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Featuring:

The Challenge of Inspection and Assessment of Critical Piping Systems in Chemical Plants

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Introduction
Inspection and fitness-for-service assessments of critical in-plant piping systems are a concern for the chemical industry. This presents a potentially insurmountable task and discovery of a number of areas where the condition is at risk. Recent failures in chemical facilities indicate that there is a present and severe risk in piping systems. Many in-plant piping systems have historically been unpiggable due to their small diameters and the obstacles inherent in valves and bends, as well as diameter changes. However, many of these piping systems can be inspected with advanced smart pigging technology that provides 100% coverage of the internal and external pipe surfaces. The high resolution inspection data captured by these advanced in-line inspection tools is analyzed to identify the location and degree of potential corrosion, as well as deformities in the piping. Assessment of the corrosion and deformation damage using API 579 Fitness-for-Service methodology dramatically improves the ability of a plant to understand and improve the mechanical integrity of these systems and better manage environmental, safety, and operational risks.

Plant Piping Design and Damage
Process piping within a chemical plant is typically designed to ASME B31.3 - Process Piping standard. Pipelines and interconnecting piping operated outside the fence is typically designed to ASME B31.4 - Pipeline Transportation Systems for Liquid Hydrocarbons and Other Liquids or ASME B31.8 - Gas Transmission and Distribution Piping Systems codes. These product distribution, raw material supply, or intermediate transfer lines may also come under the jurisdiction of the Pipeline and Hazardous Materials Safety Administration (PHMSA), which is the primary federal agency responsible for pipeline safety and enforcement.

The causes of serious incidents in pipelines are summarized in Figure 1. The proportion of incidents resulting from excavation damage has decreased and is no longer the most significant factor in pipeline incidents. Additional causes such as mechanical damage not associated with excavation (vehicle incidents, vandalism, etc.), corrosion, and material failure are also of potential concern. Pipelines and piping most often fail because of the development of critical flaws such as cracks, corrosion (including wall thinning, erosion, erosion-corrosion, and pitting), mechanical fatigue, and mechanical damage. Once initiated, defects in the pipe may continue to grow while the equipment is in service to the point at which a line can either leak or rupture. With a leak, there is typically no extension of the length of the defect. A rupture will bulge outward prior to failure and then the defect will extend into the surrounding material before either propagating or arresting, depending upon the material, the pressure, and the physical state (liquid or gas).

Some examples include:

- A partial wall defect (corrosion, cracking, etc.) eventually fails and becomes a through-wall defect.
- A pipeline may leak when the corrosion or defect reaches the point where the stress carried by the remaining ligament or section of pipe becomes too great and the material cannot sustain the load.
- A pipeline may leak when the through-wall defect is small and the pressure is low. The through-wall defect may not propagate to the surrounding material and the line may leak.
- A pipeline may rupture when the through-wall defect is large or long and the pressure is high.
In today's operating environment, it's more important than ever that the piping within your Mechanical Integrity Program complies with standards such as API-570. Challenges like corrosion under insulation (CUI), aging Class I and II piping circuits and re-rating of piping circuits add complexity and concern. Quest Integrity can help. We offer a comprehensive solution for piping circuits using our proprietary, ultrasonic-based intelligent pigging technology combined with LifeQuest™ Fitness-for-Service software.

- 100% inspection of internal and external pipe surfaces to detect and quantify damage mechanisms
- Inspection results tailored to comply with API-570
- LifeQuest Fitness-for-Service results tailored to comply with API-579

Ensure your piping integrity by identifying degradation before loss of containment occurs. Contact us today.

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Piping Inspection and Pigging

Chemical plant piping is typically inspected using conventional ultrasonic technologies to manually locate damage at specified inspection locations and to establish corrosion rate information. These local thickness readings will determine spot readings for corrosion and are acceptable as long as the damage mechanism produces broad area corrosion or the ultrasonic inspection happens to hit a spot of localized damage. However, in many instances, corrosion is not uniform or broad, and spot readings cannot be used to accurately determine the condition of the entire length of piping. Particularly difficult or costly to inspect with conventional ultrasonic methods and visual inspection are:

- Localized corrosion
- Corrosion under insulation or supports
- Localized internal corrosion
- Corrosion in jacketed piping
- Corrosion in buried lines, road crossings, or within casing
- Piping underwater or through sensitive environmental areas, or otherwise difficult to access areas.

