipelines, however, a detailed analysis of every leak can be costly and provide limited benefit if new learnings are not identified or if learnings are not properly captured and applied. What is needed is a structured RCA (Root Cause Analysis) approach that allows for quick assessment of which pipeline leaks should be fully investigated and, for those that are, answers the fundamental questions: What is the true root cause of failure?; What are the implications for the existing infrastructure?; and What lessons can be applied to mitigate future integrity issues? This paper presents a general RCA structure to achieve this for gas distribution piping assets. The approach provides for a quick assessment of the implications of a pipeline failure on the existing infrastructure and identifies how to apply the learnings to new infrastructure to increase overall system integrity through the use of life-cycle fault trees and true causal factor identification.

Requirements for Effective Root Cause Analysis

Root Cause Analysis (RCA) of gas distribution leaks has long been recognized as a critical component of overall Pipeline Integrity Management (IM) programs. To take full advantage in applying the potential learnings from RCA of pipeline leaks, a structured process is needed that enables quick selection of where RCA efforts should be applied, directs the RCA to drive to true root causes and effectively implements the learnings in a continual process that drives overall pipeline integrity.

There are five key components that should be part of an effective RCA framework:

- Initial Screening
- RCA Analysis
- Impact Assessment for Current Infrastructure
- Impact Assessment for New Infrastructure
- Development and Implementation of Mitigations

Conducting a RCA that truly drives to the root cause and identifies true causal factors can be a difficult and time consuming process and also requiring different types of specialized expertise.

With roughly half a million gas releases reported in the PHMSA database annually, conducting a full RCA on each gas release is not practical – nor is it necessary. Many gas releases stem from known integrity issues (e.g. corrosion, vintage plastic, etc.) that are being actively managed in DIMP programs. There are, however, leaks that occur on new installations, new components or that are unusual in some respect on old installations and can be used to identify emerging or previously unidentified integrity threats. The first key component in an effective RCA process, therefore, is an effective process for selecting where RCA efforts should be directed.

Conducting the actual RCA effectively is the second key component. An RCA process is needed that truly drives to the key causal factors as these are where mitigations need to be applied. Many RCA efforts, however, stop short of identifying the true causal factors. An RCA that identifies improper compression on o-rings leading to leaking of a tee cap has not identified the true causal factors that led to those fittings being installed in the gas distribution system - the true causal factors for failures like this likely lie in the specification, approval and procurement processes. To eliminate similar future integrity issues it is necessary to drive to the true causal factors and apply mitigations at this level. Understanding these factors is also necessary to assess risk in the existing infrastructure.

Once a proper RCA has been conducted and the true causal factors identified, a risk assessment needs to be conducted to characterize the potential integrity implications for the existing infrastructure. Is this a random one off failure due to unique circumstances? Are all similar components subject to similar failure? etc. This type of risk assessment is critical to developing an appropriate short-term integrity response.

Once the immediate integrity concerns for the existing infrastructure have been assessed, the causal factors need to be examined so that similar integrity issues are eliminated in the future across all potentially impacted assets. This requires assessing potential mitigations for the true causal factors as they apply to all assets and not just the asset for which the RCA was conducted.

An effective process for implementing the findings of the RCA process is then needed to ensure that the appropriate mitigations are put in place for the existing infrastructure and for future installations.

RCA Framework

JANA has developed an RCA Framework based on the five key components identified above. The framework is intended to provide for conducting efficient and effective RCAs and ensuring that the learnings are properly identified and captured and proper mitigations are implemented to drive increasing pipeline integrity. The process is summarized for each of the components below.

Initial Screening

The initial screening process is based on a Threat Register and a Field Assessment Protocol. The Threat Register (TR) contains the details of currently identified integrity threats by specific asset type (e.g. vintage Aldyl piping, corrosion, etc.), including visual guides on common failure types. Starting with a generic baseline of industry identified threats, the TR is customized based on a given utility's specific identified threats. Baseline threats that have not been identified by a given utility are flagged as Potential Threats. Field personnel receive training on the TR and have access to the TR electronically in the field.

A Field Assessment Protocol (FAP) is used by field personnel to enable a quick assessment of failures versus the TR. The purpose of the FAP is to ensure, through a structured processes, that the maximum extractible risk information is captured quickly and efficiently in the field and that field personnel can quickly identify failures that warrant a more detailed RCA. Previously identified threats are logged based on company-standard procedures. For new or unique failure types, the more detailed RCA process is invoked.

Overall, the TR and FAP provide for quick and efficient screening of failures and ensure that potential emerging threats are identified in the field.

