

## Managing Risk in Pipeline Installations

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### Abstract

Utilities continue to experience failures in recently installed piping systems. Not only do these failures increase utility risk, they also result in significant maintenance/replacement costs associated with the premature failure of a pipeline. These risks are not easy to combat after the fact or by employing standard methods.

New and formal approaches to Asset Management (AM) and Pipeline Safety Management Systems (PSMS)—such as the ISO 55000 series of Asset Management standards (“ISO 55000”) and API RP 1173<sup>1</sup> for Pipeline Safety Management – have been developed and are being adopted or considered by gas utilities. ISO 55000 was developed for all asset intensive industries and provides a general framework for an overall Asset Management system. API RP 1173 also provides a framework for asset management that is consistent with ISO 55000, yet it is focused specifically on pipelines. Both frameworks cover all stages of a pipeline's lifecycle – acquisition, operation, maintenance and renewal/disposal – and provide guidance and a requirements checklist of good practices in physical asset management. Both also include a focus on the “acquisition” phase of an asset, where systems are designed and, in the case of gas distribution, pipelines are installed and inspected. This phase is a particularly critical phase of a pipeline's lifecycle. As such, Asset Management plans need to ensure proper focus on the acquisition phase to improve the long-term system risk profile of a pipeline.

As the reliability and risk profile of new or replacement pipelines is largely set for buried pipelines by the choice of products and the installation practices used in construction, a new approach is needed for the industry; this approach is the API 1173/ISO 55000 compliant JANAcquire55™ process. The implementation of this process for the acquisition phase of a product lifecycle will help utilities eliminate early pipeline failures and extend the life of new pipelines past the point of relevance to today's stakeholders. The process is outlined and an example presented.

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<sup>1</sup> API Recommended Practice 1173, Pipeline Safety Management Systems, 1<sup>st</sup> edition- draft, American Petroleum Institute, 2014.

## Introduction

There is a growing interest by gas utilities and increased demand from stakeholders to improve pipeline safety and integrity performance through improving Risk Management (RM) and Asset Management (AM) practices. Whether it is to increase reliability, reduce risk or make better operating decisions, utilities are adopting formalized RM & AM practices. In fact, in evaluating rate cases, some public utility commissions are starting to base decision making on more sophisticated risk evaluations requiring comprehensive system knowledge and plans<sup>2</sup>. In these cases, the required information may only be available with the implementation of the appropriate AM practices and systems.

A suite of standards for Asset Management has been developed: ISO 55000<sup>3</sup> series. While these standards were developed broadly for physical asset intensive industries (e.g. railways, shipping, real estate, etc.), they provide a consistent framework for Management to identify and implement the appropriate business structures so as to be able to make effective data-driven decisions. Organizations can be independently audited and certified to these standards, indicating to the public and other stakeholders that they have a structured process to manage their pipeline assets. Most recently, Lloyd's Register certified PG&E for the operational standards of its gas operations, making PG&E one of the first utilities in the world to hold certifications for ISO 55001 and its predecessor, PAS 55-1<sup>4</sup>.

In addition, The National Transportation Safety Board (NTSB) recommended that API develop a pipeline safety system as part of its report in 2012 on the 2010 Marshall, MI pipeline spill. API has worked with the NTSB, PHMSA, states and industry to develop API RP 1173. This Recommended Practice benchmarks the current environment as it relates to PSMS, enhances the effectiveness of Risk Management and enables continual improvement of pipeline safety performance.

Both ISO 55000 and API RP 1173 provide a good framework for a pipeline asset management system; the adoption of either, or both in combination, can provide a strong foundation for pipeline safety and integrity management. The two frameworks share many common elements and have no contradictions. The primary difference is that the ISO 55000 is more general whereas API RP 1173 is specifically focused on pipelines. Both frameworks are premised on the Deming Plan-Do-Check-Act (PDCA) cycle, emphasize the importance of integrated process management, address the full lifecycle of the pipeline and emphasize the importance of the acquisition phase in an asset's lifetime. Given the commonalities of the frameworks, a functional AM system can easily be implemented with ISO 55001 as the overarching document for all asset classes and API RP 1173 as the supporting document for the provision of more detailed guidance for pipeline assets<sup>5</sup>. In this paper, the discussion is based on the more general ISO 55000 framework with reference to the more pipeline specific API RP 1173 where appropriate.

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<sup>2</sup> Order Instituting Rulemaking to Develop a Risk-Based Decision-Making Framework to Evaluate Safety and Reliability Improvements and Revise the General Rate Case Plan for Energy Utilities R-13-11-006, California Public Utilities Commission, November 2013.

