Technology Towards a Simple, Flexible Distribution Integrity Assessment Plan

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Abstract

The area of integrity management of pipelines is one of growing interest. In many pipeline applications, the aging infrastructure is posing a challenge for pipeline owners and operators. Particularly in applications involving potentially hazardous materials this is an issue that needs to be approached proactively. The Natural Gas Distribution industry is one falling into this category and new Pipeline Integrity Management Regulations are currently being considered by the federal Department of Transportation. Separate from the pending regulations, Gas Utilities are also proactively examining the integrity of plastic pipeline systems. This paper reviews the changing approach and pending legislation for managing the integrity of plastic distribution system materials. Existing technological tools that can be employed to advance Distribution Pipeline Integrity Management (D-PIM) are reviewed. Technology gaps in assessing the Functional Integrity (a subset of the overall D-PIM approach) of a pipeline are identified and explored. A future state is envisioned and presented whereby the technology gaps are filled and a robust D-PIM is functionally possible. Ultimately, the development of these technologies would help utilities manage their own simple and flexible distribution integrity plan. This would greatly aid individual operators in the three key elements of Distribution Pipeline Integrity: 1. Knowledge of infrastructure; 2. Consideration of applicable threats; and 3. Activities to reduce risk. Then, the final key element will be able to be pursued, that of monitoring performance.

Background

Pipeline Integrity Regulations

In the United States, there are approximately 300,000 miles of Transmission Pipelines and 1,900,000 miles of Distribution Pipelines in operation. These pipelines generally have an excellent record of performance and safety. There is a growing focus, however, on ensuring the consistent management of the integrity of Natural Gas Transmission and Distribution piping. Department of Transportation (DOT) Office of Pipeline Safety (OPS) regulations have been put in place for Transmission pipelines for Pipeline Integrity Management (PIM). New DOT OPS regulations are being considered for Distribution Pipelines. These Distribution Pipeline Integrity Management (D-PIM) regulations will facilitate the continuation of the impressive performance record for these plastic pipeline systems.

While Transmission pipelines are generally constructed from elastic materials such as steel, Distribution system pipelines tend to be constructed of visco-elastic materials such as Polyethylene. These two categories of materials, both with their strengths and weaknesses, behave quite differently in terms of material properties. The approach for PIM of each material category must, therefore, be tailored specific to the material type. The Pipeline Integrity Management regulations that are in existence today are specific to Transmission pipelines. While, due to the inherent differences in the materials, the details of these regulations will differ significantly from those that may be put in place for Distribution pipelines, the overall Objective is unlikely to change dramatically. The Objective of the current regulations is to:

Improve Pipeline Safety through:
- accelerating the integrity assessment of pipelines in High Consequence Areas;

- improving integrity management systems within companies;
- improving the government's role in reviewing the adequacy of integrity programs and plans; and
- providing increased public assurance in pipeline safety.

As discussed, the nature of Transmission and Distribution piping materials are different. In addition, the physical demands on a Distribution pipeline are notably different than those on a Transmission pipeline. The response to these physical loads is also fundamentally different between elastic and visco- elastic materials. The Failure Modes and Effects of the two systems are not comparable. Therefore, service life estimation for new pipelines and residual life estimation for established pipelines are determined in different ways for the two types of materials. This activity is referred to as the Pipeline Functional Integrity Assessment and represents a subset of the overall Pipeline Integrity Management activity.

Other differences of note between Transmission and Distribution pipelines that have been identified by the DOT OPS1 are:

- Most pipe in Distribution pipeline systems is small diameter and operates at low pressure. Transmission pipelines are generally large diameter and high pressure.
- Distribution pipeline systems are a more complex network, with frequent branching and interconnections. Transmission pipelines generally run for many miles without such connections.
- Distribution pipeline systems include a range of materials, including a significant amount of polyethylene pipe. Transmission pipelines are generally constructed of steel.
- Distribution pipelines are usually difficult to take out of service for inspection without interrupting gas service to customers. Transmission pipelines often include loop lines and bypasses that allow individual sections of pipe to be removed from service temporarily.
- Distribution pipeline failures tend to occur as leaks. Gas can migrate underground, accumulating in areas remote from the leak so that fires and explosions occur away from the pipeline. Transmission pipelines, because of their high operating pressure, tend to fail by rupture and the consequences occur on the pipeline.
- State pipeline safety regulators regulate most Distribution pipeline systems.

