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Pipeline & Specialty Services (P&SS)

A Pipeline Inspection Case Study: Design Improvements on a New Generation UT In-line Inspection Crack Tool

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This paper is a joint collaboration between AWP, represented by Mr. Michael Huss, and Weatherford P&SS.

P&SS Services

Pre-Commissioning & Maintenance

Pipeline

- Flooding
- Cleaning
- Pigging
- Inline Inspection
- Testing
- Integrity
- Leak Detection
- Dewatering
- Drying
- Purging & Packing
- Umbilical Monitoring & Testing
- Membrane N2

Process

- Testing
- Flushing & Jetting
- Leak Detection
- Oil Flushing
- Chemical Cleaning
- Drying
- Purging
- Camera Inspection
- Flange Management
- Controlled Bolting
- Shutdown
- Membrane N2

P&SS Services - ILI

Latest Generation ILI Technologies

- **Cleaning**
- **Gauging**
- **Geometry**
- **Mapping**
- **MFL**
- **Crack Detection**
- **Combos Tools**
- **Integrity Assessment**

Ultrasonic Crack Detection background

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

Technological improvements are still required to help operators manage the integrity of an ageing pipeline infrastructure:

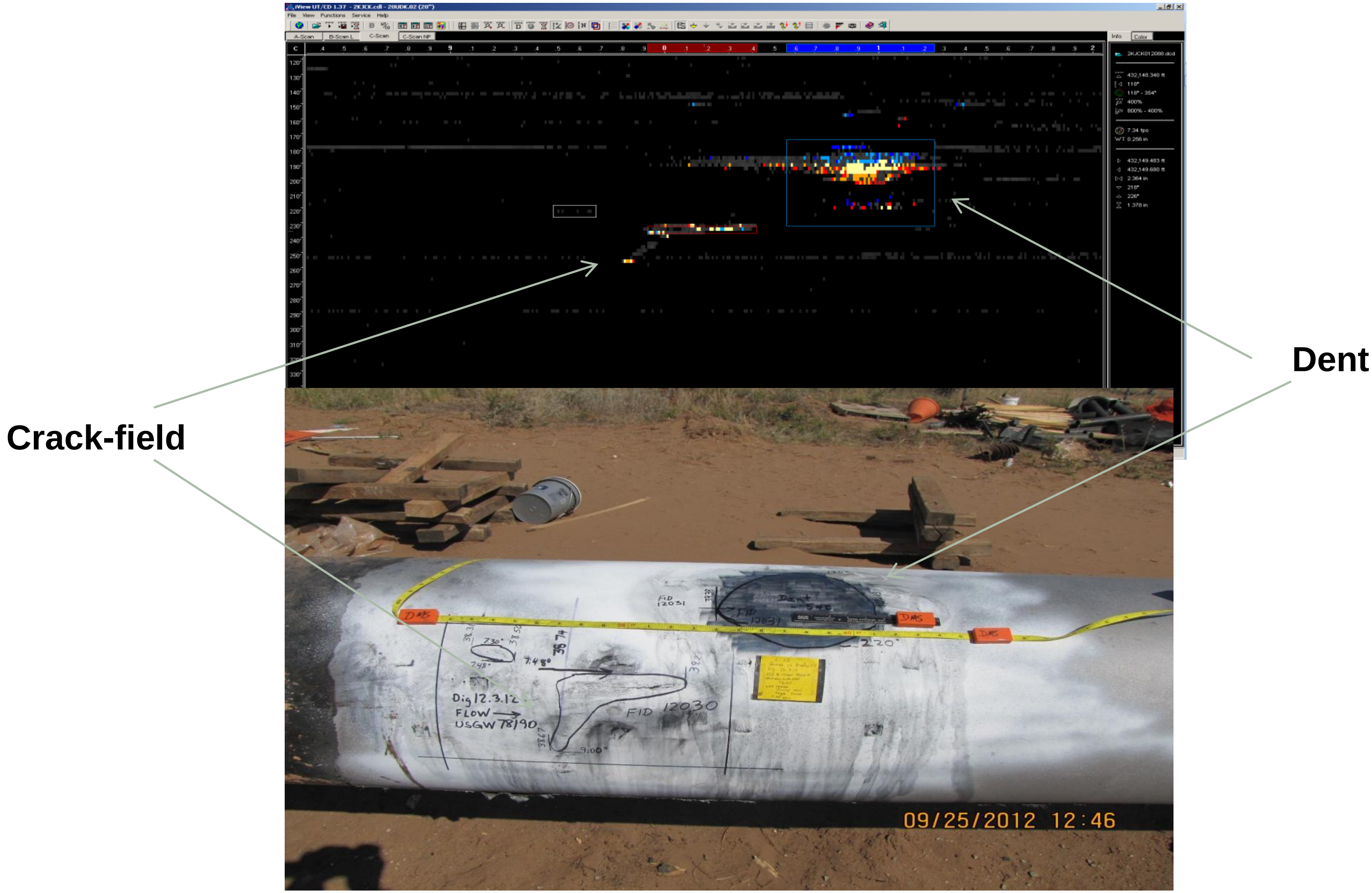
- **Probability of Detection (POD) / Probability of Identification (POI)**
- **Detection reliability under different pipeline conditions**
- **Increased ranges for pipeline operating parameters**
- **Leveraging synergies from a Combo Wall Measurement-Crack Detection (WM-CD) tool in a single run.**