<sup>3</sup> BSI ISO 55000:2014 series, Asset Management Overview, Principles and terminology, BSI, March 2014.

<sup>4</sup> PRNews, PG&E Earns Two Prestigious International Safety-Focused Asset Management Certifications For Gas Operations, San Francisco, May 23, 2014.

<sup>5</sup> JANA White Paper, "Structuring an Asset Management System for Compliance with Both API 1173 and ISO 55001 Requirements"

## Asset Management

In many industries, Asset Management has been synonymous with *equipment maintenance*. However, in the context of ISO 55000, Asset Management is a holistic approach to managing physical asset intensive organizations in order to optimize the value derived from the asset. Value is dependent upon the nature of an organization's activities and the needs and expectations of its stakeholders.

ISO 55000 lays out the benefits of effective Asset Management as:

Improved financial performance

- Informed asset investment decisions
- Managed risk
- Improved services and outputs
- Demonstrated social responsibility
- Demonstrated compliance
- Enhanced reputation
- Improved organizational sustainability
- Improved efficiency and effectiveness

Based on these benefits, it is evident that Asset Management is designed to address the principal concerns of an organization's Management and other stakeholders. Implementation of Asset Management standards starts at the Executive level with the establishment of organizational AM policies and objectives and the commitment to establishing an Asset Management System. The AM System is the set of *interrelated or interacting elements* that are used to integrate an organization's disparate activities.

The elements of an Asset Management System are:

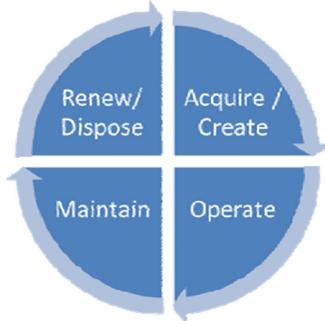
- Context of the Organization
- Leadership
- Planning
- Support
- Operation
- Performance Evaluation
- Improvement

All of these elements lead to informed decision-making that balances costs, risk, opportunities and performance in alignment with the organization's objectives.

## Asset Lifecycle

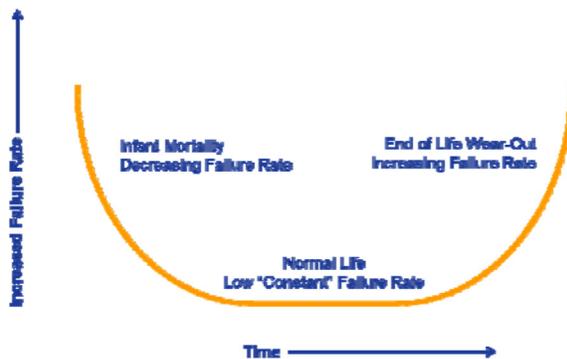
One of the key aspects of an Asset Management system is management of an asset's lifecycle. The physical asset lifecycle is typically made up of four phases (Figure 1).

**Figure 1: Asset Lifecycle Stages**



For gas distribution, the physical asset is very large and generally buried, hindering access, inspection and maintenance. This makes the Asset Acquisition phase the most critical, as the pipeline components and their installation will largely define the operating risk, functionality, longevity and reliability of the asset. Further, the failure rates over time of products, including pipelines, tend to follow a bathtub curve (Figure 2). The bathtub curve comes from the initial flurry of issues associated with a new installation over the first several years of the pipeline’s life until these are completely experienced and stop occurring; then there exists a long period of stability in performance of the pipeline until it approaches the end of its service life when failures begin to occur again and in greater and greater quantity. So, the curve a pipeline will follow – bathtub or otherwise – is cast upon its installation.

**Figure 2: Typical Product Bathtub Failure Rate Curve**



### Legacy Issues

The gas distribution industry—despite operating for over 100 years—continues to experience issues with the installed asset. These issues are related to poor installation, defective products or early wear out, resulting in either replacement or excessive maintenance (e.g. leak surveys). These issues result in leaks that are not only costly to correct but that significantly increase the risk of catastrophic consequences to workers and the general public. Distribution Integrity Management Programs (DIMP) have been mandated by federal regulation since 2010<sup>6</sup>. DIMP is focused on managing the currently installed asset base and the legacy issues within that asset base.

<sup>6</sup> Pipeline Safety: Integrity Management Program for Gas Distribution Pipelines, United States Federal Register, 49 CFR 192, Vol. 74, No. 232, 2009.

