Hydrostatic Testing as an Integrity Management Tool

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Introduction

This technical report provides guidance to pipeline operators on the appropriate use of hydrostatic testing within the integrity and risk management process. It considers, as key elements within a hydrostatic test program design process, topics such as known or assumed pipe material properties, threat type and flaw populations, operating and failure history, potential risks and unintended or detrimental effects, and the importance of a clear understanding of test program objectives. This document does not attempt to provide practical guidance for the onsite implementation of a hydrostatic testing program.

This document is primarily focused on pressure test design to achieve objectives, the effect of pressure testing on line pipe steels, and considerations for subsequent pressure testing intervals and reliability. Water, other liquids, air, natural gas, and inert gas are all acceptable test media (as permitted by applicable regulation) for pipeline pressure testing, and identical parameters of physics with respect to the hoop stresses and material properties apply. Due to the relatively high stresses that are generally targeted to achieve integrity testing objectives, water is the preferred test medium for pipelines. For this reason, pressure testing in this document is referred to as "hydrostatic testing." It is acknowledged that when using any form of pneumatic test media (e.g. gases) or liquid product (e.g. refined petroleum products) versus water, vastly different considerations shall be applied for public and personnel safety during testing to account for the potential consequence of a test failure. These are beyond the scope of this work.

This technical report was based upon the extensive hydrostatic testing knowledge that exists today in the form of API recommended practices (RPs), American Society of Mechanical Engineers (ASME) code documents, the body of work of industry consultants, standard practices of operating companies, regulatory language, and other resources. This body of knowledge was supplemented with hydrostatic testing program experience derived from discussion with representatives from a broad group of hazardous liquid and natural gas pipeline operating companies and review of case studies involving several hydrostatic testing programs.

At the time of this guideline development, several parallel pipeline industry initiatives with a focus on hydrostatic testing have been recently completed or are currently ongoing. Such initiatives include work performed by the Pipeline and Hazardous Materials Safety Administration (PHMSA)[1], the American Petroleum Institute (API), the Association of Oil Pipe Lines (AOPL)[2], and the Interstate Natural Gas Association of America (INGAA)[3]. While this completed or ongoing work is of considerable value to the pipeline industry, lacking within these industry initiatives is a focus on the specific application of hydrostatic testing as a pipeline assessment tool to support integrity management plan (IMP) requirements and objectives.

Background

Hydrostatic testing of pipelines has been historically used by the pipeline industry to ensure quality of manufacture and construction, to establish maximum operating pressures, and for management of certain threats to integrity of pipeline systems.

The first version of API 5L for the manufacture of line pipe, issued in 1928, specified requirements for manufacturing specifications, including standard pipe sizes, minimum tensile and chemical content requirements, and required mill pressure tests. In 1942, the voluntary American Standards Association (ASA) Code B31.1 first recommended pressure testing after installation of a pipeline to 1.1 times the maximum operating pressure (MOP), not to exceed 90 % SMYS. In 1959, ASA segmented the code and issued two documents, with one specific to liquids pipelines (B31.4) and the other for gas pipelines (B31.8). These currently exist as ASME B31.4 and B31.8. By the 1960s, most pipeline

1 On October 7, 2009, NTSB issued Recommendation P-09-1 to PHMSA on the safety and performance of ERW pipe. The recommendation called on PHMSA to conduct a comprehensive study to identify actions that can be implemented by pipeline operators to eliminate catastrophic longitudinal seam failures in ERW pipe.

2 The API-AOPL Pipeline Safety Excellence™ 2015 Strategic Plan includes two Strategic Initiatives to develop industry-wide guidance on the appropriate uses of hydrostatic pressure testing of pipelines.

3 Technical, Operational, Practical, and Safety Considerations of Hydrostatic Pressure Testing Existing Pipelines, December 5, 2013.

operators had instituted the practice of hydrostatically testing a newly completed pipeline in the field post-construction.[4] In 1970, Department of Transportation (DOT) federal regulations for pipelines in the U.S. went into effect with 49 CFR §192 and §195 for regulation of gas and liquids pipelines, respectively, requiring the use of hydrostatic testing at construction.

Current uses for hydrostatic testing include original construction testing, integrity assessment of existing pipelines, and pipe material verification when records may be missing or incomplete. Operators should consider the potential for in-service failures of ERW and flash welded pipe that occur after a hydrostatic pressure test is performed in design and implementation of a hydrostatic test program, and guidance on practical consideration of these potential effects is needed.

The benefits, limitations, and appropriateness of pressure testing as an integrity management tool for each recognized threat need to be clarified. Available procedures and references for implementation of a hydrostatic test do not fully account for future operational concerns. The design of a hydrostatic test program can vary based upon the objectives of the test program, specifically the threats considered by the operator for the subject pipe within a test section. For example, managing longitudinal seam integrity versus managing the threat of stress corrosion cracking requires different approaches, as do considerations when testing gas pipeline versus liquid pipeline systems. Many industry references used for guidance in development of hydrostatic test programs do not distinguish these differences sufficiently. It was requested that this effort through PRCI emphasize the differences.