Ultrasonic Inspection (CD) [Shear Wave]

Listing of the types of defects best characterized by a Shear Wave UTCD tool:

- Stress-Corrosion-Cracking (SCC)
- Axial cracking
- Crack-Like defects
- Fatigue cracking
- Hydrogen-Induced-Cracking (HIC)
- Circumferential cracking

Crack-field associated with a dent Pipeline located in the northeast USA



Stress Corrosion Cracking (SCC)

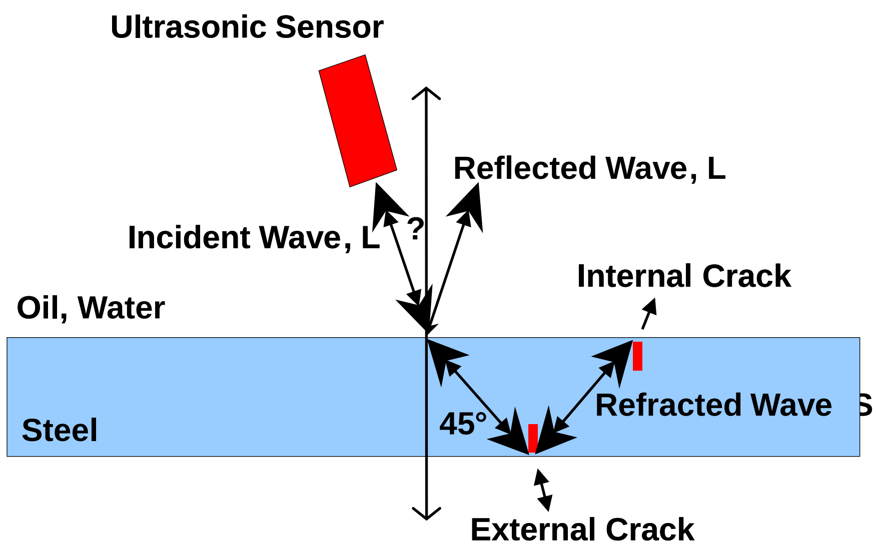
- Zoomed photo of the crack field

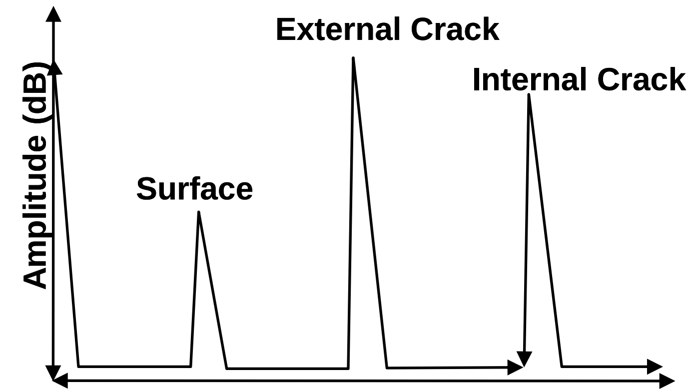
ILI:
crack-field
Depth: 40-80 mils

Field:
crack-field
Max Depth:
80 mils

Ultrasonic Inspection (CD) [Shear Wave]

Principle of Operation





An ultrasonic shear wave is propagated in the pipe-wall, by setting the crack sensors at a predetermined angle in the sensor carrier.