The legacy issues associated with steel piping and early generation plastic piping (ABS, PVC and PE) are well known and are being actively addressed by gas distribution companies. However, DIMP programs do not address other underlying issues that pose the potential of becoming future system threats. The potential threats come from:

- Design flaws within current, improved or new pipeline components
- Component quality variation
- Inadequate installation practices and controls
- Unintended consequences of other changes
- Interactions of all or some of these items

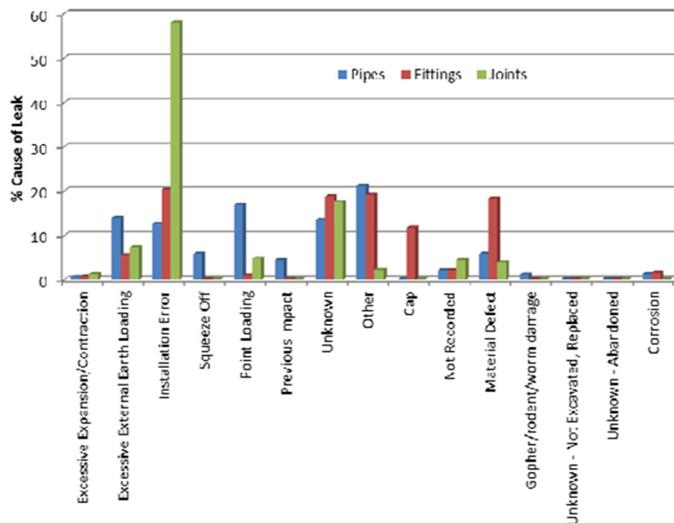
The American Gas Association (AGA) Plastic Pipe Data Collection (PPDC) findings support that there remain issues with recently installed distribution pipelines<sup>7</sup>. Of gas distribution pipeline joint leaks experienced within the first five years of installation, 53.6% of leaks are due to installation errors, 19.1% of fitting leaks are due to material defects and over 20% of the leaks have unattributed causes (unknown, not recorded or other), as shown in Table 1 and Figure 3. Similarly elevated numbers exist for pipe and fitting leaks. What is not known is how these systems will perform long-term. It is certain that product design and quality issues or poor installation issues can take years to present themselves.

**Table 1: Failure/Leak Causes for Pipe, Fittings & Joints within 5 Years of Installation<sup>7</sup>**

Cause	% of Total Pipe Failures/Leaks	% of Total Fitting Failures/Leaks	% of Total Joint Failures/Leaks
Expansion/Contraction	0.5	0.6	1.2
External Earth Loading	12.2	4.5	6.2
Installation Error	13.9	25.8	53.6
Squeeze Off	5.4	0.2	0.1
Point Loading	15.9	1.2	3.9
Previous Impact	4.3	0.3	0.2
Unknown	12.0	16.1	15.9
Other	19.7	15.6	3.0
Cap	0.0	12.6	0.0
Not Recorded	2.8	2.5	5.5
Material Defect	9.3	19.1	10.1
Critter Damage	1.1	0.0	0.0
Not Excavated, Replaced	1.8	0.3	0.4
Abandoned	0.1	0.1	0.0
Corrosion	1.2	1.3	0.0
Total	100.0%	100.0%	100.0%

<sup>7</sup> Plastic Pipe Data Committee, Plastic Piping Data Collective Initiative Status Report, December 12, 2013.

**Figure 3: Failure/Leak Causes for Pipe, Fittings & Joints within 5 Years of Installation**



### A New ISO 55000/API 1173 Compliant Approach to Pipeline Installations

With major legacy issues being addressed through DIMP programs, the industry now has the opportunity to focus on how today's pipelines are built. This is about the legacy left to future generations. It is now possible to install a PE gas distribution pipeline that will last well over 100 years and will have no early (infant mortality) failures. To achieve this, however, requires a new way of making a gas pipeline.

Hand in hand with gas utilities, an approach has been developed that specifically addresses the risks through the entire asset lifecycle by ensuring the right decisions, methods and products are employed in the construction of new or replacement pipelines, e.g. the asset acquisition phase. The approach specifically addresses the ISO 55000 and API RP 1173 requirements for Risk Prevention and Mitigation, Management of Change, Lessons Learned and Training as related to pipeline installations.

The JANAcquire55™ approach and the resulting 'toolbox' eliminate the causes of infant mortality and prolong the time before the wear-out stage begins. This approach brings together some of the tools and methods used in the nuclear, automotive and aerospace industries to address the critical risk areas in those industries. The process has been adapted to address the specific needs and constraints of gas distribution pipelines.

The JANAcquire55™ process involves:

1. Identification of the component or operational process to be assessed
2. Collection and review of all related information
3. Detailed analysis of all the potential causes of root failure
4. Mapping of all current mitigations via a fault tree analysis
5. Risk assessment of failure rate and mitigation effectiveness
6. Gap analysis to identify where additional risk is required
7. Development of appropriate corrective action to reduce risk

The data collection and analysis of the component/process is exhaustive. For a component, it examines all the steps in the lifecycle of the component including (Figure 4).

