Detection of Corrosion and Geometrical Anomalies Within District Heating Pipework Using High Resolution, Low Risk, Ultrasonic Inline Inspection Tools

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Abstract

Recently, within a coastal community in Western France, Quest Integrity completed the cleaning and inline inspection of two operationally critical sections of district heating pipework for Salines Energies Service (part of ENGIE Solutions). The inspected sections formed part of a localized district heating network providing heating and hot water for approximately 4,500 residents in 2,500 properties on the outskirts of the City of La Rochelle.

The network was constructed in 1971 and was comprised of a main carbon steel hot water feeder and cool water return pipe with distribution offtakes. The piping was laid within concrete ducting supported every 7 meters by steel crossmembers. The sections identified for inspection consisted of 1km of the main hot water feeder pipework departing from the boiler plant and the parallel 1km of return pipework terminating inside the boiler plant. The pipework had a nominal diameter of 406mm (16 inches) and constant wall thickness of 8.8mm (.346 inches).

Following an unexpected interruption of service in the winter of 2020 due to a major water leak, it was concluded during the emergency repair work that a breakdown of the concrete ducting allowed underground water to infiltrate the system, causing severe external corrosion of the main pipework. Although the repair recovered service, it raised the question as to whether additional corrosion cells were present and possibly growing at different locations and with similar or possibly worse severity.

Critical to the success of finding a solution to resolve this concern was the selection of a proven technology with capabilities to accurately detect, quantify,

locate, and discriminate corrosion defects while minimizing operational downtime and ensuring safe passage within the pipework during operations. A cross array of inspection technologies were reviewed, and Quest Integrity's InVista™ ILI (inline inspection) technology was determined to be the most accurate and lowest risk inspection solution due to its high-resolution ultrasonic detection, identification, sizing and discrimination capabilities packaged within a compact, lightweight single-bodied tool design with up to 30 percent inline collapsibility. These characteristics, coupled with a minimal execution window of opportunity, were all crucial aspects of the risk assessment prior to executing the inspection campaign.

Following a progressive cleaning program, the InVista™ UT ILI tool was launched and received, achieving 100 percent sensor data capture and greater than 99 percent valid internal radius and wall thickness measurements. The downloaded tool data and analysis results provided defect type, severity, precise locations and an engineering assessment, empowering Salines Energies Service to develop a repair or replacement strategy easily and quickly.

The final engineering report provided by Quest Integrity enabled Salines Energies Service to rapidly re-establish the network's operational integrity by prioritizing repairs to the immediate high risk corrosion areas identified. Furthermore, the report and its findings substantiated the decision to repair the pipework (as opposed to replacing it) and underpin the integration of a Network Integrity Management Strategy to safeguard future operations.

The utilization of an inline inspection service within a district heating network provided precise, actionable data, empowered the operator to assess risk and identify a robust future operational strategy. Utilizing this approach realized a cost saving of approximately 85 percent compared to the cost of a systematic and non-conditional replacement of the pipework.

Introduction

District heating and cooling (DHC) systems are quickly becoming recognized as a globally significant opportunity for owners and operators to contribute to the reduction in carbon emissions through a focus on more efficient heat generation, heat recovery and utilization of renewable energy sources. Continuous investment in advanced technology necessary to meet future emissions and decarbonization targets is occurring within all tiers of DHC Industry, often with incentives and initiatives supported by governmental policy and funding.

Whilst these front-end initiatives inevitably grab media headlines, much less is publicized about the actual distribution networks themselves, the unseen thousands upon thousands of kilometres of piping infrastructure buried just metres below the metropolitan surface delivering and recovering heating and cooling mediums 24 hours a day, 7 days a week, 365 days of the year. As focus continues to shift towards more sustainable DHC networks with minimal operational impact to the environment, public and end user disruption, the importance of understanding the condition of these assets (in various stages of age design and operational condition) is critical to the success of this investment strategy.

This case study will demonstrate the application of inline ultrasonic inspection technology within district heating networks, addressing the complete process from data acquisition to final reporting. This paper will detail the challenges and the benefits of inline inspection (ILI) for the specific project referenced in the above abstract.

ILI Tool Development History

Reference: *Interstate Natural Gas Association of America 20 F Street, N.W, Suite 450, Washington, D.C. 20001 phone: 202.216.5900 www.ingaa.org: Response to NTSB Recommendation: Historical and Future Development of Advanced In-line Inspection (ILI) Platforms for Natural Gas Transmission Pipelines*

Since their inception in 1965, inline inspection tools (often referred to as intelligent or smart pigs) have transformed pipeline and pipework integrity management. The initial tools used sleds carrying magnetic flux technology and could only identify metal loss in the bottom quadrant of the pipe for distances of up to 30 miles. By 1970, ILI tools could inspect for metal loss anomalies around the entire pipe circumference, with the acceleration of notable advancement beginning in the 1980s. ILI developments have dramatically increased data acquisition and accuracy, measurement capability, distance range, speed tolerances, and the types and sizes of addressable pipelines. While inline inspection was initially limited to a low-resolution detection and sizing methodology for metal loss alone, technology improvements from 1980 to 2000 broadened its application to include additional sensors for measuring mechanical damage and pipeline deformations such as dents and ovalities, crack detection caused by operational and environmental stresses, and improved sensor technology and density that drastically improved data resolution for all anomaly types. In the early 2000s, ILI providers advanced the application of electromagnetically coupled acoustic technology (EMAT). This is used today to identify and characterize stress corrosion cracking in dry product environments where ultrasonic technology is possible only by introducing a batched liquid medium to provide an appropriate coolant. ILI providers now combine multiple inspection technologies into single “combo” tools to enable detection of a variety of anomalies in a single run.

ILI Tool Navigation of District Heating Network Piping

In 2007 Quest Integrity launched their range of Ultrasonic InVista™ inline inspection tools which were specifically engineered for the un-served “difficult to inspect” pipeline sector of the oil and gas industry.

Similar to the challenging pipeline configurations which InVista™ was designed to navigate within the oil and gas industry, district heating networks present the same tool navigational challenges.