In addition a set of compression wave sensors is used to obtain pipe-wall thickness and girthweld information.

New Generation Ultrasonic (UT) Tools

In 2009/2010, Weatherford P&SS commissioned its new generation fleet of ultrasonic wall measurement and crack detection tools. A major design objectives was to address some of the ILI tool limitations identified in a previous slide.

This presentation 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).

New Generation Tool Characteristics

- Previous generation UT tools utilized since 2003
- Latest generation (2009) are better adapted for challenging pipeline conditions. For example, improved:

Bend passing capability	1.5D versus 3D
Probability of Detection	POD = 90%
Probability of Identification	POI = 95%
Crack Sizing	Depth Ranges Increased
Performance in Challenging Pipelines	Improved SNR; Improved Sensor Sensitivity

First generation UT-CD tool

Performance in Challenging Environments

- To achieve a successful operation in challenging environments much attention to prove performance under following conditions:
  - Rough internal pipe walls
  - Increasing temperature (now -20°C to + 70°)
  - product velocity (up to to 2.2 m/s)
  - bore restrictions (now 1.5D bend capable)
  - product deposits (wax or scale)

- Design included development of a Combo Wall Measurement / Crack Detection Tool
  - All WM and CD tools ≥ 14” are WM-CD Combo capable

Improved Ultrasonic Transducers

Many CD – WM Combo ultrasonic immersion-type transducers were investigated to ensure improved detection and sizing characteristics for the UT tools.

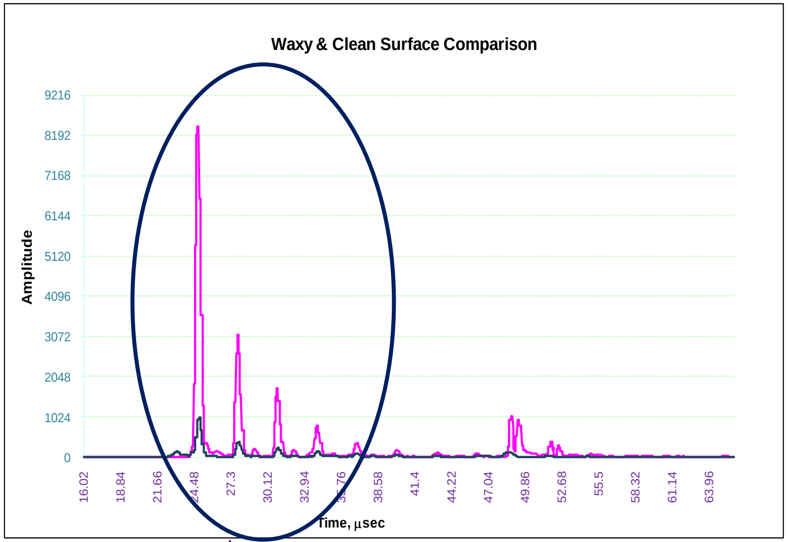
- High sensitivity – signal is 15-20 dB greater sensitivity
  - Improved signal to noise ratio
  - Improved detection in waxy environments

- Improved transducer focusing
  - Less sensitivity to medium acoustical properties
  - Reduction in signal losses from transducer to medium transition

