A PIPELINE INSPECTION CASE STUDY:
DESIGN IMPROVEMENTS ON A NEW GENERATION UT IN-LINE INSPECTION CRACK TOOL

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Abstract

For over 20 years, ultrasonic in-line inspection (ILI) tools have played a crucial role in helping operators manage pipeline integrity threats. The predominant ILI applications utilizing ultrasonic (UT) technology have been for wall loss and crack inspection.

Despite the high success rate experienced with ultrasonic ILI tools, technological improvements are still required to help operators manage the integrity of an aging pipeline infrastructure: improvements in the Probability of Detection (POD), improving detection reliability under different pipeline conditions, increased ranges for pipeline operating parameters, and leveraging synergies from a Combo Wall Measurement-Crack Detection (WM-CD) tool in a single run.

In 2010, Weatherford Pipeline and Specialty Services (P&SS) commissioned its new generation fleet of ultrasonic wall measurement and crack detection tools. One of the design objectives was to address some of the ILI tool limitations identified above.

This paper focuses on reviewing the latest design improvements for the new generation tools and presents a case study on a recent survey conducted on the Adria-Wien Pipeline (AWP). The pipeline sections inspected were the 30” x 4 kilometer and 18” x 420 kilometer pipeline. This paper is a joint collaboration between AWP (represented by Michael Huss) and Weatherford Pipeline & Specialty Services.

Project Scope

The **Adria–Wien Pipeline** GmbH operates a 416 kilometre crude oil pipeline connecting the Transalpine Pipeline, from Würmlach at the Italian-Austrian border, with the Schwechat Refinery near Vienna, Austria. It allows oil supplies to Austria from the Italian oil terminal in Trieste.

The diameter of the main pipeline is 18 inches (460 mm) and, divided into 3 sections, encompasses a 30” x 4 kilometer section of pipeline which connects the main pipeline with the TAL system.

The pipeline was constructed in 1970 from seam-welded pipe material conforming to API 5L Grade X52 standard, with a nominal wall thickness ranging from 6.35 mm to 9.52 mm. The pipeline has an external bitumen coating with an inlay of glass fiber fleece. Several in-line inspection surveys were performed in 1991, 2000, 2006 and 2010 using Geometry, Magnetic Flux Leakage (MFL) and UT tools to determine the condition of the pipeline and identify any potential threats to the integrity of the pipeline.

In 2010 Weatherford were awarded a contract to inspect 4 sections of the AWP pipeline using the latest generation of angled beam ultrasonic crack detection (UTCD) tools. The pipeline reference names are as follows:

- PS01 to PS06 18” x 169 km
- PS06 to PS09 18” x 121,5 km
- PS 09 to US02 18” x 123 km
- TAZ1 to PS01 30” x 4 km

The project scope called for identification of all axial cracks, crack-like anomalies in welded seams, and parent material. Following the crack detection survey the vendor also performed a crack assessment in accordance with API 579.

Summary of Crack Inspection Field Operations

It should be noted that the marker locations were provided by AWP from previous run data and, in addition, a geometry survey was performed prior to mobilization. Weatherford mobilized its crew from an ILI base in Germany to provide the turnkey service, to include:

- Pre-inspection cleaning by magnetic and brush scrapers
- A Gauge Pig run
- UTCD inspection runs

After data evaluation it was determined the UTCD tool accurately recorded the locations, crack sizes and crack-like anomalies. Features also recorded included axially-oriented manufacturing anomalies.

As pipeline integrity operations comprise of several stages it was important to meet AWP's planned schedule, which we achieved, with all 4 sections completed within the scheduling parameters.

After completion of the field inspection work Weatherford performed analysis of the recorded data and provided AWP with a preliminary report. The preliminary report included all reportable cracks, crack-likes and axially-oriented anomalies. Based on analysis of the preliminary report AWP selected 4 locations in order to verify the accuracy of the defect sizing and location. The 4 features excavated comprised of two cracks, one crack-like and one longitudinal weld anomaly.

During the verification process Weatherford provided a verification specialist to aid AWP personnel in locating, classifying and identifying the dimensions of the selected anomalies. All of the 4 verified locations confirmed the ILI predicted measurements were within stated tolerance. The probability of detection and probability of classification specifications were also confirmed as adhering to stated specification tolerances.