Some of the known challenges to inspecting district heating network piping include:

+ **Access –** a conventional untethered, free-swimming tool cannot be easily introduced or removed from the piping system;
+ **Low Pressure and Low Flow –** there is often insufficient flow to overcome the friction of typical inline inspection technologies necessary for propelling the tool;
+ **Physical Barriers –** Challenging piping configurations such as short-radius bends, back-to-back bends, reduced port valves, multiple wall thickness, multiple diameters, and geometrical deformations create additional risk for sticking less flexible inspection tools or causing high velocity speed excursions resulting in compromised inspection data;
+ **Operational and City Infrastructure Service Disruptions –** System downtime and untimely city street excavations create stress on the downstream customers and city governments.

Fig. 1 – Mitred Bend

Fig. 2 – Back-to-Back ‘S’ Bend

Figures 1, 2 and 3 of 4-inch “difficult to inspect” piping demonstrates some of these challenges for piping operators: tight mitre bends, back-to-back short-radius 1D bends and expansion joints.

These types of challenging piping configurations are routinely navigated by the Quest InVista™ ILI tool.

InVista™ is an ultrasonic corrosion and geometry inspection tool which requires a liquid coupling; the source of which is abundant within district heating networks either from the operational process itself or through utilisation of ring main/fire main water, accessible via hydrants which are generally located close to the network.

Quest Integrity InVista™ Metal Loss and Geometry ILI Tool

Fig. 3 – Expansion Joint

CASE STUDY

Detection of Corrosion within District Heating Piping Using High Resolution, Low Risk, Smart Inline inspection tools at Salines Energies Services (ENGIE Solutions) – La Rochelle, France

Overview

Salines Energies Services (SES) is a subsidiary of ENGIE Solutions and is the operator of a second-generation district heating system located in La Rochelle, France. This system provides heating services to approximately 4,500 residents (2,500 properties). Its key attributes include:

1. Date of original installation – 1971.
2. Heat generation – 2 Biomass fuelled boilers, installed in 2002 and 2015.
3. Main feeder and return pipework - DN400 (16”) diameter with a distance of 1.5km. Total distance of network including reduced diameter offtakes 7.74km (4.8 miles)*.
4. Design pressure - 25 Barg (363psig).
5. Operating pressure – 10 Barg (145psig).
6. Nominal pipework wall thickness - 8.8mm (.346”).
7. Minimum bend radius - 1.5D.
8. Minimum operating temperature - 60°C (140°F).
9. Maximum operating temperature - 110°C (230°F).
10. Pipework Situation - Concrete channel supported every 7 metres by steel crossmembers (Fig. 4).
11. Since original installation approximately 4km of the network has been renewed with more modern pre-insulated pipework.
12. Original sections of the network are insulated with rockwoll with a material protective wrapping (Fig. 5).

*Distance to be multiplied by 2 to realize feeder & return total distance

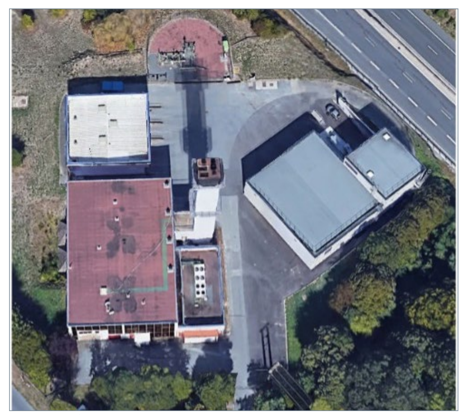


Fig. 4 – Satellite View of SES Boiler House – Source Google Earth

Fig. 5 – Feeder and return pipes supported within concrete channel

Unexpected Interruption of Service

In the winter of 2020 during critical operations, service was disrupted due to a major water leak on the mainline (feeder). The mainline required immediate repair by SES in order to recover continuous operations and fulfil contractual client energy and heat delivery commitments (Figure 6 and 7).

The leak occurred within a section of the pipework located approximately one kilometre away from the boiler room. The section of pipework impacted was part of the original network situated at the Robespierre Street Chamber located close to the point of transition from old to upgraded pipework.

During the repair, the cause of the leak was identified as severe external corrosion resulting in a 'through wall' loss of containment.

Fig. 6 - Section of pipework removed following leak

Fig. 7 – Finalization of repair using replacement pipe

Cause of Leak / Failure Mechanism

As often experienced within concrete ducted district heating networks, the cause of the corrosion (often referred to as the failure mechanism) was the result of a breakdown of the chamber cover (roof) (Figure 8). The damage to the cover allowed for water ingression into enter the chamber, saturating the insulation layer and instigating the onset of corrosion to the pipework.

Fig. 8 – Cross section of broken-down ducting cover enabling water ingression

Plan of Action Following a Significant Leak

At the conclusion of the winter and now cognizant to the fact that corrosion had developed within the network piping, SES recognized the need for a more robust and predictable operational and maintenance program to ensure future reliability of the entire network. Having realized that there was now a known risk and high probability of future leaks within the feeder and recovery pipework, the operational scenarios to be considered were as below:

+ Continue with previous operational strategy and risk similar unpredictable and reactive-based system failure repairs
+ Replacement/upgrade of 2 x 1km 16-inch (DN400) sections of feeder and recovery pipework
+ Inspection and repair of 2 x 1km 16-inch (DN400) sections of feeder and recovery pipework

The fundamental operational, commercial and integrity impact and risk of the above options are summarized within the following impact/risk assessment grid.

IMPACT / OPTION	Operational (Customer) Impact	Financial (SES Impact)	Future Operations (Customer & SES Impact)	Summary
Continue	High	High	High	+ Immeasurable financial cost/risk. + Incapable of reliable client service delivery. + Contractual obligation to always ensure bestpractice of operations.
Replace / Upgrade	High	High	Low	+ Greatest financial cost/risk. + Greatest operational revenue loss. + Greatest client inconvenience. + Future integrity of replaced segments secured.
Inspection & Repair	Low	Low	Low	+ Financial consequences managed with minimal impact to customer and operator. + Future integrity of evaluated and re-paired/replaced segments secured. + Provision of physical data as to support business case should pipework be beyond economical repair.

The conclusion from the above risk-based integrity management options assisted SES in deciding upon what is regarded as the “win-win” option of “inspection and repair.”