Ultrasonic Inspection Tools

In-line inspection (ILI) tools have been developed to overcome piping design challenges which generally limit the use of traditional tools. These tools are capable of rapid ultrasonic inspection of difficult-to-inspect piping of significant length and include features such as free-swimming (untethered), self-contained, and bi-directional. The high resolution data captured by these ultrasonic tools provides information for piping system reliability analysis. These tools are also capable of navigating short-radius bends, take-offs or tees, and diameter changes which is quite beneficial for the inspection of in-plant piping systems.

Ultrasonic (UT)-based pigging technology can detect and quantify flaws related to corrosion (e.g. wall thinning, erosion, pitting, mechanical wear, etc.), in addition to piping deformations (e.g. denting, ovality, bulging, swelling, etc.). UT-based pigging technology has some limitations and cannot detect crack-like flaws and may have difficulty detecting very small and isolated pits in piping.

Even with these limitations, ILI tools are well-suited for the inspection of process plant piping to find localized corrosion, corrosion under insulation, localized internal corrosion, as well as dents and other dimensional anomalies. ILI inspection technology is also capable of detecting internal corrosion in jacketed piping, inspection of buried lines, road crossings, or piping within casing under roads or tank containments, as well as piping located underwater or through sensitive environmental areas, or otherwise difficult to access areas.

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Figure 1. Causes of Significant Pipeline Incidents on Hazardous Liquid Transmission Pipelines from 1988-2008

Assessment of Critical Piping Systems in Chemical Plants
Ultrasonic technology directly measures anomalies. The data collected by this inspection technology allows for the fitness-for-service (FFS) and remaining life assessment data of piping systems which in turn can be used by operators to make real-time operating decisions.

**Assessment Methods**

Various methods and types of piping inspections, including but not limited to ILI tools, are utilized by plant operators to gather data about the current condition of their piping. The data obtained is analyzed and acted-up-on to prevent a future failure of the system and to increase operational efficiencies. Confidence and level of risk of both the present and future operations are highly influenced by the quality of the inspection data and the method used in assessing the piping system.

The ultimate objective of a FFS assessment of piping or other types of equipment is to avoid a leak or rupture in-service. Leaks are generally avoided by applying a safety factor based on the percentage of original wall thickness or an absolute minimum thickness value, both of which consider a future rate of corrosion. API 579 considers a maximum allowable wall thinning of 80% of original thickness or an absolute value of 0.10 inch (2.54 mm). The leak versus rupture condition requires an assessment of the remaining material strength and the stress resulting from the size and shape of the defect(s).

API 579-1/ASME FFS-1/2007 is the 2nd edition of the FFS standard and incorporates a number of important changes and additions from the older version. The API/ASME standard includes three levels of analysis that differ primarily in regard to the data considered at each analysis level and the associated analytic rigor.

**Fitness-for-Service Assessment Procedures**

Fitness-for-service assessment is a multi-disciplinary approach to evaluate structural components to determine, as the name suggests, fitness for continued service. The API 579 Fitness-for-Service standard is used to evaluate several classifications or types of flaws including general metal loss, localized metal loss, pitting corrosion, crack-like flaws, creep, and brittle fracture.

API 579/ASME FFS-1 is particularly applicable for pipelines and in-plant piping systems. Piping systems within chemical plants are subjected to a wide range of operating conditions and service environments. These conditions can expose the piping to a variety of damage mechanisms that localize either inside or outside of the pipe. This damage must be evaluated both independently and in conjunction with other adjacent or neighboring damage, defects or anomalies. The piping may also be used differently and in more severe operating conditions than those specified in the original design. The typical outcome of an FFS assessment is a “go or no-go” decision on continued safe and compliant operation. An evaluation of remaining life and/or appropriate inspection intervals may also be part of such an assessment.

**Summary**

Combining ILI inspection information with engineering assessment enables chemical facility maintenance or reliability engineers to apply a API 579 FFS assessment to in-plant piping systems and evaluate its condition for continued service. The assessment may provide the facility with information and confidence to extend the life of the asset. Utilizing currently available ultrasonic in-line inspection and assessment technology helps operators reduce inspection costs associated with difficult-to-inspect piping systems, reduce maintenance costs by more accurately pinpointing anomalies and assessing fitness-for-service conditions, and accurately determine the actual condition for lines that are very difficult to inspect.

**References**