**Figure 4: JANAcquire55™ Asset Lifecycle Considerations**



The root cause analysis is conducted in the form of a Fault Tree, as illustrated in Figures 5 and 6 for an electrofusion tee. The Fault Tree analysis is exhaustive and, as such, it ensures that possible causes of failure are not overlooked.

**Figure 5: Illustration of Top 2 Levels of Fault Tree**

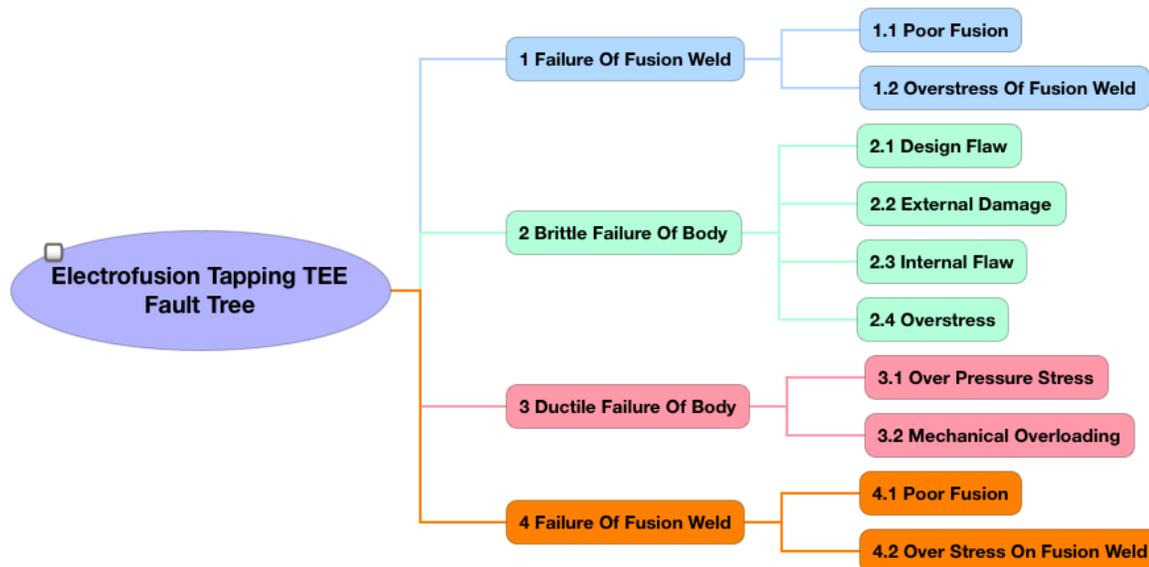
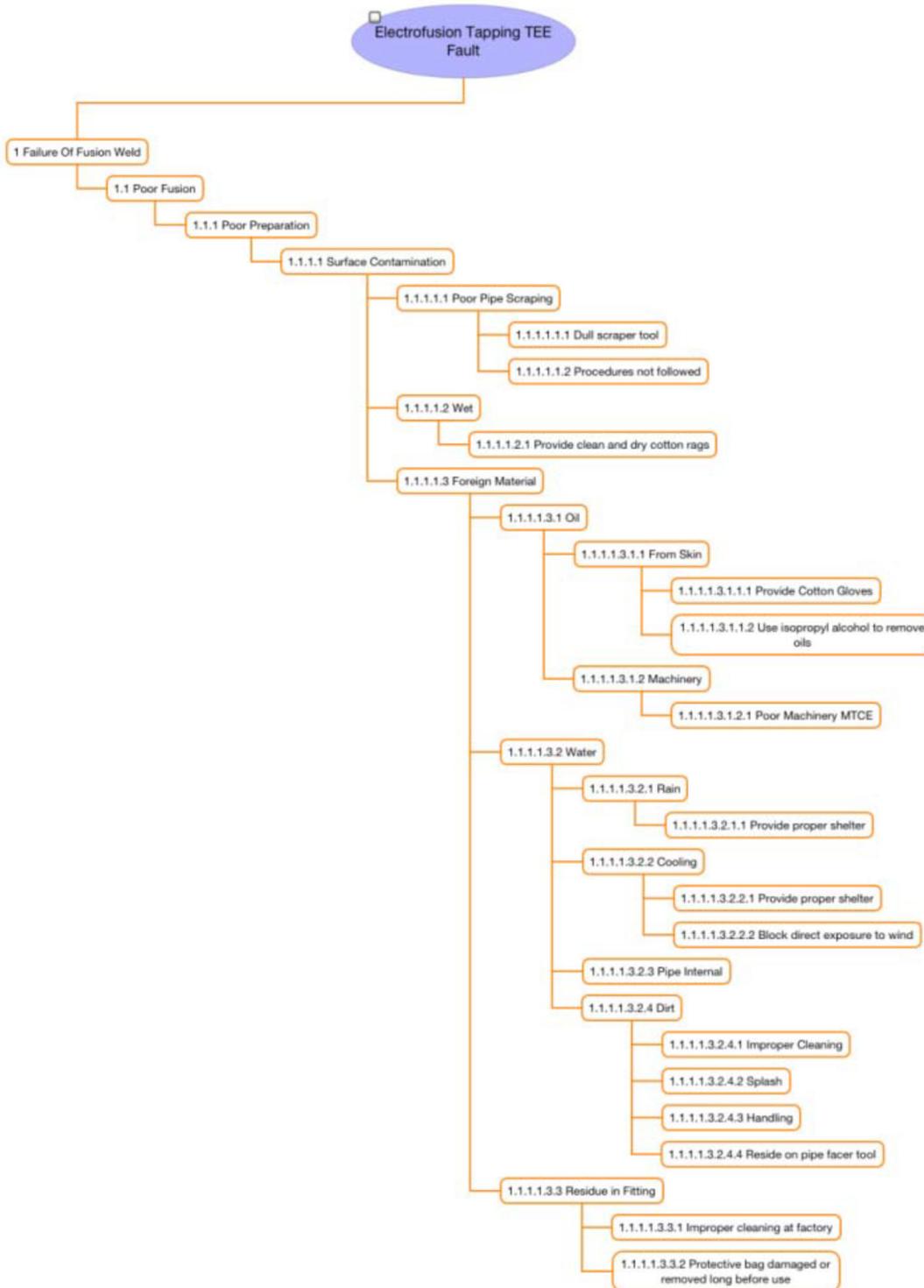