As summarized, the strategy minimized commercial impact upon the organization whilst operationally it offered a minimal impact on the customer (end user) with a manageable repair and integrity strategy easily identified and set in motion following completion of the inline inspection phase.

Thanks to its 20-plus years of technology development and experience within the field of difficult-to-inspect pipelines — including 5 years of field experience inspecting Parisian district heating network piping — SES (via ENGIE Solutions) awarded Quest Integrity the contract to complete the network evaluation phase of the program, selecting Quest’s InVista™ inline inspection technology as the means to acquire the critical line data.

Scope of Work

Following an initial onsite meeting where critical information was acquired by Quest, the scope of work was agreed and defined as the provision of:

Pipework, cleaning, pumping, inline inspection, and reporting services of two DN400 (16-inch) x 1.1km pipework sections referred to as feeder/return pipework departing from the boiler plant and terminating at Robespierre Street. (Location – La Rochelle France)

The main elements of the program are detailed within the table below:

Step	Inspection Plan	Provision
1	Site Visit	Project Manager to visit site to survey location and confirm location of equipment and utility provision
2	Field Pigging Equipment	Supply of Quest Field Crew, Launcher/Receiver, tracking equipment, valves, hoses, flow meters and elbows to faciliate the introduction, negotiation & recovery of pigs within and from the pipework
3	Pre-Inspection Cleaning & Gauging	Supply of cleaning/gauging tools to prove pipework bore passage and cleanliness
4	Geometry & Inspection	Quest InVista™ Inline Inspection Tool and Technician
5	Dewatering	Provision and running of dewatering foam swabs
6	Project Management	Project Management and monitoring of operations
7	Reporting	Site Completion Report & Final Reports

Methodology of Cleaning & Inspection

Minimal impact in terms of modification to the district heating piping with rapid re-instatement was the priority of SES to ensure service would be resumed as soon as possible following completion of the cleaning and inspection phase.

Following the site visit, the method for creating a cleaning/inspection circuit via isolation of the lines and installation of crossover piping was developed.

The benefit of the identified methodology created a single point entry/exit location for cleaning/inspection equipment whilst also allowing water logistics to be managed from one fixed point.

Preparation of the boiler plant and network pipework prior to the arrival of Quest Integrity to SES's site is as described below.

Preparation of SES District Heating Piping

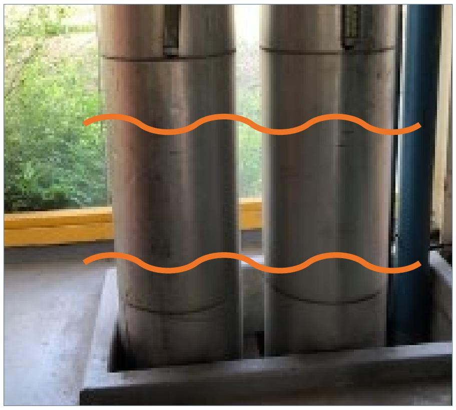


Fig. 9 – Sections for removal (feeder & return line)

Launch and Receive Location inside Boiler Plant (Start Location)

+ Removal of 0.8m long piece of pipe on each line (Figure 9)
+ Welding of flanges on the pipe ends
+ Installation of temporary 16-inch/DN400 elbow on both lines (Quest)
+ Installation of temporary 16-inch/DN400 launcher/receiver with temporary supports on both lines (Quest)
+ Installation of hose connections between launchers and pumping unit (Quest)

Fig. 10 – Robespierre Street Loop Set Up

Looping Location - Robespierre Street Chamber (End Location)

+ Installation of two 4-inch/DN100 offtakes on both lines
+ Installation of valves on the offtakes
+ Installation of two hose connections between the valves to create a loop for flow between feed line and return line (Quest)
+ Closure of the two main line valves

Fig. 11 – Quest Pump Unit

Water Logistics / Pumping Unit (Boiler Plant)

+ Quest pump unit to be connected to the temporary launcher/receiver at the boiler plant
+ Utilize Pump Unit's dual pump, filtration, and tank storage capability to separate feed and receipt water during operations
+ Pre-filling of the created network circuit and feed water tank and system to be facilitated by boiler plant water hydrant

Project Schedule

Minimal downtime was an identified critical path and key metric to what would be considered a successful project execution. Following discussions with SES, the project schedule was signed off at a maximum of 3 days of offline operations as summarized below:

7-Day Program - Includes 3 Days On-Site	Project Span (Days)						
Work Task	1	2	3	4	5	6	7
Equipment Preparation							
Mobilize Crew and Equipment							
Safety induction, Permit approval							
Equipment Setup							
Feeder Line Cleaning & Inspection							
Equipment Transfer to Return Line							
Return Line Cleaning & Inspection							
Data Check & Line Reinstatement							
Demobilize Crew & Equipment							
Equipment Servicing & Replenishment							
Denotes Days On-Site							
Denotes Travel/Mob/Preparation Days							
Denotes Days With 24-Hour Shift							
Denotes Days Site Specific Training							

Fig. 12 – Project Schedule

Provision and Installation of Quest Equipment (Boiler Plant)

Preparation of the network by SES was completed, allowing intervention and rigging up to occur as planned.

Fig. 13 – Feeder & Return Line during operation (left) and prepared for project (right)

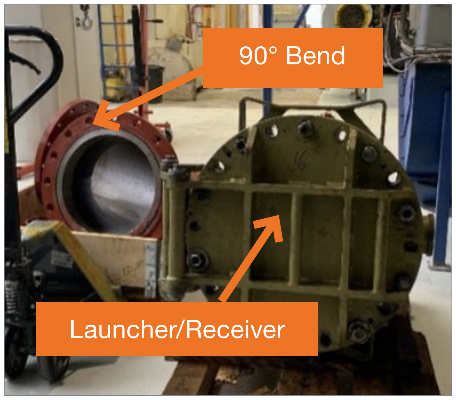


Fig. 14 – Quest Supplied 90° Bend & Launcher / Receiver

Fig. 15 – Completed Setup at Boiler Plant Including Hoses and Temporary Piping Connected to Quest Pump Unit

Creating the Water Circuit – Robespierre Street

To complete the water circuit, SES installed DN100 (4-inch) valved offtakes to the feeder and return line situated slightly ahead of the transition to the upgraded piping located within the pipe chamber.