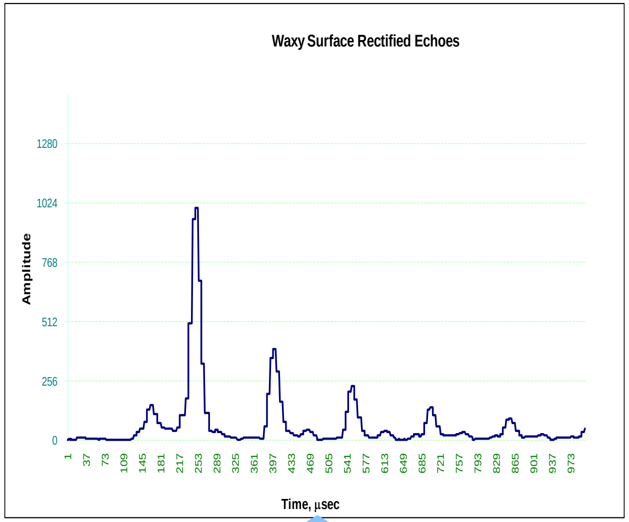
- Improved operational parameters:
  - Operating pressure up to 200 Bar
  - Temperature range of -20°C to 120°C

Latest Generation Ultrasonic transducers

Data Processing Software and Sensors



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



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

Leveraging technology to minimize impact of degraded data

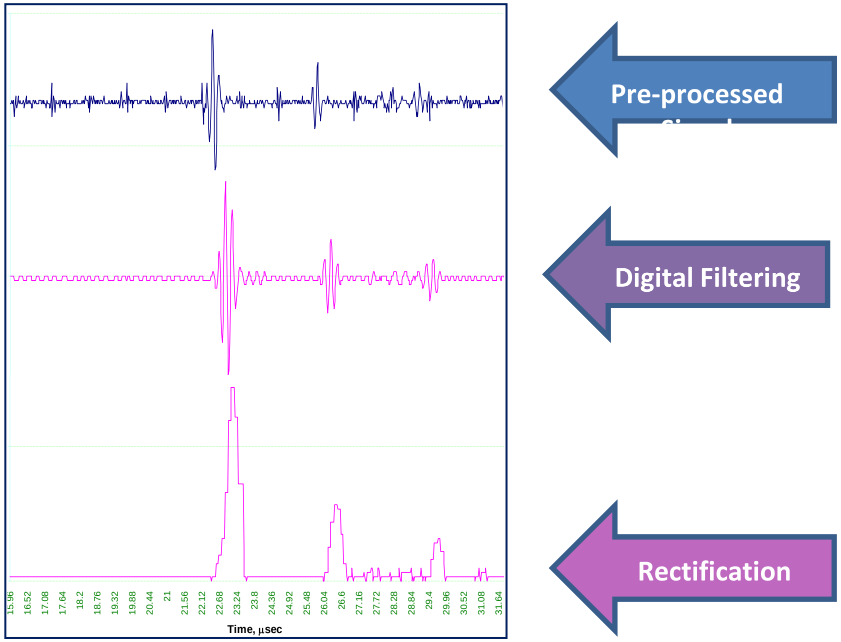
New Data Acquisition System

Specifications of the New Generation UT ILI tools are also based on the data acquisition system features:

- Echo-signals processing chain
  - Higher capacity for up-to-date signal processing algorithms
  - Optimum recording levels of inspection data.
- New data acquisition system scalability:
  - Covers diameter ranges required

