Flattening the investment peak of pressure pipelines with

‘INSPECT BEFORE INVEST’ APPROACH

Unprecedented replacement exercise

On a global scale water and wastewater pipelines are aging and reaching their theoretical end of lifetime. In the 50’s, 60’s and 70’s vast lengths of pipelines have been installed to expand and modernize the drinking water distribution networks and the sewage water collection systems. The theoretical lifespans of these pipelines, contingent on materials and pressure classes, span from 50 to 80 years. This means that in current decades owners of underground assets are facing a need for investments in their networks of an unprecedented scale.

For many utilities, replacing their assets in a reactive manner has long been a safe way to keep up with aging of assets. However, now more and more utilities are getting aware of the replacement peak that is approaching, a reactive asset management is no longer a way to stay in control of annual underground asset investment plans.

One percent per year

Considering an optimistic average lifetime of 100 years, asset owners should ideally replace a minimum of 1% of their assets annually. However, two key factors contribute to elevating this necessary replacement rate. Firstly, pipe failure is not solely attributed to material degradation; external factors like differential settlement also play a significant role. Secondly, the 1% is an average number that was hardly ever met over the past decades. Now the replacement peak is approaching, an even higher replacement rate is required to catch up with the years of reactive management.

Understanding the necessity of suitable replacement rates is crucial. However, in the absence of a noticeable increase in failure rates within networks, identifying degraded pipelines and prioritizing assets for replacement becomes challenging. Relying on the anticipation of failure rates to rise is a risky and irresponsible strategy. Therefore, the proactive collection of more data becomes imperative to inform well-funded investment decisions.

The missing data piece

Water utilities can employ theoretical residual lifetime models incorporating factors such as age, material, soil type, and failure history to estimate the likelihood of failure. This allows them to prioritize extensive sets of pipelines approaching their technical lifetimes. By integrating theoretical technical lifetime data with external factors like above-ground activities (e.g., rural vs. urban) and assessing the pipeline’s criticality in the network, asset managers can refine the prioritization for replacement. This targeted selection of pipelines is denoted as Critical Assets.

Given that asset age is a crucial parameter in the selection methodology for Critical Assets, the count of identified assets that need attention is steadily increasing at many utilities. Consequently, replacement budgets are proving increasingly inadequate to address the growing number of aging pipelines. Conversely, it is widely acknowledged among owners of pressure pipelines that proactively replacing pipelines upon reaching theoretical lifetimes without technical condition validation often reveals that the majority of the pipe wall material remains in good to excellent condition.

The aforementioned contrast underscores the absence of a crucial element in the pipeline replacement puzzle. This missing piece is the validation of theoretical models through the assessment of the actual condition of the Critical Assets, allowing for a more refined prioritization of manageable volumes of pipelines.

Gathering asset condition data

While owners and operators of gravity sewers are accustomed to regular and structural assessments of their sewer systems, this remains a largely unexplored realm for most owners of pressurized pipes. Gravity sewers rely on hydraulic height differences, creating an unpressurized atmospheric system that allows for easy entry to deploy robots equipped with CCTV, radar, or other sensors. In contrast, pressurized pipeline systems present greater challenges for inspection, often requiring depressurization and/or dewatering to facilitate entry.

Pressurized systems can be categorized into the following primary functions:

1. Pressurized networks for the distribution and transportation of potable water from water production plants to households and other users. The larger pipelines (>200mm/8") are commonly referred to as water mains. Typical asset owners include drinking water utilities.
2. Pressurized networks or pipelines for the transmission of collected sewage from a collection pit to sewage treatment works. Larger diameter pipelines in this category are known as force mains or rising mains. The typical asset owners are municipalities, wastewater utilities, waterboards, or other local sewage water authorities.
3. Raw water mains responsible for pumping untreated water from its source (e.g., a river) to a user or treatment plant. These are typically owned by drinking water utilities or industrial users.
4. Effluent pipelines tasked with pumping treated wastewater towards a point of discharge. Common asset owners for this function include wastewater utilities, waterboards, or industrial plant owners.

Especially, the larger diameter (>200mm / 8") water mains and force mains rank higher on the scale of Critical Assets due to the significant consequences of pipe failure. For water mains, this includes substantial service interruptions and elevated repair costs. In the case of force mains, the stakes are even higher, with the potential for severe environmental risks in the event of a failure.