In addition to the ILI analysis, an API 579 assessment was performed which enabled the operator to confidently continue to operate the asset with an understanding of Remaining Strength Factors and Maximum Allowable Operating Pressure (MAOP) pursuant to industry standards. This also provided detailed sizing information to enable the operator to monitor defect growth following future inspections.

ILI tool Technology Characteristics

The latest generation of UT ILI pigs were introduced to the market in 2009 – 2010[1] having utilized the previous generation since 2003. The latest generation of UTCD pigs are better adapted for challenging pipeline conditions. For example, this generation has improved the bend passing capability (Previous generation – 3D bend capability, versus latest generation – 1.5D), the probability of detection (POD), defect sizing, and improved performance in challenging pipeline environments.

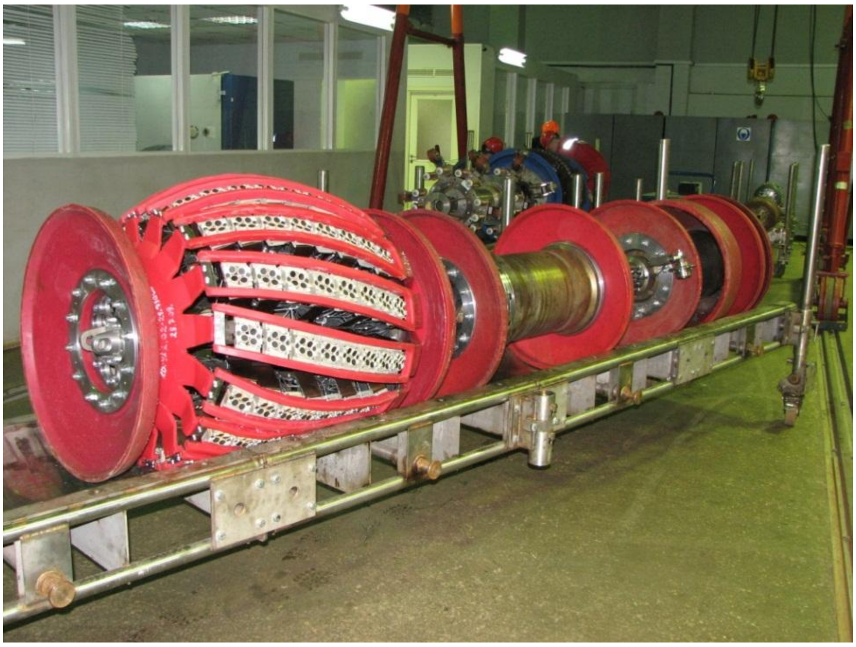


Figure 1 – Latest generation UT-CD tool used on this project.

In order to achieve a successful operation in challenging pipeline environments much attention has been paid to addressing issues associated with rough internal pipe walls, increasing temperature (now -20°C to +70°) and pressure (now up to 120 bar) ranges, product velocity, bore restrictions and product deposits (wax or scale).

During the design phase of the tool development special emphasis was also applied to the development of a Combo WM-CD tool inspection capability for a single run. As a result all WM and CD tools ≥ 14” are now capable of a WM-CD Combo tool configuration.

The design parameters for the new generation Combo WM-CD tool are identified below. The requirements for these parameters are as follows:

- Wall Thickness (WT) measurement resolution: < 0.06 mm
- Minimum detectable depth for general metal loss: < 0.3 mm
- WT measurement range: 3 mm to 60 mm
- Minimum crack-like defect length: 30 mm
- Minimum crack-like defect depth: 1 mm
- Probability of Detection (POD): > 90%
- Maximum inspection speed at 3 mm axial resolution: up to 2.2 m/s
- Bend passing: up to 1.5D x 90°
- Maximum pressure: 120Bar
- Operating temperature range: -20°C…+70°C

Improved Ultrasonic Transducers

A lot of combo ultrasonic immersion-type transducers have been investigated in order to ensure appropriate characteristics for the UT ILI tools.

Figure 2 – Latest Generation Ultrasonic transducers

The types of ultrasonic transducers selected for this technology possess the following key attributes and advantages:

- High sensitivity - transducer signal is 15-20 dB greater than transducers of the previous generation, allowing for increased sensor density and a better signal to noise ratio.