Quest Integrity attached flexible hoses to the offtakes, and with the downstream mainline valves closed and all offtakes isolated, the closed loop circuit was created.

Creating a closed loop circuit concluded the set-up phase of the project and allowed both sections of pipework to be filled and vented using the hydrant water supply controlled via the Quest pump unit.

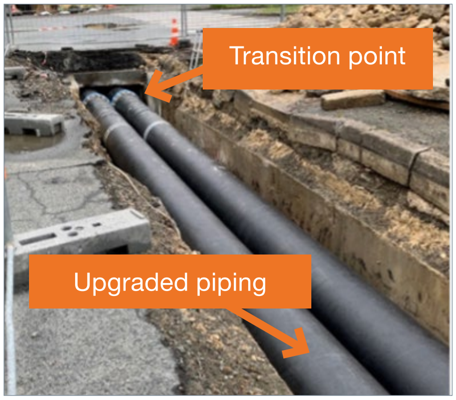


Fig. 16 – Robespierre Street Transition of Old Piping to Upgraded Piping

Fig. 17 – Installation of Flexible Hose on pre-installed DN100 Offtakes

Pipework Cleaning

Critical to acquisition of an optimum dataset during the inline inspection phase, removal of any loose or adhered debris from within the pipework is considered as best practice. Selection of the correct cleaning tools is essential, including evaluation of the following main pipework characteristics:

+ Pipework Internal Diameter(s) – a variance within ID may exist especially where upgraded piping has been added
+ Bends – the type of bend, bend radius, location, back-to-back bends
+ Fittings – Wye pieces, tees, reducers, compensators (expansion joints)
+ Instrumentation - any intrusive instrumentation within the system (thermocouples etc)

The same above factors also must be considered for the inspection tool itself. The condition of the cleaning tools used prior to the inspection provide critical feedback in terms of their condition and act as "go, no-go" decision-gates as to whether it is safe and appropriate to proceed to the data acquisition (running of the inspection tool) stage of the project.

All tools utilized for the SES project were installed with an electromagnetic transmitter, enabling them to be tracked and located at critical locations throughout the inspection route. Combined knowledge and experienced gained from other district heating projects ensured that the most effective tools were identified and supplied for the project.

Flow, pressure, and volume during pumping were regulated and monitored by Quest Integrity Pump Unit operatives, with flow being reversed when cleaning tools reached the end of the pipework within Chamber Robespierre and were recovered back at the boiler plant from which they were launched.

Dislodged debris during the cleaning operation was observed by both SES and Quest Integrity personnel through a viewing area situated within the pump unit. Level of cleanliness was visually monitored by the level of discolouration of the return water during the cleaning process. Captured debris was isolated and contained within the filter system of the pumping unit.

Once Quest Integrity personnel were satisfied with cleanliness of the return water the cleaning was ceased, the final cleaning tool was recovered from the pipework for evaluation prior to loading and launching the Quest InVista™ inline inspection tool.

The configuration of the water circuit necessitated individual bi-directional runs of the 1km feeder and 1km return line, requiring the launcher/receiver and 90° bend set up to be switched over within the boiler plant upon completion of the first inspection run. The methodology ensured that each section was inspected immediately after cleaning, ensuring that the allocated project schedule remained on time. All recovered debris and contaminated water resulting from the overall campaign were disposed of by SES.

Fig. 18 – Loading of Cleaning Tool into Pipework

Pipework Inspection

Following successful cleaning and condition assessment of the results from the cleaning tools, the DN400 (16-inch) Quest InVista™ inline inspection tool was prepared by a Level II Qualified Quest Integrity Project Manager ensuring all pre-inspection inputs were uploaded prior to launching the tool.

The process of running the Quest InVista™ inline inspection tool was a repeat of the cleaning in terms of utilizing the pump unit, however, the optimum inspection speed of approximately 0.5m/s was required to be maintained and managed via the Quest Integrity Pump Unit personnel.

One key benefit from the individual bi-directional inspection process as performed for the project was doubling the acquisition of data from the boiler plant to Robespierre Chamber. When reversed, the tool continued to record from Robespierre Chamber back to the boiler plant, therefore acquiring a duplication of data which, post-download, was "flipped" and overlaid. This provided favorable data redundancy with the end result equating to the delivery of an optimum dataset for each pipework section.

Upon arrival into the launcher/receiver, the InVista™ tool was recovered (Figure 19) by Quest Integrity personnel, cleaned and subsequently connected to Quest's proprietary data processing software to allow download of the datasets for initial data quality review.

Fig. 19 – Recovery of Quest InVista™ Inspection Tool from Pipework

About Quest InVista™ Technology

Quest Integrity has engineered innovative inspection solutions for many industries. One of these solutions, InVista™, is an ultrasonic inspection technology capable of inspecting piping with an internal diameter range of 2 to 48 inches. InVista™ has been employed primarily in the refining, chemical and pipeline industries, with a focus on difficult to inspect pipelines and pipework.

InVista™ was introduced to the pipeline industry in 2007 and incorporates several key technological characteristics and industry advantages, such as the tool being easily transportable, short and lightweight. These characteristics often reduce or even eliminate the need for large lifting equipment. Advanced data resolution, bi-directional capabilities, an odometer distance measuring system with above ground tracking, inertial measurement capabilities for precise X-Y-Z mapping, and an innovative software viewing package are additional features incorporated in the InVista™ inline inspection tool. When coupled with the tool's design and form factor, these features uniquely position the Quest InVista™ technology as the safest, most accurate and reliable inspection solution for district heating and cooling systems.

Reporting capabilities provide pipework operators accurate and timely information for making critical risk-based decisions. Data can be viewed in a range of displays, including standard line plots, tables, graphical two-dimensional and three-dimensional pipe layouts, and exportable files.

Significant External Wall Loss Detected

While still onsite, an initial review of the captured data was completed to ensure data quality. Confirmation of acceptable data quality signified the completion of the data acquisition phase of the project allowing all mechanical work to be de-rigged and the network placed back into operational service. As per the planning and contractual requirements, all works was completed within the allocated three-day operational schedule.