Data Acquisition System continued…

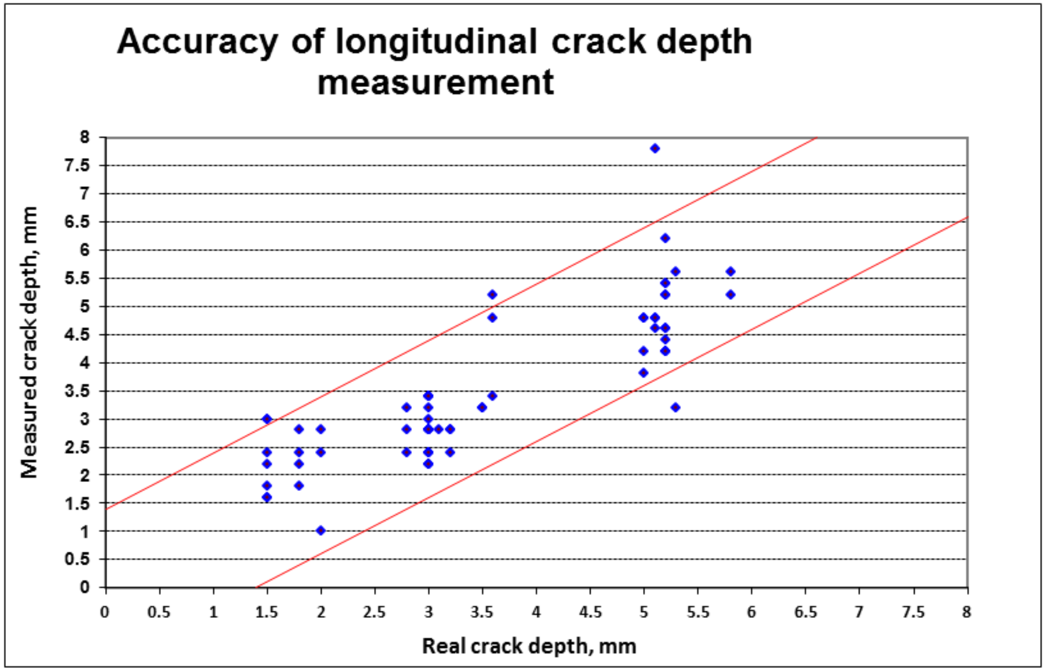
- To minimize echo-loss:
  - Pulses are processed using a high selectivity matched digital filter
  - Filter criteria is chosen during UT system testing and calibration prior to the inspection run
- Digital rectifier sharpens max signals peaks
- A wide dynamic range of the receive path prevents signal saturation
  - Ensures maximum possible SNR



Noisy weak echo signals processed with onboard digital filtering, followed by rectification process for improved detection and signal recording accuracy

iView Data Processing Software

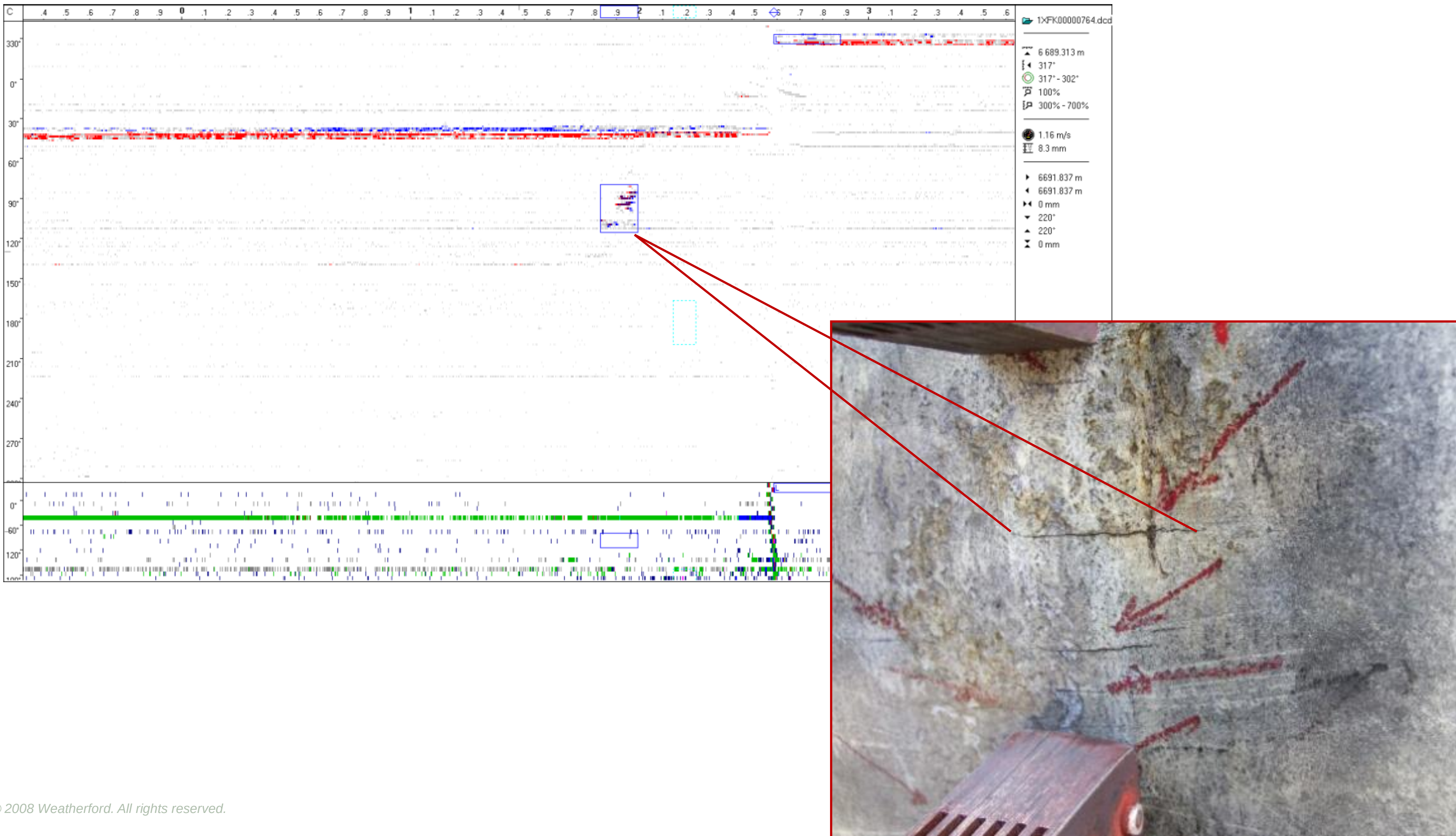
- Data processing software upgraded to improve accuracy of inspection data
- Field trials and pull tests confirmed the quality of data improved from previous Generation ILI tools
  - Increased quality of data for internal surface roughness, and…
  - Heavy oil with high content of wax in pumping medium and inner coating