- Improved transducer (Figure 2) focusing based on a new design, provide the following advantages:
  - Less sensitivity to medium acoustical properties
  - Reduction in signal losses from transducer to medium transition

- Higher resolution due to shortened pulse width and customized signal processing

- Improved operational parameters:
  - Operating pressure up to 200 bar
  - Temperature range of -20°C to 120°C

Data acquisition system

Specifications of the New Generation UT ILI tools are primarily based on the data acquisition system features, including an echo-signals processing chain. The data acquisition system was designed to meet the capacity requirement of up-to-date digital signal processing algorithms and ensure recording of inspection data.

This new data acquisition system is based on a 32-channel processing board, providing scalability from 6” WM UT ILI tool (64 channels) up to 36” Combo CD&WM UT ILI tool (1024 channels).

To minimize echo-loss, the received pulses are processed using a high selectivity matched digital filter, with individual parameters preset for each particular sensor. Filter criteria is chosen during the course of the UT system testing and calibration prior to the inspection run. If required, filter criteria can be individually calibrated for each transducer.

In addition, a special digital rectifier which sharpens max signals peaks is used in the detector of the reflected echo signals. A wide dynamic range of the receipt path (72dB) prevents signal saturation and ensures maximum possible signal-to-noise ratio.

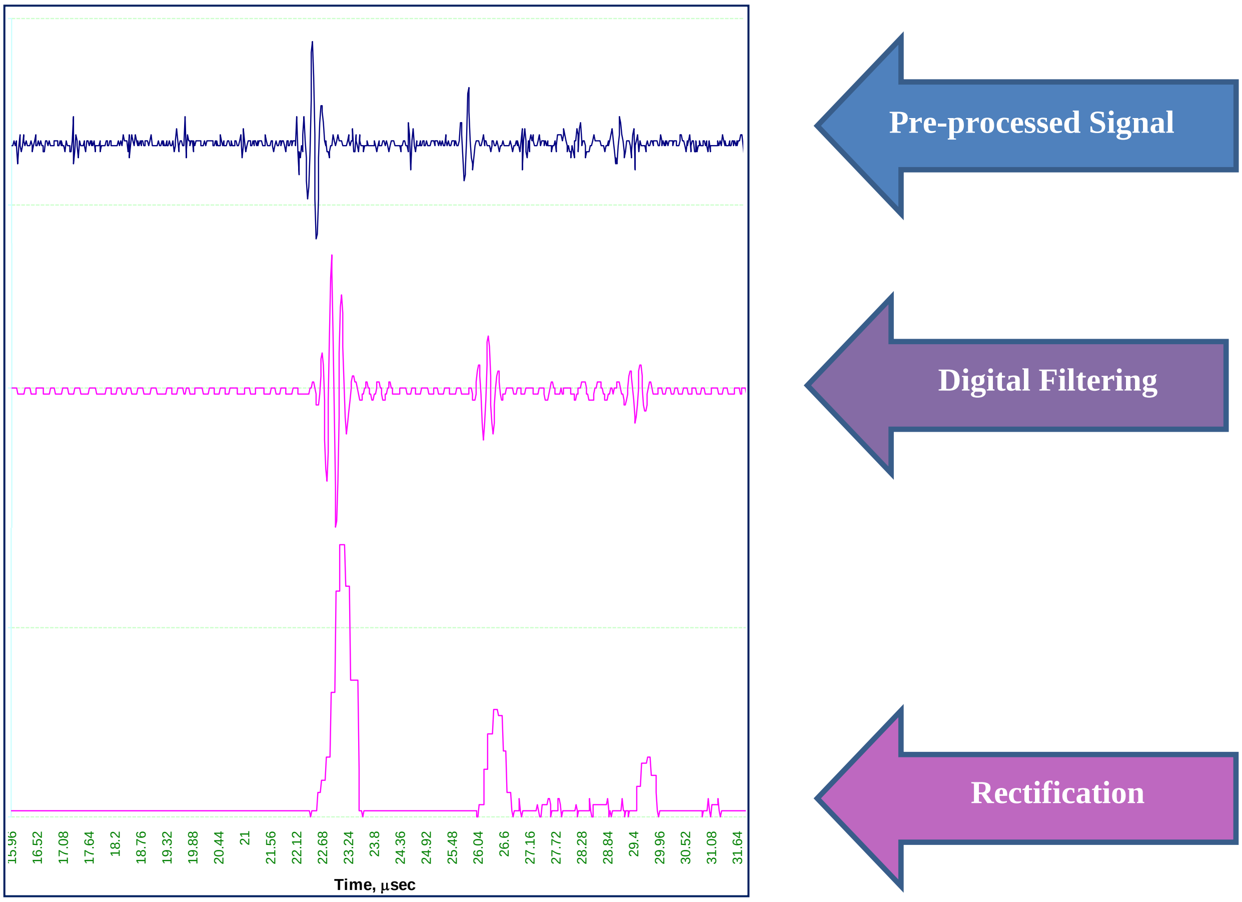


Figure 3 – Illustration of noisy weak echo signals with onboard digital filtering process followed by rectification process for improved detection and recording accuracy