During the initial data review, one significant defect was detected and discussed during the close out meeting with SES. The defect was located 165m from the boiler plant within the return pipe and showed an external wall loss of 80 percent orientated at the 13:00HRS clock position within the pipework (Figure 20).

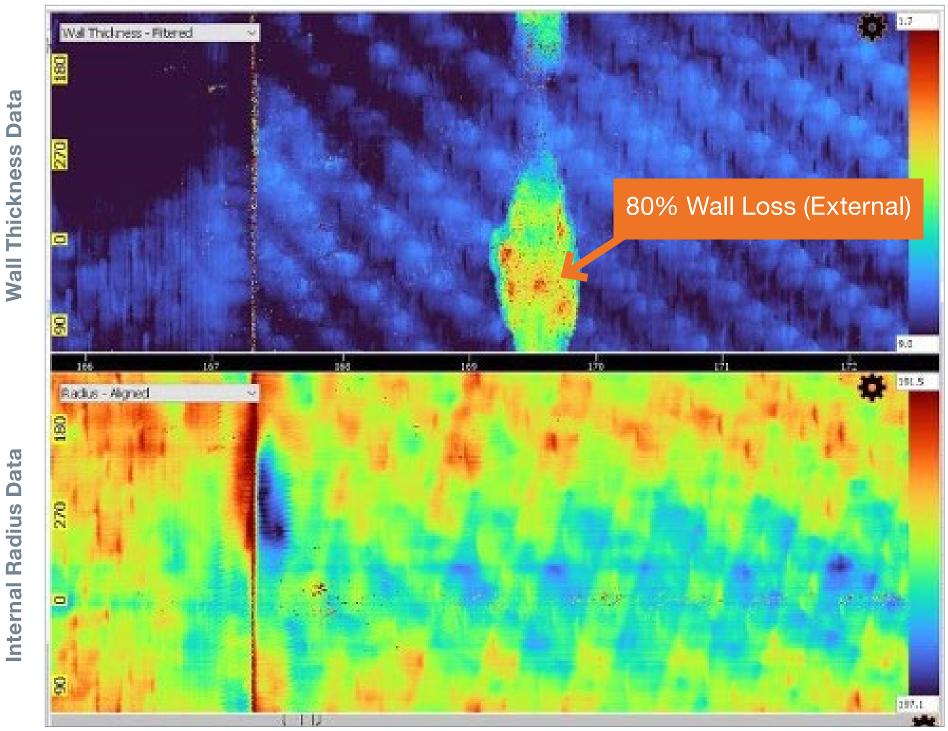


Fig. 20 – Quest InVista™ Inspection Data Indicating Significant External Wall Loss

Immediate Verification of Defect

Quest Integrity and SES were immediately able to align the data within the SES GPS system to pinpoint the location of the 80 percent metal loss defect. Due to the location of the defect being near the boiler house and on land belonging to SES, an excavation of the lines at the stipulated location was completed overnight.

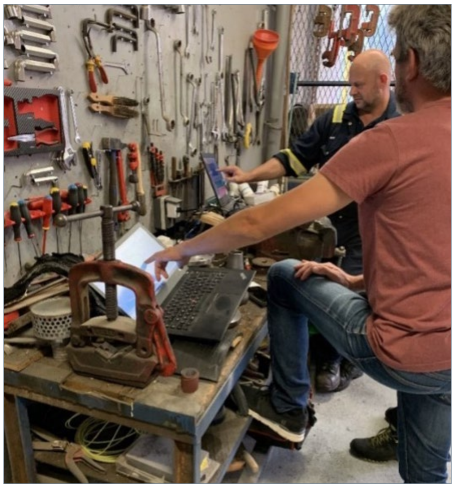


Fig. 21 – Quest Integrity & SES Personnel Pinpointing Defect

Fig. 22 – Excavation Trench

As demonstrated within Figure 23 below, the metal loss was visually confirmed once the degraded duct cover was removed.

Fig. 23 – Visual confirmation of defect following excavation.

Fig. 24 – Section of detached corroded pipe wall removed.

Figure 24 shows corroded piping material recovered by hand from the excavation location. SES immediately started the plan of repair and awaited the final reports to be compiled and submitted by Quest Integrity.

Of extreme significance is the fact that this threat was on the return line close to the boiler plant, effectively being at the opposite position to the original leak location. Without the application of the Quest Integrity InVista™ tool, this critical defect and threat to future operations would have remained undetected.

Site Completion Report

With the mechanical phase completed, de-rigging completed, and initial data review concluded by the Quest Integrity Project Manager, SES was provided with a Site Completion Report within 24 hours. The report is a record of field activity and is used as a point of reference by both Quest Integrity and SES. It captures dates, tool performance and any recordable observations and is jointly agreed by the respective managers of the project prior to leaving site.

Data Processing, Analysis and Final Assessment Reporting

The downloaded datasets of both the feeder and recovery lines were uploaded to Quest Integrity's data centre allowing post inspection processing and reporting to commence by a dedicated team of analysts. The final report was delivered to SES within 45 days.

The assessment report was delivered within the Quest Streamline Universal Platform™ Viewer software enabling SES complete access to the inspection data and the basis of the engineering assessment.

Figure 25 provides an example (not SES specific) of the data viewing capabilities of the Quest Streamline Universal Platform™ Viewer.

The analysed data from the InVista™ tool was assessed using Streamline Universal Platform™ to determine:

+ The inspected pipework's fitness for continued service
+ The remaining strength factor for each pipework segment and major features
+ The maximum allowable operating pressure for each pipework segment and major features
+ Potential limitations to the safe and reliable operation of the inspected pipework
+ Features of the pipework requiring higher level evaluation and assessment

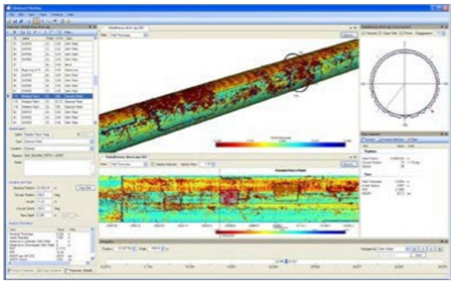


Fig. 25 – Quest Streamline Universal Platform™ Viewer Example

Summaries of Final Reports Submitted to SES

Below are extracts from the final reports submitted to SES by Quest Integrity.