Mechanical field tests for new Generation UT tools

i-View™ software window

- **Pemex SCC Project**
- **ILI identified crack, confirmed by field verification**



Case Study
Adria–Wien Pipeline (AWP) Pipeline

The Adria–Wien Pipeline GmbH

- Main pipeline is 3 sections of 460mm (18”) x 416 kms
- 762 mm (30”) x 4 kms connecting to the Transalpine Pipeline (TAL) system
  - From Würmlach to Schwechat Refinery, Austria
  - Provides oil supplies to Austria from oil terminal in Trieste
  - Improve classification of features and Fitness for Purpose

Pipeline Details

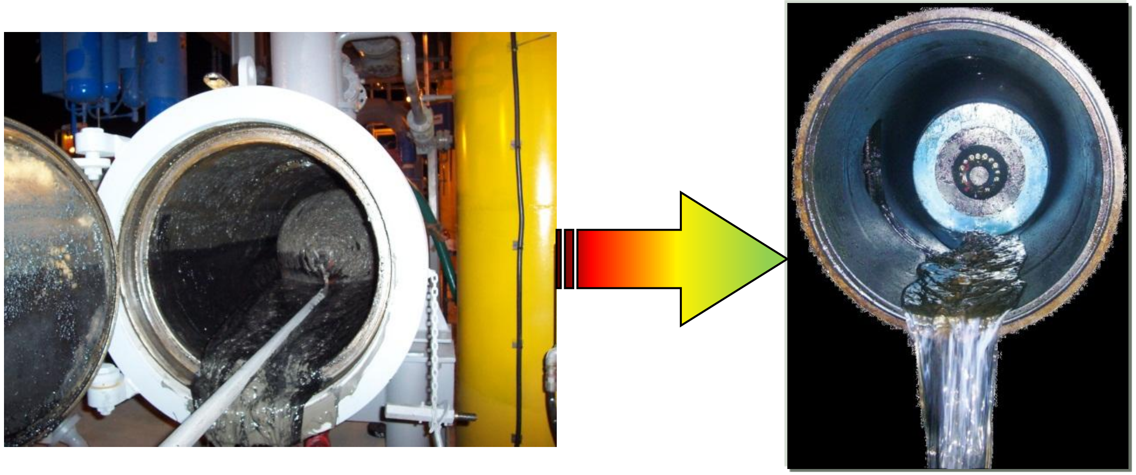
Construction Date	1970
Material	API 5L X52
Wall Thickness	6.35mm - 9.52 mm
Coating	External Bitumen with fiberglass inlay