Confirmation of Latest Generation UT ILI Specification

Numerous laboratory, bench, and pull-through tests, containing artificial and natural defects, have been performed to validate the design specifications[1, 2] of the new UT ILI tools. In addition, subsequent customer inspection surveys, including this case study project, have further validated the published specifications for this technology. Photos of lab and field trials are located below (Figures 4, 5)

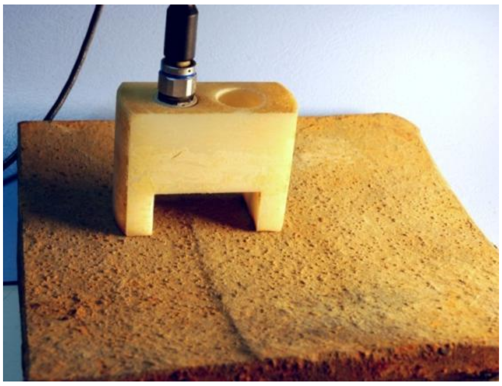


Figure 4 – Sensor lab test for surface roughness capability

Figure 5: – Mechanical field tests for new generation UT

Data Processing Software
The existing data processing software has been upgraded to improve accuracy of inspection data obtained by the new Gen UT ILI pigs.

Fig. 6 shows depth sizing accuracy for cracks. In accordance with accepted standards [3,4], the field trials and pull tests confirmed the quality of data obtained by the new Generation UT ILI pigs is improved from previous Generation ILI tools[5] for challenging pipelines with the following features: increased internal surface roughness, heavy oil with high content of wax in pumping medium and inner coating.

The capability of the new Generation UT ILI tools to operate properly in various products i.e., unstable condensate and sea water, has been confirmed.