External Metal Loss

+ Eighty-nine (89) external metal loss anomalies with a depth greater than 15 percent were identified in the inspection data.
+ Based on a nominal wall thickness of 10.31 mm (0.406 inches), this metal loss corresponds to an 86.8 percent wall loss.

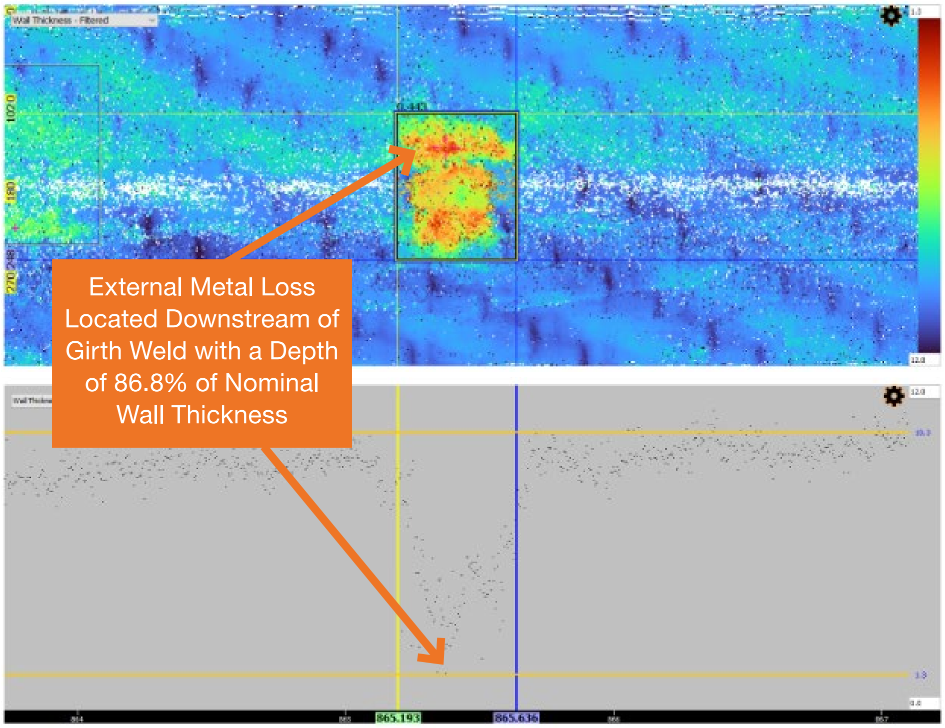


Fig. 26 - C-Scan and B-Scan of External Metal Loss

Internal Metal Loss

+ Two (2) internal metal loss anomalies with a depth greater than 15 percent were identified in the inspection data.
+ Based on a nominal wall thickness of 10.31 mm (0.406 inches), this metal loss equates to a 41.2 percent wall loss. This internal metal loss anomaly is a wall thickness variation in a bend.

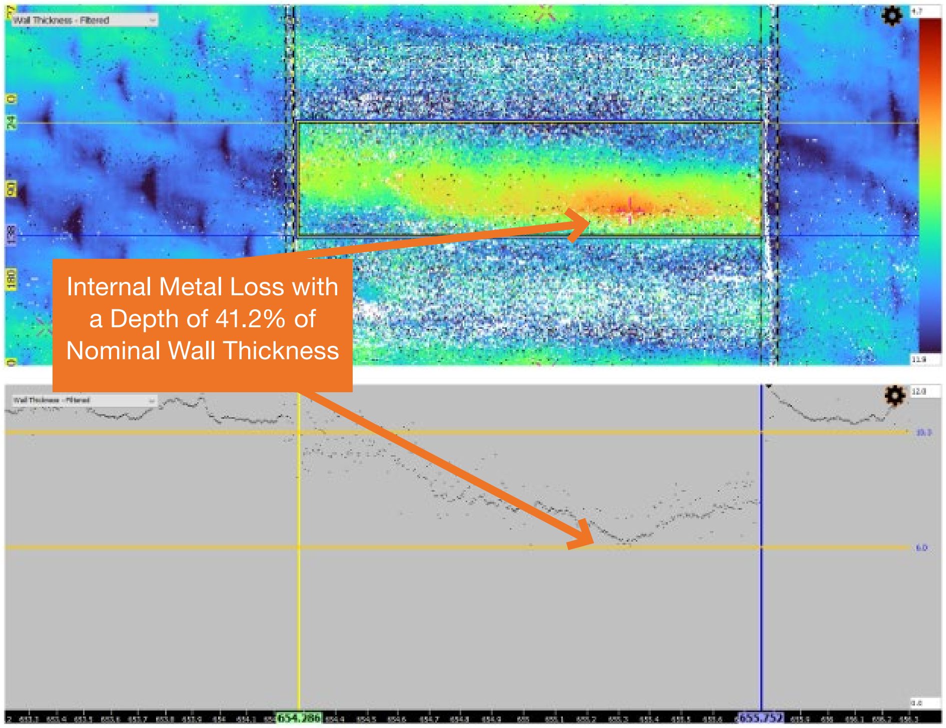
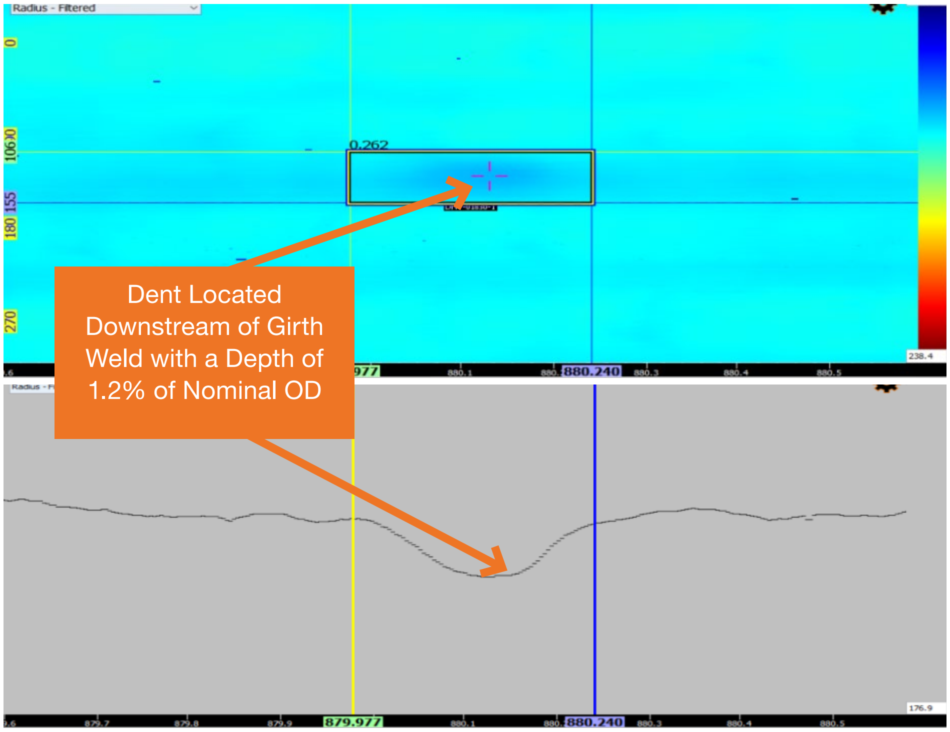