Figure 6: Illustration of an Expanded Branch of the Fault Tree



## Benefits

With comprehensive knowledge related to the product or process, current mitigations are mapped to each branch of the Fault Tree. Assignments of probability of failure from each root cause and the current effectiveness of each mitigation can be made using utility-specific data, industry data and subject matter experts.

Employing detailed and novel statistical techniques, the risks can be quantified and areas of high residual risk identified. Corrective action in the form of improvements in current mitigation or the addition of new mitigation approaches can be specifically targeted to reduce this residual risk to an acceptable level. Business decisions can be made regarding the risk profile of the new pipeline as a cost-benefit analysis of the corrective action can be conducted given that the risk has been quantified.

As an illustration of the benefits of the approach, a recent analysis for a utility was conducted on electrofusion fittings. The use of electrofusion fittings, already ubiquitous in Europe, is gaining ground in North America. Utilities and installers may assume that these fittings are a solution to high defect rates in jointing of PE gas pipelines. In fact, these fittings can have a high installed defect rate<sup>8</sup> that may not become evident for many years. Ensuring the product is of high quality and that the entire installation procedure is robust will help to avoid embedded issues in the future. A detailed JANAacquire55™ analysis was performed on this element of concern for the utility. The following corrective actions resulted:

- A revised product specification
- Formalized product performance validation requirements
- A product specific manufacturer audit checklist
- A revised, detailed installation procedure
- A controlled critical tool and supplies list
- A detailed installer training curriculum

When this type of analysis is completed and the resulting corrective actions implemented systematically through the list of critical distribution system components, a complete understanding of the risks and the role of current mitigations throughout the pipeline is achieved. The work is extensive and can take several years but it has long-term benefits that can transform the risk profile of a company. Further, managing risk into the future is also transformed as the process results in a fully documented fault and risk map of all the critical components and mitigation processes. These maps can be used to inform and verify the impact of changes to products or processes. Further, they capture the organization's knowledge and experience, which can then be used to train future generations of engineers and specifically manages the issue of personnel change in terms of integrity management. The maps can be used very effectively in root cause analysis associated with operating events to determine the root cause as well as potential impact of those events.

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<sup>8</sup> Ingham, E., Wheeler, M., Leakage from PE Pipe Systems, Report Ref. No 10/WM/08/43, UK Water Industry Research Limited, 2011.



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## Conclusion

In conclusion, the industry is dealing with the legacy distribution system threats via DIMP processes. Now, the industry can proactively examine its current practices in installation of new pipelines to reduce long-term risk and provide a proud legacy for future generations. JANAcquire55™ provides the tools and processes to do just that.