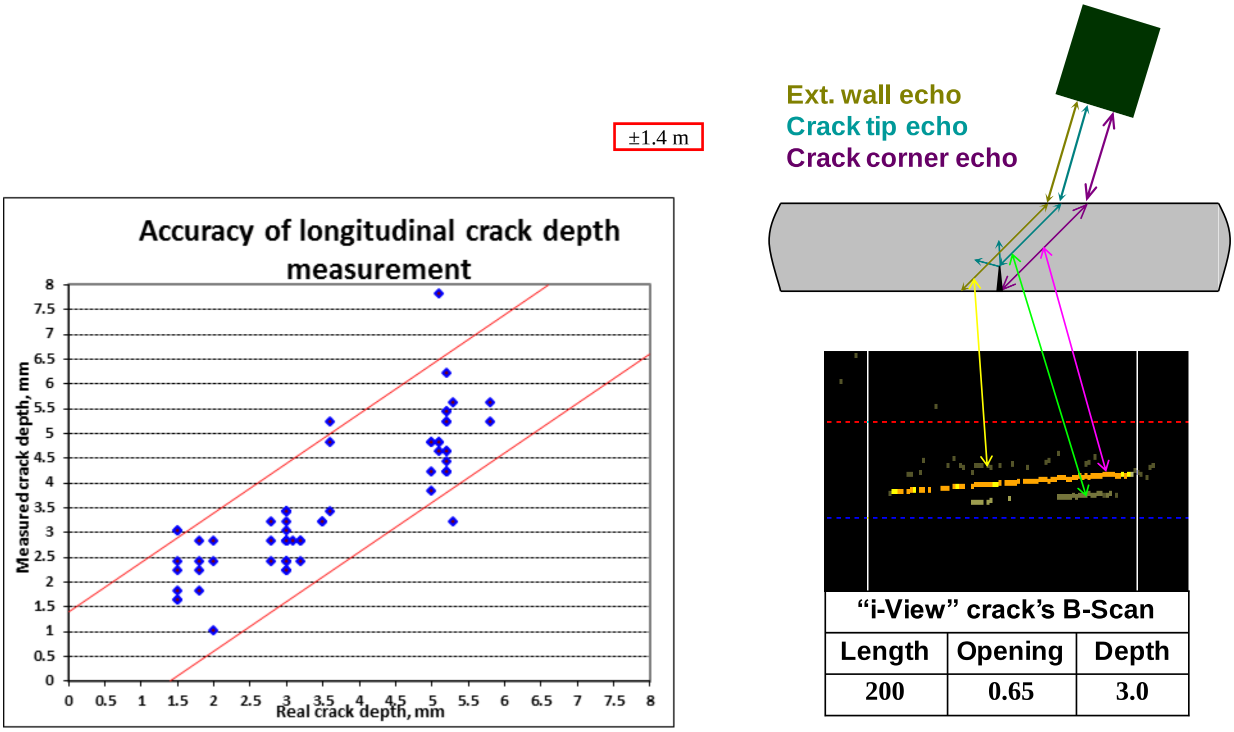


Figure 6 – Sizing accuracy tests based on echoes' time evaluation (illustration on the right)

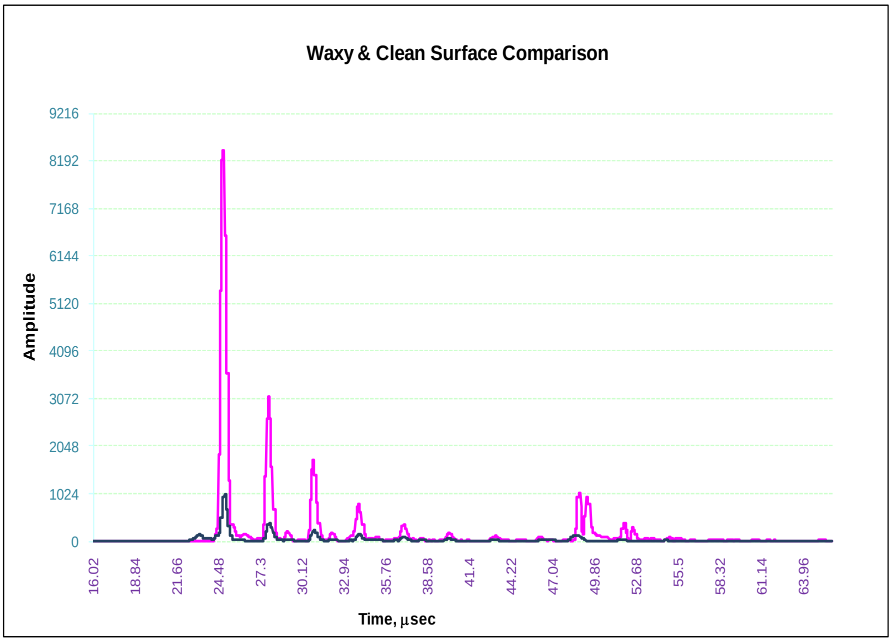
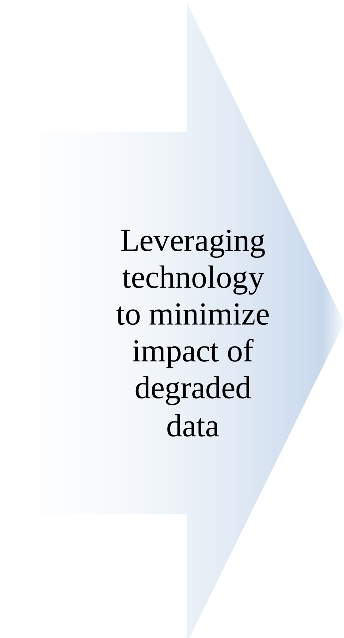


Figure 7 – WM sensor echoes comparison: 1mm hard wax deposit (blue) and clean internal surface (magenta)