Acquaint is a SME business from the Netherlands that has developed an intelligent pig to assess the condition of potable water mains and force mains while still pressurized and without large service interruptions. The pigging principle has been used for many decades to clean pipelines where a foam plug is tightly-fit inserted into a pressurized pipeline. Water pressure propels the pig through the pipeline and effectively cleaning the inner pipe wall. Acquaint has customized these cleaning pigs and equipped them with a large set of sensors, allowing them to test a wide range of failure and aging mechanisms in both the pipeline and its joints while simultaneously recording the XYZ position (location and depth).

Acquaint's intelligent pigging technology, Acquarius, employs ultrasonic sound for the precise measurement of diverse failure mechanisms contingent upon the pipeline material. The technology exploits variations in sound velocity corresponding to different materials and levels of degradation. Through extensive research and collaboration with the academic water technology institute Wetsus, alongside several Dutch water utilities, Acquaint has achieved a notable precision of 0.45mm in identifying variations in wall thickness caused by corrosion in metals or sulfate attacks in sewers.

A distinctive attribute of Acquarius is its capacity to detect changes in material density, particularly relevant in instances such as the leaching of Asbestos Cement. This unique capability facilitates the accurate identification of leaching spots, including those as small as 15mm, with a precision of a few millimeters. This technological advancement provides a nuanced and precise approach to understanding pipeline conditions, contributing to a comprehensive assessment of their integrity.

Another common cause of pipe failure is the separation of couplings between pipe segments. Using the same ultrasonic signals and IMU output, Acquarius can measure the joint gap and compare it against applicable standards. Couplings can also shift out due to the settling of pipes on either side of the coupling or the lateral movement of the pipeline. This is respectively termed vertical and horizontal angular displacement, accurately determined by Acquarius with a precision of 0.25 degrees for each individual coupling passed.

In addition to these prevalent failure mechanisms, a single inspection run also examines the ovality of the pipeline (particularly relevant for plastics), deformation in the longitudinal direction, the presence of gas accumulations or debris, and, in the case of prestressed concrete pipes, fractures in the winding wires.

This complete condition assessment is accurately aligned with very precise location data based on GPS measurement. Wint an accuracy of 0,5 meters the exact location of the pipeline and the associated condition is reported.

Proven and independently validated technology.

The Ultrasound based Acquarius technology has been applied in more than 125 full scale commercial projects in both drinking water mains and sewer force mains. Also several independent validations of the technology have confirmed accurateness. Two examples are provided:

Firstly, under supervision of the Dutch Water Utility Brabant Water and in collaboration with Delft Technical University, Ultrasonic scans of asbestos cement pipelines have been compared with laboratory CT scans of the same pipeline samples.

The below graph is one extract of large set of results showing a strong overlap between the UT signal and validation by CT scans confirming practical applications, where inspections are conducted in field, ultrasound in combination with the unique leaching analysis patented by Ac-

AGING INFRASTRUCTURE

ASCE 2021 Report Card states:

- Water main break every two minutes, with an estimated six billion gallons of water loss daily.
- 16,000 Wastewater Treatment Plants functioning, on average, at 81% of their design capacity.
- 15% of Wastewater Treatment Plants have reached or exceeded capacity.

Now is the time to create a Proactive Asset Management Program utilizing Acquaint's Acquarius in-line inspection technology.

With on-board ultrasonic testing (UT) circumferential scanning sensors, hydrophones and internal mapping unit (IMU), the Acquarius is an ultra-flexible, configuration-friendly tool that provides wall thickness measurements, ID changes, precise pipe geometry, joint defects, leaks, air pockets, pipe ovality, delamination, AC leaching (degradation of asbestos cement), and plots XYZ coordinates of the entire alignment in a single run.

The comprehensive data-driven report helps asset managers set actionable decisions with known budgets for rehabilitation, while eliminating disruptive pipe breaks, and associated environmental and economic impacts.

Contact CPM Pipelines to learn how to proactively manage your valuable assets starting with an Acquarius inspection.