Guidance is also needed to understand the conservatism and variability of current methods for determination of test intervals. Safety factors can be compounded many times through deterministic approaches generally used within the industry. While these may be the simplest from an analytic standpoint, pipeline operators need to develop a thorough understanding of the cumulative effect of applying multiple safety factors when developing hydrostatic pressure testing plans and analyzing data. Safety factors when compounded can sometimes exceed 20, leading to repeat tests at short intervals and potentially exacerbating detrimental effects of testing.

Value

This technical report provides a source of knowledge for pipeline operators, consultants, and contractors tasked with managing or being involved with pipeline hydrostatic testing programs. It is also anticipated that regulatory and industry bodies contemplating the adoption of industry consensus standards and/or regulations pertaining to pipeline hydrostatic testing will view this document as a valuable resource within those development processes.

This technical report provides guidelines to pipeline operators for use in selection and application of hydrostatic testing as an integrity assessment. Specifically discussed are development of test objectives and design considerations when determining the target hydrostatic test pressure(s) to achieve test objectives. Such guidance will aid in achieving the goal of reducing in-service failures, and will assist operators in limiting the number of pressure test failures, providing for increased public safety and reduced environmental impact.

The distinct value that this project brings to the pipeline industry is to supplement the existing standards and body of knowledge in the area of hydrostatic testing with guidelines developed from a pipeline operator perspective and supported by application of hydrostatic testing through the case studies.

Approach

This project began in early 2015 and was managed by Dynamic Risk Assessment Systems, Inc. (Dynamic Risk). The PRCI membership for the IM-3 program at the time the project began consisted of 59 members. A short timeline for completing the project was desired, with a goal to create a guideline document within approximately one year. A smaller core working team was established that consisted of a group of 12 project team members, each of whom committed to have representatives attend monthly face-to-face working meetings through the spring and summer of 2015.

[4] Kiefner, J.F. and Trench, C.J. Oil Pipeline Characteristics and Risk Factors: Illustrations from the Decade of Construction, 2001.

To gather operator experiences and develop practical case studies, in addition to the working meetings among the project team, a series of five meetings were held with pipeline operator representatives from 17 individual operating companies to exchange information and share industry best practices on the design, implementation, data analysis, and evaluation of hydrostatic pressure testing for integrity management. These were held between March 10, 2015 and May 7, 2015. The working team also invited consultants representing five separate pipeline consulting firms to an additional meeting held in conjunction with the PRCI Spring Technical Committees meeting in New Orleans, Louisiana, in May 2015. The purpose of this meeting was to invite these respected researchers to challenge this work and to provide their unique perspectives from their experience in this subject-matter area.

Hydrostatic Testing as an Integrity Management Tool

1 Scope

This technical report provides guidelines related to hydrostatic testing as a tool for integrity management in gas and liquids pipelines. It specifically focuses on program design and key parameters for consideration in hydrostatic test programs, as well as potential detrimental effects of hydrostatic testing. Several case studies (see Annex A) supplement the guidelines provided.

2 Normative References

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document applies (including any addenda/errata).

API 579-1, *Fitness-For-Service*

API Specification 5L, *Specification for Line Pipe*

API Specification 5LX, *High-Test Line Pipe*

API Recommended Practice 1110, *Pressure Testing of Steel Pipelines for the Transportation of Gas, Petroleum Gas, Hazardous Liquids, Highly Volatile Liquids, or Carbon Dioxide*

API Recommended Practice 1160, *Managing System Integrity for Hazardous Liquids Pipelines*

ASME B31.4, *Pipeline Transportation Systems for Liquids and Slurries*

ASME B31.8, *Gas Transmission and Distribution Piping Systems*

ASME B31.8S, *Managing System Integrity of Gas Pipelines*

ASME STP-PT-011, *Integrity Management of Stress Corrosion Cracking in Gas Pipeline High Consequence Areas*

AGA NG-18 Report 194, *Hydrotest Strategies for Gas Transmission Pipelines Based on Ductile-Flaw-Growth Considerations*

Michael Baker Jr.., Inc. *Spike Hydrostatic Test Evaluation*. July 2004. OPS TT06

U.S. DOT Title 49, *CFR* Part 192, Subpart J—*Test Requirements*

U.S. DOT Title 49, *CFR* Part 195, Subpart E—*Pressure Testing*

Leis, B.N., et al. *Final Summary Report and Recommendations for the Comprehensive Study to Understand Longitudinal ERW Seam Failures-Phase One.* Washington DC: s.n., 2013. G0060804.

McAllister, E.W. *Pipeline Rules of Thumb Handbook: A Manual of Quick Accurate Solutions to Everyday Pipeline Engineering Problems.* Gulf Professional Publishing: 2013