Fig 27 - C-Scan and B-Scan of Internal Metal Loss

Dents

One (1) dent with depth greater than or equal to 1 percent of the nominal OD was identified in the inspection data. The maximum depth was 1.2 percent of the nominal OD and the deepest point of deformation is located at 880.13 m (2,887.56 ft.) with an orientation of 4:17 O'clock (Figure 28).



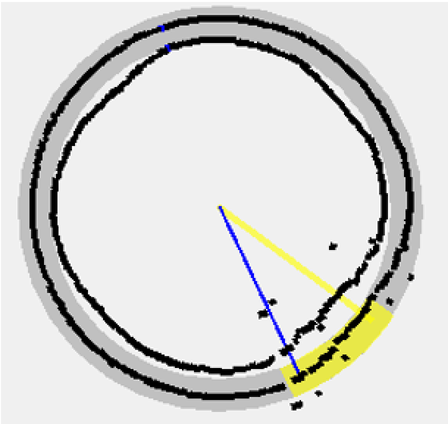


Fig. 28 -C-Scan, B-Scan, and Cross-Section of Dent

Geometric Anomaly

+ One (1) geometric anomaly was identified in the inspection data.
+ The feature is adjacent to a girth weld located at 567.22 m (1,860.97 ft.) (Figure 29). This anomaly is a possible weld misalignment.

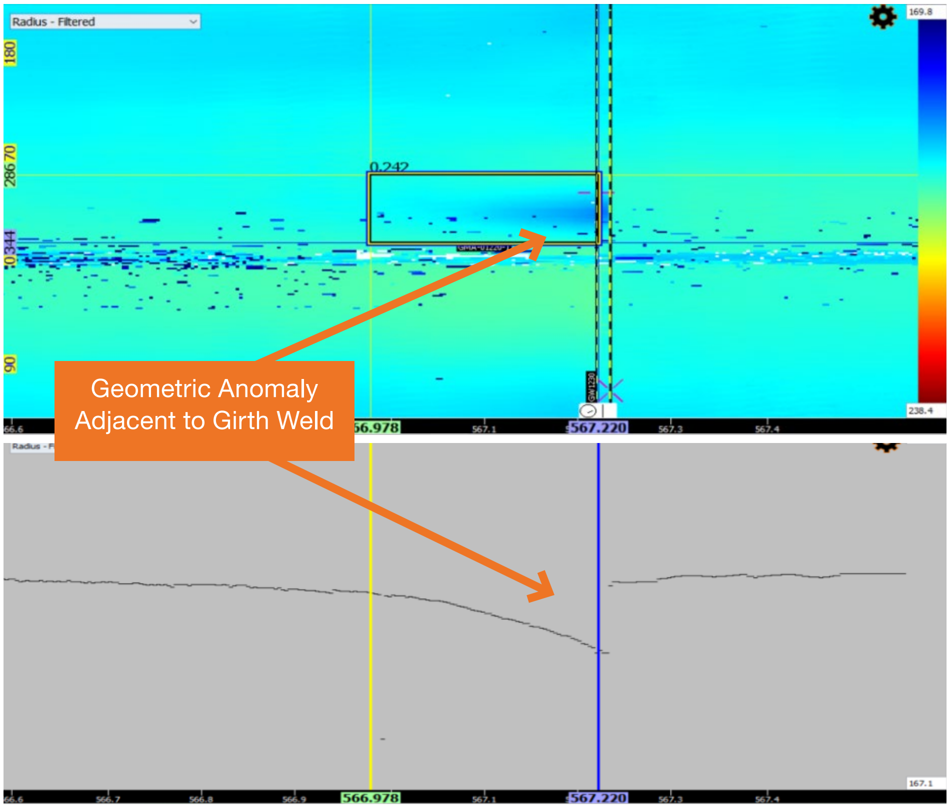


Fig. 29 - C-Scan and B-Scan of Geometric Anomaly

Return Line

External Metal Loss

+ Forty-eight (48) external metal loss anomalies with a depth greater than 15 percent were identified in the inspection data.
+ Based on nominal wall thickness of 8.74 mm (0.344 inches), the deepest metal loss corresponds to an 80.5 percent wall loss anomaly.