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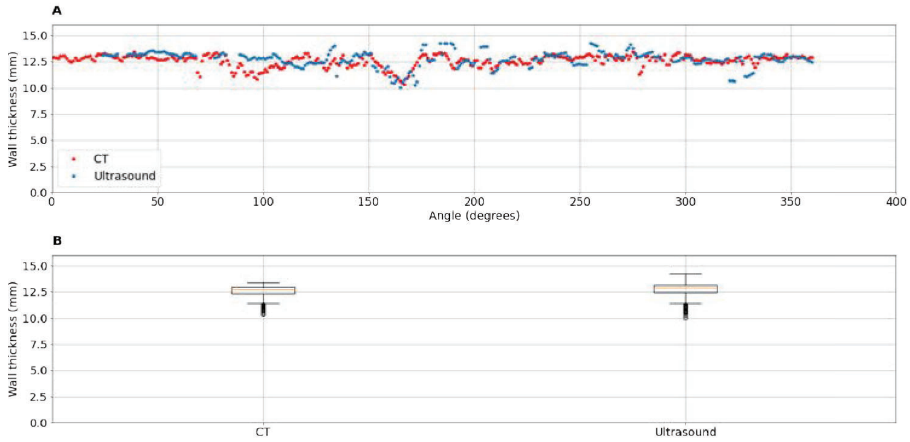
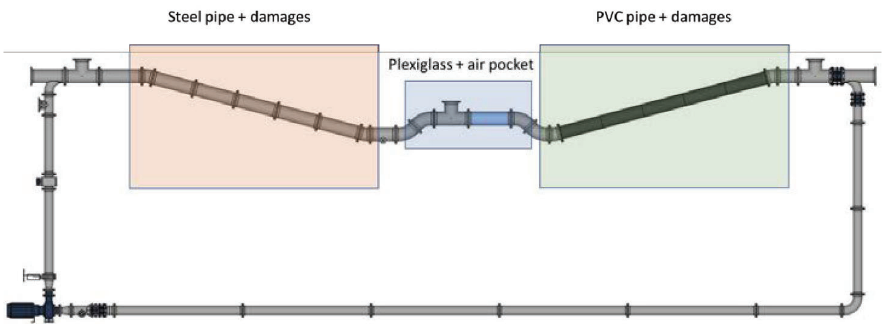


quaint, offers a viable and accurate technique for assessment of calcium leaching.

Secondly, in the summer of 2023 an European funded research project “Assessment of Inspection Tools for Rising Mains (AIR)” led by Co-UDLabs was delivered. Part of the project was an independent blind laboratory test in the facilities of the IKT institute in Gelsenkirchen, Germany.



In the test setup a broad range of artificial damages were created for the technology companies and universities to independently validate their technology. The setup was made from 2 main materials; steel and PVC. Each section was introduced with damages such as: pin holes, pipe deformation, decreased wall thickness, air pockets, outside surface scratches and leakages.

The independent lab research validated all qualitative claims of Acquaint’s condition assessment technology (see table xx). As a next step, the research consortium is preparing a full-scale field validation on asbestos cement force mains to be carried out in 2024.

From inspection data to asset management information

Having reported on over 125 inline condition assessment projects for drinking water mains and force mains globally, Acquaint has undergone extensive development and modernization of data processing and asset condition information presentation. In collaboration with clients, an online GIS platform was devised to deliver pipeline condition data to asset owners. The following functional design parameters have demonstrated the highest value through this collaborative effort:

1. Dynamic granularity: the asset owner should be able to shift from high level, overall condition figures of the whole pipeline or pipeline sections all the way down to highly accurate and local anomalies and condition data of individual joints or pipe lengths.
2. Contextual enrichment: for the asset owner to interpret and evaluate data or understand root causes it is critical to view the pipeline in its context. Therefor presenting pipe condition data combined with information about above ground activities (e.g. road crossings, rural vs urban), soil type/risk of ground settling and the presence critical infrastructure is key for asset owners to make well-informed decisions.
3. Uniform safety factor: as asset management levels of expertise vary widely from utility to utility, asset owners appreciate a uniform way to express the risk of failure of a pipeline. Even though replacement decisions lay with the asset owner, a unform calculation will assist in valuing and assessing all individual condition and contextual parameters into a scale of safety.