The regulations being considered for Distribution pipelines will need to address these differences. Although the current form of the pending regulations is not known, Gas Utilities have been proactively examining the integrity of plastic pipeline systems through internal PIM programs and pending regulations will likely be comprised of the same general elements as the current 'best practices'.

Pipeline Integrity Management (PIM)
Pipeline Integrity Management (PIM) of plastic Distribution piping systems, if properly conducted, promises to provide reduced pipeline operating costs through: 1. Improved Safety; 2. Improved Reliability; 3. Reduced Replacements; and 4. Reduced Leak Survey Requirements. There are two key areas for PIM of plastic distribution piping systems: 1. New and Future Pipeline Integrity Management; and 2. Current Pipeline Integrity Management.

Proactive methodologies can be applied to PIM for new/future pipelines. These proactive methodologies involve: 1. Material Performance Characterization (MPC); 2. 'Perfect' Key Data

Collection (PKDC); 3. Auditing of Installation Quality (AIQ); and 4. Pipeline Performance Tracking/Monitoring Systems (PPTS). The issue with existing systems is that much of the data required for Pipeline Integrity assessment is not available. The question becomes one of how can one best assess the projected performance of an in-the-ground pipeline? Answering this question involves many components, including: 1. Dealing with a Lack of Performance Characterization Data; 2. Managing the Lack of Key Data; 3. Risk Assessment; and 4. Risk Management.

In this paper, a methodology for examining the first of these is reviewed. Technology gaps contributing to the lack of Performance Characterization Data and the lack of Key Data are identified. Technological tools to bridge the identified gaps are conceptualized and discussed. Ultimately, the development of these technologies would help utilities manage their own simple and flexible distribution integrity plan. This would greatly aid individual operators in the three key elements of Distribution Pipeline Integrity: 1. Knowledge of infrastructure; 2. Consideration of applicable threats; and 3. Activities to reduce risk. Then, the final key element will be able to be pursued, that of monitoring performance.

Functional Integrity Assessment
As outlined in the literature[2], Jana Laboratories has developed a technique for the quantification of the Residual Life Estimation for in-service plastic pipe. This is an involved process that is applicable to early generation polyethylene (PE) pipe. The technology allows for a macroscopic overview of the "health" of a pipeline segment. The information derived from this analysis allows an Operator to understand the overall performance capability of a pipeline and plan within the context of that information.

This information is very valuable to the Operator. However, it is very narrow in that: 1. The approach is specific to early generation PE pipes; 2. The analysis provides for an overview, or bulk, understanding of the pipeline performance capability; and 3. Specific locations of potential problems are not identified.

An Operator has needs that include: 1. Knowing the three dimensional location of the pipeline, exactly; 2. Knowing what is the material comprising the pipeline, everywhere and Knowing the condition of this pipeline along every mile; 3. Knowing the quality of the fusion joints in the pipeline; and 4. Collecting pertinent and standard information upon failure in the pipeline.

As with any quality program, D-PIM will come down to 'what do you know?' and 'how do you know that you know?' It is important, with D-PIM, to add one more question: 'How can you know?' We will moot potential answers to the 'How can you know?' in this paper.