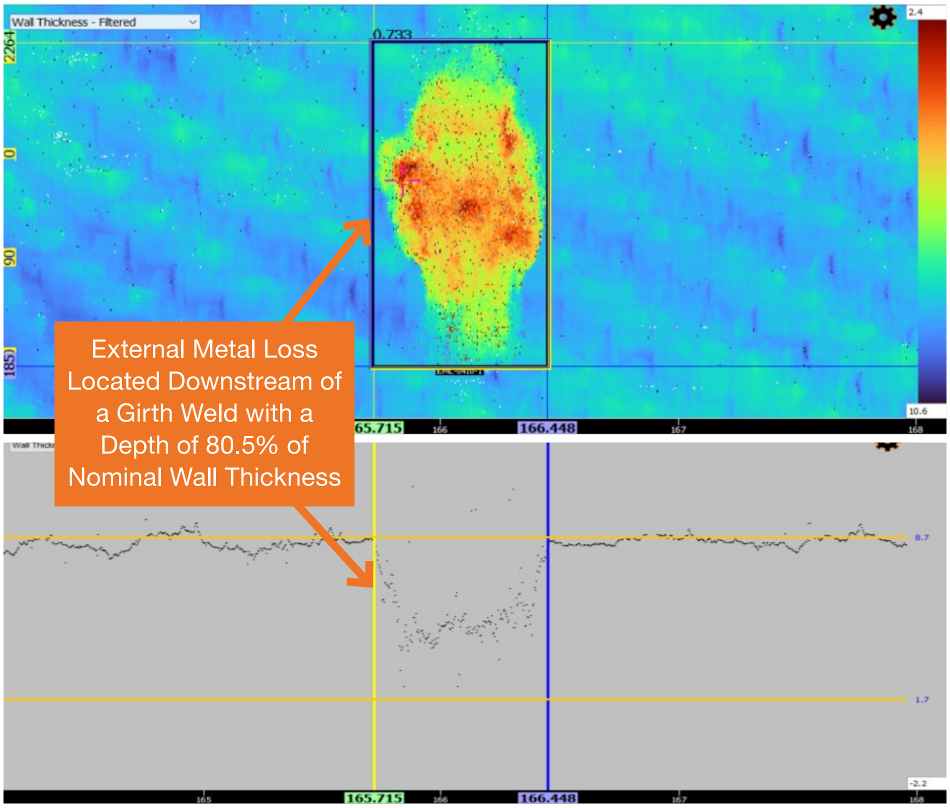


Fig. 30 - C-Scan and B-Scan of External Metal Loss

Dents

+ Six (6) dents with depth greater than or equal to 1 percent of the nominal OD were identified in the inspection data.
+ The deepest dent is located at 627.17 m (2,057.66 ft.), with an orientation of 3:37, length of 101.6 mm (4.00 inches), and width of 128.8 mm (5.07 inches). The maximum depth is 1.5 percent of nominal OD.

Manufacturing Anomaly

+ One (1) manufacturing anomaly was identified in the inspection data.
+ The identified manufacturing anomaly was located at 747.88 m (2,453.68 ft.), with an orientation of 10:48, length of 188.7 mm (7.43 inches), and width of 249.3 mm (9.82 inches) This anomaly is in a bend.

Summary of Metal Loss Anomalies

A summary of the identified anomalies and reporting conclusions within the feeder and return lines are captured within the tables below:

Feeder Line

*Metal Loss Depth %	External	Internal	Total
15% ≲ * < 20%	17	1	17
20% ≤ * < 30%	56	1	57
30% ≤ * < 40%	10	0	10
40% ≤ * < 50%	5	1	6
50% ≤ * < 60%	0	0	0
60% ≤ * < 70%	0	0	0
70% ≤ * < 80%	0	0	0
* ≥ 80%	1	0	1

Return Line

*Metal Loss Depth %	External	Internal	Total
15% ≲ * < 20%	7	0	7
20% ≤ * < 30%	23	0	23
30% ≤ * < 40%	7	0	7
40% ≤ * < 50%	5	0	5
50% ≤ * < 60%	2	0	2
60% ≤ * < 70%	0	0	0
70% ≤ * < 80%	3	0	3
* ≥ 80%	1	0	1

Condition Assessment Conclusions

Based upon the inspection data and as concluded within the delivered reports, the following observations were made:

+ Only 5 external metal loss defects between 70 percent and 80 percent required repair or remediation.
+ Two (2) external metal loss defects within the return pipework were to be considered as borderline threats (shown as the 50 percent-60 percent Metal Loss Depths within the Return Line Table).
+ In general, the feeder pipework had experienced more external corrosion with 89 recorded defects versus 48 of the Return Pipework; however, the corrosion was more severe within the return pipework due to greater wall loss.
+ Only 3 areas of internal corrosion were identified within the feeder pipework and posed no immediate threat to operations
+ No internal corrosion was detected within the return pipework.

The results provided sufficient validation and confidence to allow SES to conclude that the detected damage caused by corrosion could be remediated by repair therefore restoring network operational integrity.

Feature List & Defect Location Sheets

As part of the standard deliverable, Quest Integrity provided a Feature List delivered as a spreadsheet itemizing each defect in terms of position, type (internal or external metal loss, dent, etc.) and defect measurement. To support this document and to assist in location of detected defects, Defect Location Sheets of the top 10 anomalies were generated and provided to SES to assist them with their maintenance plan.

Future Operations - Re-inspection

SES are now in an educated position with a thorough integrity understanding of the feeder and return lines. Both sections are now baselined in terms of their current levels of corrosion. With the significant threats repaired and confidence restored within operating the system, SES has elected to perform a re-inspection of the same sections planned for 2026.

The re-inspection will allow SES and Quest Integrity to identify any new areas of corrosion occurring since the previous inspection and most critically measure the growth of previously measured corrosion. The benefits of the re-inspection will allow a corrosion growth rate to be observed and when combined with a corrosion growth analysis, an advanced engineering report can be generated predicting future failure timing for all anomalies.

Final Conclusions

Utilizing Quest Integrity's InVista™ ultrasonic inline inspection method, SES was equipped with the necessary detail on their pipework sections to make an informed decision of how to operate their piping network in a safer and more reliable manner, reducing and possibly eliminating the risk of unexpected leaks and system disruptions to the City of La Rochelle.

The inspection process challenged the convention of performing a systematic pipework replacement and demonstrated that the most severe defects identified could be managed by repair whilst the minor defects did not pose a short to medium term threat to operations.

In comparison to a replacement campaign of the feeder and return pipework, the cost of the inspection alone equated to approximately 10 percent of the replacement alternative. In total, the inspection and following remediation to return the pipework to reliable performance accounted for an 85 percent cost savings to SES versus replacing the entire piping system. SES was also able to minimize system and city disruption to only 3 days for the inspection versus several months when compared to an overall replacement program.