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Assessment of Damage Mechanisms Affecting Pipeline Integrity

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The worst case scenarios for flaws and damage mechanisms affecting pipelines are ruptures. This article will discuss the various types of flaws and damage mechanisms, the types of pipelines involved, and the regulations applicable to the mechanical integrity of both liquid and gas transmission pipelines.

The first question to be addressed is whether or not pipeline ruptures are *accidents* or *preventable tragedies*. During the last two decades, from 1995 to 2014, there were 121 pipeline accidents in the United States as reported by the National Transportation Safety Board. That is just over six per year. There are three questions that result from such experiences.

1. How do we assess pipeline damage?
2. How do we establish pipeline integrity?
3. How do we prevent pipeline failures?

The cost for corrosion damage in gas and liquid pipelines is $7,000,000,000 annually in the US. Yes that is $7 Billion with a *B*. There are over 480,000 miles of transmission pipelines and the majority of which are gas transmission pipelines. The majority of these pipelines are also over 40 years old. How many of you are over 40 years old? In terms of expense within our infrastructure, pipelines rank second behind highway bridges. While regulations require certification of corrosion control staff, only 30% of the pipeline companies have personnel dedicated to corrosion control, at a cost of $32 million. That's to say, "*a drop in the bucket.*"

Pipelines and Hazardous — Safety Administration

The Office of Pipeline Safety established the Pipeline and Hazardous Materials Safety Administration (PHMSA) in 2015 with new legislation that defines rules governing issues related to mechanical damage and corrosion. The PHMSA rules differentiate between mechanical damage and corrosion while mechanical integrity concepts reconcile both with respect to the susceptibility of failure.

There are four types of flaws and damage:

1. Volumetric flaws
2. Crack-like flaws
3. Environmental damage
4. Mechanical damage

Upcoming Training Courses

- *API 579 Delayed Coke Drum FFS & Damage Assessment to ASME FFS-1*
  September 12-14, 2017
  Rockaway, NJ, USA
- *API 936 Refractory Inspection & Code*
  October 24-26, 2017
  Fort Erie, Ontario, Canada

For more information, see our website at **www.carmagen.com**.

Work Highlights

Mechanical

- *Performed mechanical and materials engineering review of failed flexible metal hose installed in a pump piping system at a new chemical plant. After an onsite visit and subsequent failure analysis, concluded that the hose should never have been used in this application since it was not intended for the required service conditions, and the piping system design and installation details subjected the hose to excessive loadings and deflections. There were many locations at the facility where similar hoses were incorrectly specified and installed. Recommendations were made to rectify the situation, which will likely include replacing all the hoses with properly designed expansion joints, and adding anchors and restraints to the piping systems. During a subsequent visit by a process safety engineer, concerns were identified regarding the pressure relieving systems.*

None of the four types of flaws or mechanical damage are directly addressed in design codes because design codes only address the quality of fabrication. Codes are Black and White. The mechanical integrity concept, however, does address the four types of damage because mechanical integrity addresses the serviceability of equipment for operation (i.e., mechanical integrity addresses All Shades of Grey).

US Regulations and Standards, *49 CFR 192 and 195*

This Federal regulation governs the transmission of hazardous liquids and gases and gives the minimum standards for design and operations. It also defines the requirements for protection from most forms of corrosion damage. Industry practices are governed by ASME and API. ASME B31.4 applies to liquid pipeline transmission systems while B31.8 applies to gas pipeline systems. API 1160 and ASME B31.8S relate to managing pipeline integrity.

Methods of determining the mechanical integrity of all pipelines, according to ASME or API procedures, are described on one of four levels from the most conservative to the most accurate, which include:

1. ASME B31G
2. API 579 Level 1 and ASME Modified B31G
3. API 579 Level 2 and ASME RSTRENG
4. API 579 Level 3

Compatibility of ASME and API procedures are also indicated.

If a consultant insists that it is necessary to start with an API 579 Level 3 assessment, FIND A NEW CONSULTANT. There will be cases where a Level 3 assessment is required. But since it is the most data intensive, time consuming, and typically the most expensive approach, it is preferable to first determine if one or more of the other approaches will be acceptable for the situation.

Types of Damage Found In Pipelines

Types of corrosion damage found in pipelines include the following:

VOLUMETRIC CORROSION

Atmospheric corrosion
Weathering damage
Corrosion under insulation
Microbiologically-induced corrosion
Environmentally-induced corrosion
Ethanol corrosion
Erosion
Erosion-corrosion

CRACKING CORROSION

Stress corrosion cracking
Wet H_2S damage
H_2S stress corrosion cracking
Hydrogen blistering
Hydrogen-induced cracking
Stress orientated hydrogen-induced cracking

In addition to corrosion, there is mechanical damage, some of which is self-inflicted such as excavation. Other types include:

- Earth movements and rock penetrations
- Heavy rains and floods
- Wild animals – bears, caribou and camels
- Fire and explosion
- Excavation
- Dents and gouges, grooves
- Sabotage

Code Versus Integrity Concepts

The principal difference between the Code and Integrity concept is as follows:

- Codes govern Quality of Fabrication
- Integrity governs Serviceability

The Code is an absolute compliance with respect to the end of life. Integrity is a grey area addressing compliance after the end of code life has been past. How often have you seen a 20 year design life pressure vessel operating 40 years after being put into service? Even the design codes have arbitrarily reduced the design margin for pressure vessels.

Mechanical integrity concepts can be applied through a varying degree of complicated assessments. There are *Quantitative* assessments which are virtually impossible to complete within the necessary timeframe and economically-viable budget allocated for such a task, and there are *Semi-Quantitative* and *Qualitative* assessments that are perfectly suitable for virtually every integrity assessment that arises, and gather the low-hanging 80-20 fruit with skillful application.

Industry practices, developed from years of experience, have standardized these integrity assessments into joint-industry approved documents published by both the ASME and API, along with technical support from NACE, the Corrosion Society. Some of these practices and acceptance criteria have been evolutionary. The most dramatic shift resulted with the first publication of the API Recommended Practice, RP 579, *Fitness-for-Service*, in 2000, and later supported by ASME in 2007.

General and Specific Damage Assessments

The mechanical integrity assessment concept is divided into two major components. The first of which is the general engineering method which consists of eight steps starting with the identification of damage and ending with the documentation of the assessment results and recommendations. The second part of the method focuses on each of 12 specific forms of damage and prescribes three levels of increasingly complex assessment methods and associated acceptance criteria for each method, along with limits and conditions to be satisfied.

Included within every specific assessment procedure are several additional requirements that were not necessarily included in earlier condition assessment studies. These additional requirements relate to *Remaining Life Determination, Remediation of Damage, and Damage Monitoring*. The mechanical integrity concept requirements to determine these values and to develop these programs have become more stringent than were applied in the past with traditional inspection methods and surveillance techniques. The problems with probability of detection, accuracy of characterization, phantom defects, and false calls that had plagued industry have become of greater importance with advances in materials, design, and process conditions. We have more inspection and analytical capabilities today than we had years ago. The challenge is how best to apply them to accomplish our evaluation goals in a timely, reliable, and cost effective manner.

About the Author

L. Louis Loushin has over 40 years experience in the worldwide petroleum and chemical industry which included a wide range of materials, corrosion, and welding engineering assignments. He was actively involved with major organizations developing "best practices" and consensus documents for application to industry problems. Les has been recognized as a creative and innovative contributor to a team environment.

Please contact Vince Carucci (vcarucci@carmagen.com) if you'd like more information on Carmagen's expertise in this area.