Process Piping Integrity Management System which Combines Intelligent Pigging Inspection Technology and API 579 Fitness-for-Service Approach

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Piping infrastructures continue to age in process facilities globally which require plants to have Integrity Management systems in place to ensure a reliable piping infrastructure. Refineries and chemical plants operate with hundreds of miles of piping routed throughout the facilities, often routed near control rooms or office complexes with close proximity to staff. Failure of piping systems within these areas, which operate under both elevated pressure and temperature present significant risk, require sound inspection and fitness-for-service programs.

For decades, various industries (e.g. terminals, transmission pipeline) have applied intelligent pigging technology to inspect pipelines. Due to an aging infrastructure and numerous highly publicized failures with fatalities, loss of containment, fires, etc. within various refining and chemical complexes, these facilities are being forced to push the envelope in terms of advancing their overall piping systems or circuit integrity management approaches. Similar to the challenges the refining and chemical industries face today, the terminals and transmission pipeline industries operate with hundreds of miles of inaccessible piping which branch off of main transmission lines that have gone uninspected since the original construction.

To address the global inspection demand of complex piping circuits found within process facilities (see Figure-1) an ultrasonic-based intelligent pigging technology, InVista™, was developed. InVista is a compact, light weight intelligent pig which operates autonomously as it’s propelled through 76mm (3") - 610mm (24") diameter piping systems. (see Figure-2) The inspection reports generated shortly after completion of the inspection take into consideration that most process facilities apply API-570, "Piping Inspection Code: In-service Inspection, Rating, Repair, and Alternation of Piping Systems" and API-574, "Inspection Practices for Piping System Components". Adapting to industry recognized standards ensures inspection results fit within existing inspection data management systems.
InVista provides a comprehensive inspection solution for piping systems which are routed in overhead pipe racks, at elevated positions, encased within concrete, buried below grade, etc. or are otherwise inaccessible for external NDT/NDE inspection practices. Quest Integrity has been working closely with numerous refinery and chemical plants utilizing InVista to provide 100% inspection of their piping circuits. Key applications have been piping which runs between assets (e.g. process heaters, distillation towers, coke drums, etc.) or piping which transports both raw and finished products between the plant and associated above ground storage tanks (AGST) where product is stored in bulk. Piping ranging from 76mm (3") - 610mm (24") diameter is the immediate focus; however, larger piping diameters are also under consideration. The current piping systems contain a variety of materials such as carbon steel and stainless steel.

Figure-3
Complex Piping Configuration
Adjacent to Fired Heater

In order to detect the anticipated damage mechanisms in refinery piping, InVista provides 100% inspection coverage of both the piping’s interior and exterior surfaces. Each InVista instrument size contains between 48 and 366 discrete (1/4" diameter) ultrasonic sensors, ensuring high resolution inspection results. The intelligent pig travels through the pipe at speeds of 60mm (24") per second. Many of the piping systems within process facilities have limited internal access points, which means bi-directional travel is required. The bi-directional InVista instruments can be launched and retrieved at the same location, eliminating the need to cut piping at both ends. It's not uncommon for the piping systems to be configured much like a “bowl of spaghetti.” These systems contain numerous short radius bends (45°, 90° and 180°) throughout. InVista easily navigates challenging and complex piping configurations and negotiates unlimited short radius bends (as tight as 1D), including welded back-to-back (S configuration). (See Figure-4) Internal weld backing strips (chiller

Figure-4
Back-to-Back, 180° Short Radius Bends in "S" Configuration
rings) located at each circumferential weld is common place; however, these do not present a challenge for InVista.

The collected data is viewable immediately after the inspection in high resolution 2D and 3D formats. (See Figure-5) The ability to view near photo-like graphical images of damage mechanisms is powerful, especially when the damage patterns are an indicator of the root cause.

The ultrasonic sensors provide direct measurement of detected anomalies, which in turn provides superior piping integrity assessment in comparison to utilizing indirect measurement techniques.

Important attributes of intelligent pigging technologies are:

- 100% overlapping axial and circumferential coverage
- Absolute measurements with +/- 0.127mm (0.005") accuracy
- Between 2,500 and 12,000 (depending on pipe diameter) ultrasonic measurements per linear foot
- Capable of inspecting pipe diameters down to 76mm (3")
- Differentiates between defects on interior and exterior of the pipe surfaces
- Pinpoints circumferential and longitudinal location of defects
- Bi-directionality (ability to enter and exit the piped system at one location)

Quest Integrity's proprietary LifeQuest™ Piping software has automated the API 579 / ASME FFS-1 Fitness-for-Service Standard, enabling processing of the inspection data to produce fitness-for-service (FFS) assessments of inspected piping circuits. FFS assessment is a multi-disciplinary approach to determine if a given structure is fit for continued service. The structure may contain flaws or other damage, or be subject to more severe operating conditions than anticipated by the original design. The outcome of an FFS assessment is a decision to operate as is, repair, retire, or rerate.