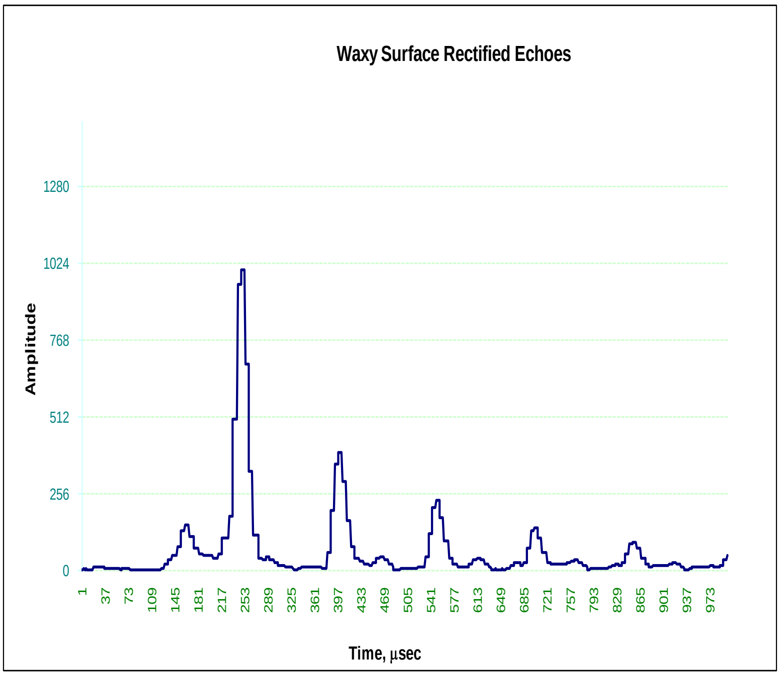


Figure 8 – WM echoes with 1 mm hard wax deposit (zoomed), measurement capability is maintained

Summary of Data Analysis

Below are the results of the ultrasonic crack inspection of the 30" and 18"' TAZ1 – USO1 pipeline with a total length of 418 km.

	Cracks	Notches	LW Anomaly	Total
30" TAZ1 - PS01, 4 km	0	0	0	0
18" PS01 – PS06, 169 km	25	297	12	334
18" PS06 – PS09, 121.5 km	34	228	4	266
18" PS09 – US02, 123 km	20	258	2	280
Grand Total of Anomalies				880

Table 1 – Total Anomalies – All 4 Sections

Summary of Results with DAF > 1

Below are the results of Anomalies DAF>1 according to API 579

	Cracks	Notches	LW Anomaly	Total
30" TAZ1 - PS01, 4 km	0	0	0	0
18" PS01 – PS06, 169 km	0	2	0	2
18" PS06 – PS09, 121.5 km	0	4	0	4
18" PS09 – US02, 123 km	0	2	1	3
Grand Total of Anomalies				9

Table 2 – Anomalies with DAF > 1 – All 4 Sections

ILI Predicted				Verification		
ILI	**Def. #**	**Description**	**Depth mm**	**Decription**	**Depth mm**	**Estimate of the convergence**
18" PS01 – PS06, 169 km	31	external crack	2	internal crack	1.9	Possible inclined crack
18" PS06 – PS09, 121.5 km	2149	external crack	2	laminations and external surface crack	0.9	Possible the signal amplitude on data is increased due to a combination of crack + lamination.
18" PS06 – PS09, 121.5 km	2148	possible external crack	1	laminations and external crack	1.1	Satisfactory
18" PS09 – US02, 123 km	2348	poss. long weld anomaly	2	weld anomaly, linear slag inclusions	1.6	Satisfactory

Table 3 – Verification Detail Summary

Excavation Results

Detailed results from the excavation are shown below. The first two tables highlight the predicted versus actual results from 2 anomalies identified on the same pipe joint. The tables below show the corresponding software screenshot of the anomalies and a photo of the excavated pipe joint.

18" PS06 – PS09, 121.5 km Defect no. 2148		
Defect Parameters	**ILI Results**	**Dig verification results**
Feature	Possible crack	Laminations and crack
Orientation	204°	210°
Length mm	281	300
Width mm	44	55
Nominal wt in feature area	7.1	7.3
Maximum depth mm	1.0	1.1

Table 4 – Actual Versus Predicted - Anomaly 2148

18" PS06 – PS09, 121.5 km Defect no. 2149		
Defect Parameters	**ILI Results**	**Dig verification results**
Feature	Crack	Laminaations and surface cracks
Orientation	191°	195°
Length mm	507	500
Width mm	36	75
Nominal wt in feature area	7.1	7.3
Maximum depth mm	2.0	0.9