RCA Analysis

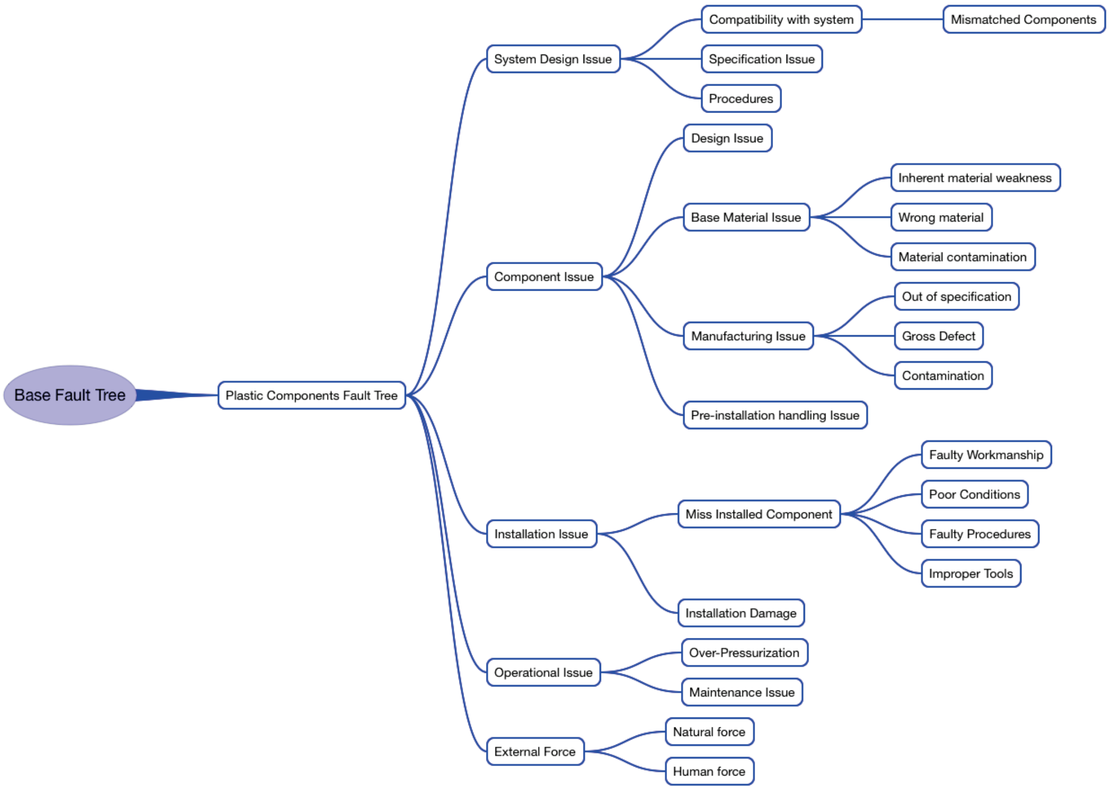
A structured RCA process is used to identify the true causal factors driving the failure. Based on a database of Fault Trees, the primary mechanism of failure is identified. Once the primary failure mechanism is identified, the end-use environment and component properties are assessed to enable determination of the mechanistic cause of failure. For example, for a leaking tee cap the mechanism of failure may be leaking through the cap caused by low compression on the o-rings. The base mechanism of failure is then fed into the process for impact assessments for existing and future infrastructure.

Impact Assessment for Current Infrastructure

Founded on the base mechanism of failure and Life-Cycle Fault Trees, a risk assessment is conducted to determine the potential impact of the failure on risk in the existing infrastructure. A simplified Life-Cycle Fault tree is shown in Figure 1 for reference. For the example of the leaking tee cap with low compression on the o-rings, this would be identified as a component design issue in the Life-Cycle Fault Tree. It is then easy to identify that this issue could potentially impact all tee caps with similar design. A risk assessment is conducted on this basis and appropriate mitigation activities are identified (e.g. stop installation of same tee caps, replace caps on existing installed tees, etc.).

A further assessment is then conducted to drive to the true, foundational, causal factors that enabled the tee caps to be installed in the field. At the base level, the true causal factors are typically related to: procedures, training, quality control, communications, management systems, human engineering or work direction. In the case of the tee caps, for example, it is likely a process gap in the specification, approval or procurement processes that enabled a new tee cap design into the field without proper validation or enabled a supplier to make design changes without notification. A higher level risk assessment is then conducted to determine how these true causal factors could impact overall pipeline integrity (i.e. are other components potentially at risk from the same causal factors and if so what actions should be taken to assess the risk for these assets in the existing infrastructure).

Figure 1: Simplified Life-Cycle Fault Tree



Impact Assessment for New Infrastructure

Based on the identification of the true causal factors, an assessment is made on the potential impact on new infrastructure. As appropriate, mitigations are identified to address the potential future risk implications. In the case of the tee cap, this would involve assessing the necessary changes to the specification, assessment and procurement processes for all components in the pipeline that the same true causal factors could potentially impact.

Implementation

The final stage of the process is implementation of the mitigations identified in the Impact Assessments. This is typically handled through the utility's existing DIMP or change management processes.

Overall Process

A structured framework with fault and causal factor trees ensures that the whole RCA process is completed effectively and efficiently. The process also ensures that the true causal factors are identified and addressed, maximizing the impacts of learnings and continually increasing overall pipeline integrity. From the initial screening in the field through to implementation, the process is supported by structured processes and guidance material so that it can be easily implemented and integrated into utilities operating practices. The overall result is optimization of, and genuine derivation of value from, the RCA process.