The most comprehensive guidelines for FFS assessment are contained in a standard jointly published by the American Petroleum Institute (API) and the American Society for Mechanical Engineers (ASME). The API/ASME FFS Standard includes 3 levels of assessment for each flaw type and damage mechanism:

- *Level 1* is a simplified and conservative analysis that is used for initial screening purposes.
- **Level 2** is a basic engineering analysis that uses standard formulae for the various calculations that comprise the FFS assessment. Typical Level 2 FFS calculations can be performed with a spreadsheet.

The API/ASME FFS standard includes an assessment of local metal loss. The Level 2 assessment is based on the “river-bottom” and effective area concepts, and is very similar to the RSTRENG method. The API/ASME procedure expresses the condition of a pipe in terms of a remaining strength factor (RSF), defined as the ratio of the burst pressure of the corroded pipe to that of the pipe in the undamaged condition:

\[
RSF = \frac{P_{\text{burst, corroded}}}{P_{\text{burst, undamaged}}}
\]

The burst pressure of a pipe that is a perfect cylindrical shell of uniform wall thickness can be estimated to within a few percent from published formulae, provided the tensile properties of the material are known. The API/ASME FFS standard includes equations for the RSF of a damaged pipe based on the effective area and length of the metal loss. Given the absolute burst pressure of the undamaged pipe and the RSF for the damaged pipe, the burst pressure of the corroded pipe can be easily calculated:

\[
P_{\text{burst, corroded}} = RSF \times P_{\text{burst, undamaged}}
\]

- **Level 3** is an advanced assessment that may include finite element simulation.

LifeQuest Piping applies an automated fitness-for-service evaluation of the inspection data and also calculates a remaining strength factor (RSF) and the maximum allowable operating pressure (MAOP) for each segment of the inspected pipe, while completing an API 579/ASME FFS-1 compliant fitness-for-service assessment of the entire inspected piping system. LifeQuest Piping also contains advanced visualization tools for viewing both the inspection data and calculated results in both 2D and 3D along the full length of the inspected piping system.

The LifeQuest Piping evaluation will determine if the piping system passes the Level 2 assessment. In the event any line fails the Level 2 assessment and an operator decides to proceed with a Level 3 assessment, Quest Integrity can perform Level 3 assessments.

Quest Integrity provides software for fracture mechanics and fitness-for-service analysis either as stand-alone commercial offerings or as part of an integrated inspection package. With capabilities that span the full range of applications from simple API 579 Level 1 assessments to advanced finite element analyses, the suite of Quest Integrity’s software applications can be applied to a wide range of problems. Free demo versions of the software are available for trial use, along with documentation and example problems.

**SUMMARY**

By applying more advanced inspection and assessment technologies, plants will achieve a greater level of piping integrity, with the additional benefit of maintaining public and regulatory confidence. Pinpointing areas of degradation will ensure critical locations are identified when pipe repairs are necessary. By determining the condition of various piping systems, plants will also satisfy the direct assessment...
requirements required by process plants. Most importantly, the probability of damage and injury to personnel, the environment and assets is significantly reduced.

Use of the most advanced intelligent pigging designs play a significant role in reducing costs associated with difficult to inspect piping systems, reducing maintenance costs by more accurately pinpointing anomalies and assessing fitness-for-service conditions, and gaining insight into conditions for piping systems previously not capable of being inspected. The ultrasonic-based direct inspection technology is highly accurate and goes beyond assessing risk of potential problems to pinpoint the problems themselves. These findings often reduce or eliminate the need for remediation or field work, thereby decreasing overall operational and safety costs year over year.

REFERENCES

1) API-570, "Piping Inspection Code: In-service Inspection, Rating, Repair, and Alternation of Piping Systems", Washington DC USA

2) API RP-574, “Inspection Practices for Piping System Components”, Washington DC USA

3) API-579-1 / ASME FFS, “Fitness-for-Service Standard”, Washington DC USA

4) ASME Section V, “Boiler and Pressure Vessel Code”, New York NY USA

5) Roberts R, "Inspection of Buried or Inaccessible Piping in Nuclear Power Plants Utilizing Ultrasonic Based Intelligent Pigging Technology“ 9th Annual International NDE Nuclear Plant Conference” Bellevue Washington USA, May 2012