Table 5 – Actual Versus Predicted - Anomaly 2149

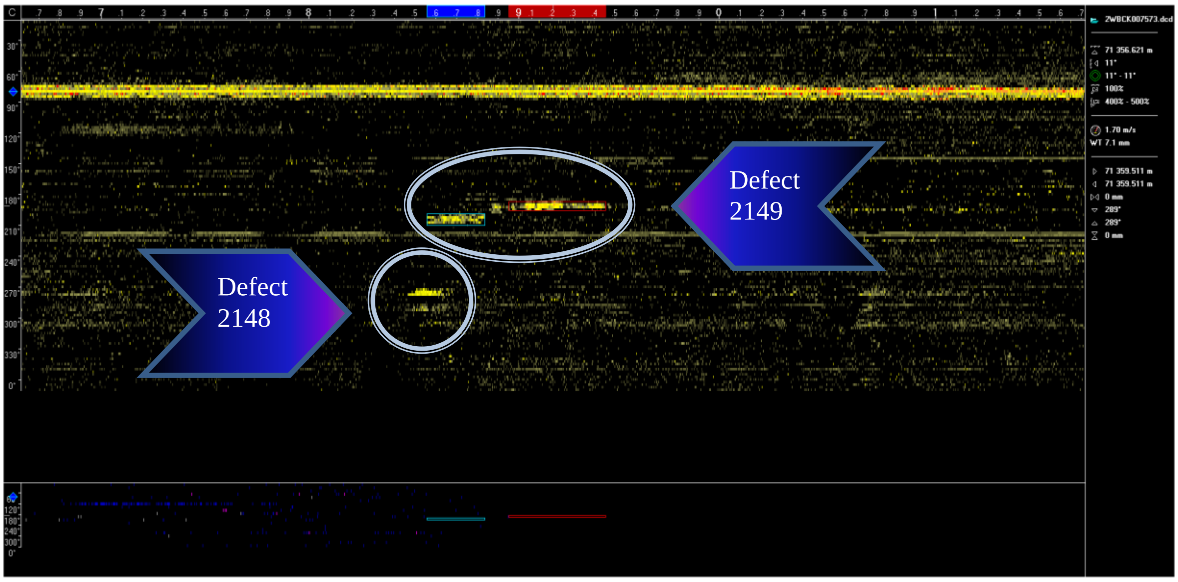


Figure 9 – i–View™ Screenshot of Anomalies 2148 and 2149

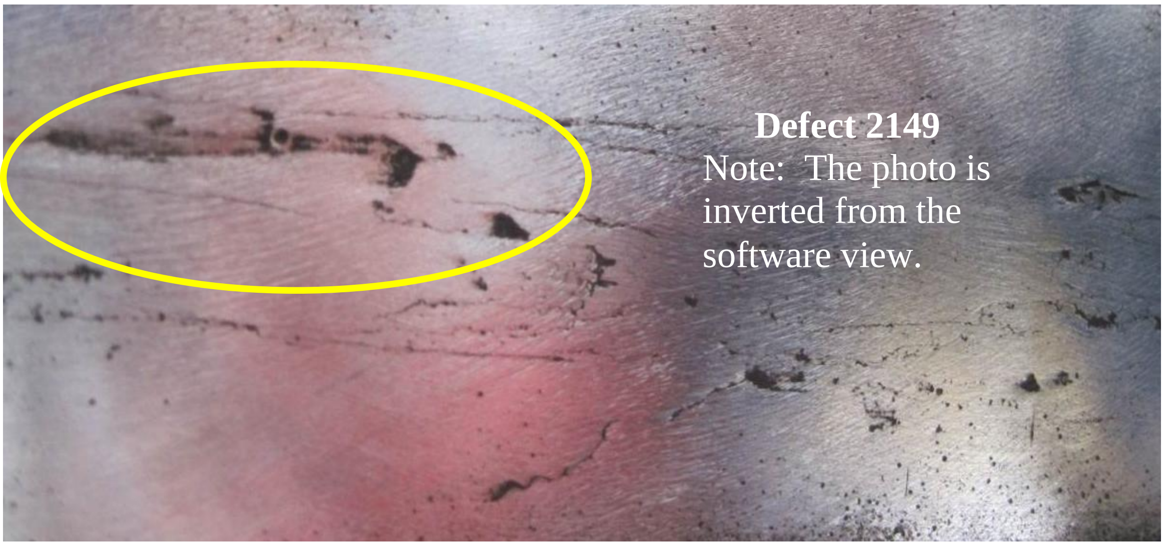


Figure 10 – Photo of pipe joint - Anomalies 2148 and 2149

Additional Dig Results

The actual versus predicted results of Feature no. 31 and Feature no. 2348 are outlined in Tables 5 and 6 below.