Knowledge
'How can you know?' We do not want to become overtly philosophical, yet it is important to define 'know'. Knowledge is never perfect. This is where an iterative approach is necessary as outlined in Figure 1. In this figure, defining the Knowledge Needs results in the identification of Existing Knowledge (or Knowns). Subsequently, we look to what is Capable of being Known. To perform this task we look to existing technologies in our field and analogous fields. It is in this context that 'what CAN be known' is identified. Unfortunately, the implicit part of this is an assumption about what CANNOT be known. In Figure 1, changing what CAN be known changes every aspect of the circle of knowledge. As more CAN be known, more will be. Further, with this knowledge other questions will

arise that will influence and change what we WANT to be known. It never ends, nor (like any circle) should it.

Technology Gaps

In terms of D-PIM, we are in the first iteration of the circle. We are looking at what CAN be known and we want to maximize that answer in this first pass. The following conceptualized solutions are proposed to bridge the Gaps and increase what CAN be known to the industry.

Solution 1: Pipeline Locating and Material Identification

We envision a technology that would facilitate the cost effective locating and mapping of Natural Gas Pipelines. This mapping would be exact within inches of the pipe and would allow for a three dimensional view of its location. The technology would allow field service personnel to locate pipe, exactly, in the real world from mapped locations. The technology would already have identified the broad material type (e.g. -PE, Cast Iron, Steel, etc) and pipe diameter to facilitate repair operations. Further, '3rd party' damage by Operator personnel could be eliminated with effective application of this technology.

Solution 2: 'Smart Pigging' of Distribution Pipelines

We envision a technology that would allow for cost effective live 'smart pigging' of Distribution Pipelines. This would mean that pipelines would remain in service during 'smart pigging' operations. A specific set of data would be acquired by the system including: 1. Potential for Rock Impingement

Failure; 2. Percent out-of-round of inspected pipe; 3. Major deformations and cracking; 4. General inspection of the fusion joints; and 5. Potentially, identification of the specific material type of the inspected pipeline.

Solution 3: Qualification and Validation of Fusion Joints

We envision a technology that would allow for cost effective qualification and validation of every new fusion joint prior to it being placed in the ground. This would be a system whereby a field technician would be able to follow specific procedures while using portable equipment to assess a fusion joint. An objective and precise analysis of the acquired data would then be performed via a computer. The fusion joint would then be qualified on the basis of these results.

Solution 4: Standard for Data Collection

We envision an industry standard for the collection of data upon failure of a pipeline. This standard would also facilitate a Lingua Franca, or common language, for the industry to be able to discuss failures and their potential ramifications on the industry pipelines. Further, we see the development of a database program that collects this data and incorporates analytical and reporting tools. We believe that this technology would enable field personnel to collect the data automatically and directly into the database, without paper. The database would allow for the inclusion of photographs and any other files or information.

The Future of D-PIM

A credible Distribution Pipeline Integrity Management program has many dimensions. One primary dimension is that of Pipeline Functional Integrity Assessment: the component that deals with the condition of the physical asset of the pipeline. A credible system to address this aspect of D-PIM will be greatly enhanced by addressing the Technology Gaps outlined in this paper.

The first step has been taken by Jana Laboratories, Inc. As an engineering firm, the focus of Jana has been to understand if these technologies can be developed with existing science (i.e.–can it be engineered and thereby be done quickly). The scope for each Technology Gap was chosen to meet this requirement. None of the future state solutions needs new science, though there is considerable engineering required.

Conclusions
The area of Pipeline Integrity Management (PIM) for plastic distribution systems is one of growing focus. Although the specific form of pending regulations is not known, tools for assessing pipeline functional integrity are currently available. New tools are technically able to be developed in reasonable timeframes. The industry can identify the priority Technology Gaps, establish Criteria with respect to these Gaps and quickly develop the technology to create solutions.

References
1. Federal Register/Vol. 69, No. 208/Thursday, October 28, 2004/Notices.
2. W. Bryce, K. Oliphant, G. Palermo, Integrity Management of Plastic Pipelines, Society of Plastics Engineers Annual Technical Conference (ANTEC), Boston 2005.

Figure 1: Iteration of Knowledge

What do you WANT to know?

What do you know?

What can you know?