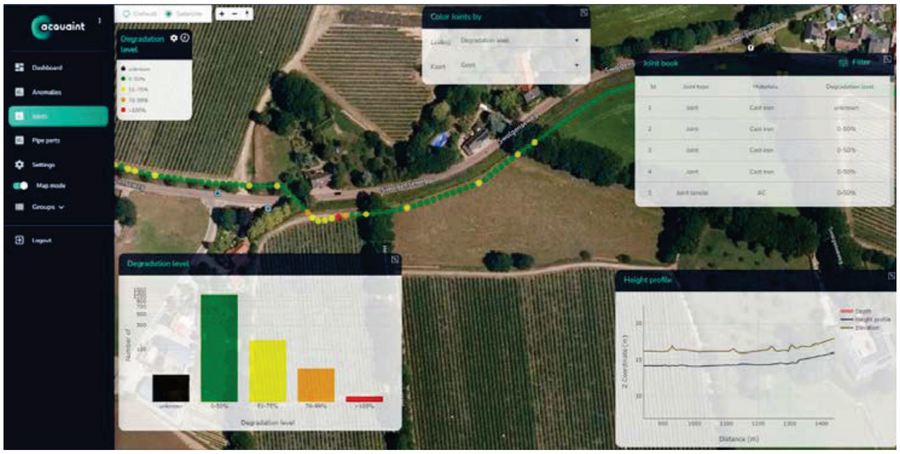
Aforementioned functional design parameters together with client input and years of experience have been used as input for the development and delivery of the Acquaint’s Pipeline Inspection Dashboard that was launched early 2023 and received the prestigious Innovation award 2023 from the international Aquatech jury in November 2023. The dashboard is a custom-made GIS interface presenting the clients inspected pipelines and has several filters and lenses to look at the pipeline condition data, categorized under: anomalies, pipe segments, joint condition and safety factor.

All pipeline information can be combined with contextual data by enabling different GIS layers such as: satellite view, risk soil differential setting, agricultural crop plots and water protection zones. The latest addition to the Pipeline inspection dashboard is the Safety Factor, which is a multiplication factor applied to the calculated maximum load or stress that a construction can theoretically withstand. The safety factor is defined as the ratio between the ultimate strength of a material or construction and the maximum expected load or stress it will experience during its intended use. The stress in pipeline material is calculated using a model developed by the internationally recognized water research institute KWR: COMSIMA. In this model, internal pressure, vertical load due to various factors, and bending moments due to differential settlement are taken into account. Three safety factors will be visible:

1. Low Safety Factor: 97.5% of the calculated values are above this number.
2. Average Safety Factor: the average of the distribution.
3. High Safety Factor: 97.5% of the calculated values are below this number.

	ACQUAINT	Alternative suppliers (Rosen, Xylem)
Leaks through 3 mm hole	No	No
Leaks through 6 mm hole	Yes	Yes
Ovality in steel of 6%	Yes	No
Pinn hole in steel 7 mm	No	No
Wall loss outside 200x200x3mm in steel	Yes	Yes
Ovality in PVC of 3% or more	Yes	Partially (>6%)
Scratch external 1 x 3.4 x 500 mm in PVC	Yes	No
Scratch external 3 x 3.4 x 500 mm in PVC	Yes	No
Scratch external 5 x 3.4 x 500 mm in PVC	Yes	No
Scratch external 7 x 3.4 x 500 mm in PVC	Yes	No
Incrustation 400 x 90 x 15 mm	Yes	Yes
Several joint displacements	Yes	Partially
Air pockets	n/a	Yes

Depending on the impact of a failure, an asset manager can determine which of these values should be used to assess a pipeline section. Because many input parameters introduce uncertainty in the outcome of the safety factor, it is possible to analyze which input parameters most influence the uncertainty.



Inspect before invest

As the global pipeline replacement peak becomes increasingly evident, the "inspect-before-invest" strategy emerges as a pivotal approach to prioritize investments in critical pressure pipelines. Given that the costs for condition assessment of pressure pipelines are typically about 100 times lower than the outright replacement of the pipeline, the business case for inspecting before investing is inherently compelling. Inspection of pressure pipelines seldom necessitates complete replacement; in most instances, asset owners can significantly extend the theoretical residual lifetime of a pipeline by selectively replacing sections or employing rehabilitation techniques such as relining.

When inspections result in partial rehabilitation or maintenance interventions, thereby extending the pipeline's lifespan by several decades, the investment curve is flattened, and global networks undergo renewal in a faster and more efficient manner. Asset managers leveraging condition assessment data for their underground assets ensure that investments are directed precisely where and when needed. This strategic use of data contributes to a more targeted and cost-effective approach to maintaining and renewing underground pipeline networks.

About Acquaint BV

Acquaint is a Dutch SME business that spun out from the Wetsus water technology institute in 2014. Acquaint has developed several technologies based on ultrasound to assess the condition of pressure water pipelines. Current operational management: Erik Driessen CEO and Christine van der Valk CFO. Founders and non-executive directors: Rudy Dijkstra and Siemen van der Heide. More info on: acquaint.eu