18" PS01 – PS06,169 km Defect no. 31		
Defect Parameters	**ILI Results**	**Dig verification results**
Feature	Crack	Crack
Orientation	69°	68°
Length mm	156	160
Width mm	32	25
Nominal wt in feature area	6.3	6.3
Maximum depth mm	2.0	1.9

Table 6 –Actual vs. Predicted - Anomaly 31

18" PS09 – US02, 123 km Defect no. 2348		
Defect Parameters	**ILI Results**	**Dig verification results**
Feature	Possible long weld anomaly	linear slag edges
Orientation	23°	26°
Length mm	275	330
Width mm	64	-
Nominal wt in feature area	6.3	6.4
Maximum depth mm	2.0	1.6

Table 7 – Actual vs. Predicted - Anomaly 2348

Crack Assessment

To assess the cracks, calculations were performed in accordance with API 579 methodology (LEVEL 2)[6]. Below is an example of a Failure Assessment Diagram (FAD) highlighting defects in red that fall outside the acceptable size for the pipeline section. The defects in red represent those that are > 1 for the defect acceptability factor (DAF) described in API 579.

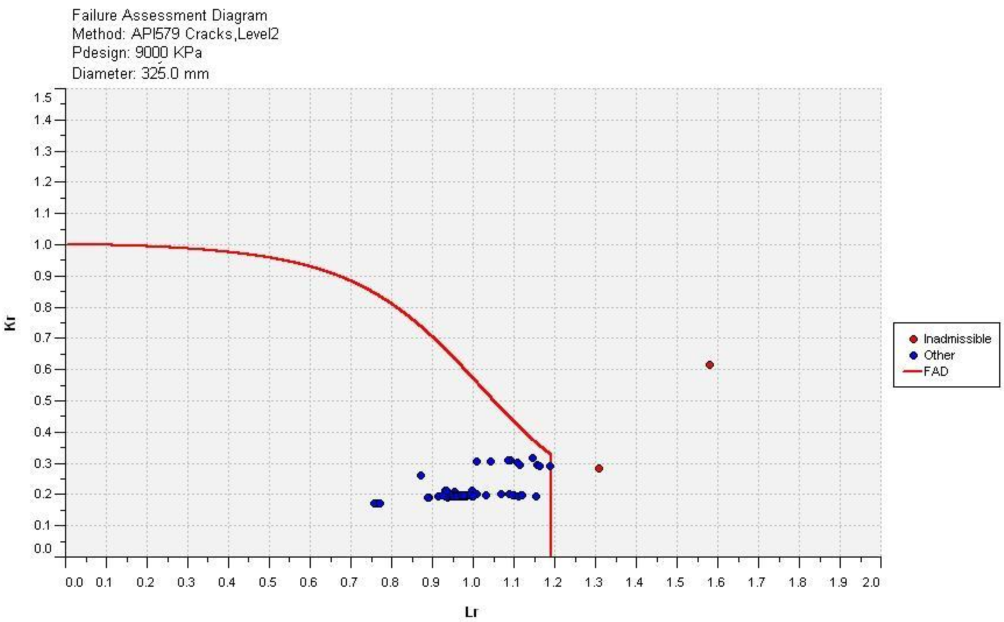


Figure 11 – Example of FAD diagram, API 579 Level 2

Conclusion

The projects preparation and planning, tool technology, and positive client-vendor collaboration contributed to a successful project. In accordance with the vendor's internal project management performance indicators the scope was delivered on time, within budget forecast and to the client's satisfaction. Also, from the vendor's perspective, this was a very successful and important project, successfully introducing the newest generation UTCD tool to the European market.

References

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2. IPC2010-31140, Assessment and Management of SCC in a Liquid Pipeline — Case Study; P. Cazenave, S. Tandon, R. Krishnamurthy, M. Gao, Blade Energy Partners; R. Peverelli, PIMS of London; C. Moreno Ochoa, E. Diaz Solis, Pemex Refinacion

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4. American Peroleum Institute; API Standard 1163, In-Line Inspection Systems Qualification Standard. August 2005

5. Weatherford New Generation ILI Tools; S. Panteleymonov, PhD, A. Smirnov, Weatherford P&SS, Lukhovitsy, Russia

6. American Petroleum Institute, API RP, 579 Second Addition.