Inspection History

Previous Inspections	1991, 2000, 2006 and 2010
ILI Technologies	Geometry, MFL, UT Crack
Weatherford 2010	Crack Inspection
	Crack Assessment

Crack Inspection Field Ops Summary

- Weatherford mobilized its crew from an ILI base in Germany to provide the turnkey service, services included:
  - Pre-inspection cleaning by magnetic and brush scrapers
  - Gauging Pig run
  - UTCD inspection runs



- Field data quality evaluation determined UTCD tool runs were successful.
- From preliminary report, AWP selected 4 verification locations
- The 4 features excavated comprised of 2 cracks, 1 crack-like anomaly and 1 longitudinal weld anomaly.

ILI Verification

- Weatherford provided a verifications specialist to aid AWP personnel in locating, classifying and sizing:
  - All 4 verified locations confirmed the measurements predicted by the ILI tool were within stated tolerances.
    - The probability of detection (crack POD @ 90%) within tolerances
    - Probability of classification within tolerances (POI @ 95% confidence)
    - Sizing within tolerances
- API 579 crack assessment was also performed:
  - Continue to operate with understanding of Remaining Strength Factors for a certain Operating Pressure.
  - Detailed sizing allows operator to monitor defect growth following future inspections.

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 420 km.

Total Anomalies – All 4 Sections

	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

Additional Dig Results

The actual versus predicted results of Feature no. 31 and Feature no. 2348 are outlined in the tables 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
Nominal wt in feature area	6.3	6.3
Maximum depth mm	2.0	1.9

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
Nominal wt in feature area	6.3	6.4
Maximum depth mm	2.0	1.6

Actual vs. Predicted - Anomaly 31

Actual vs. Predicted - Anomaly 2348

Excavation Results

- These two tables highlight the predicted versus actual results from 2 anomalies identified on the same pipe joint.

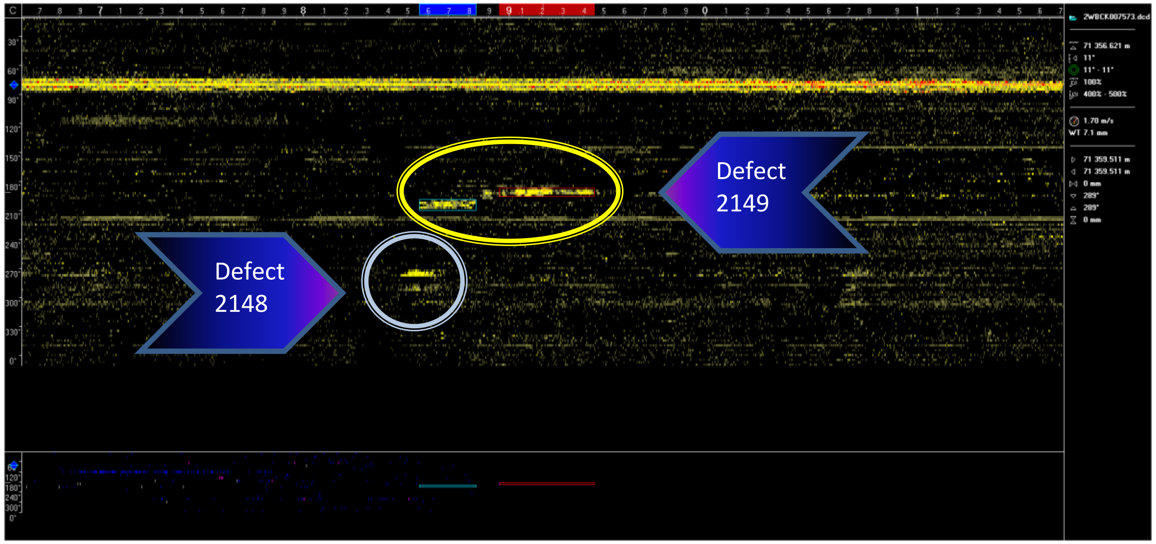
18" PS06 – PS09, 121.5 km Defect no. 2148		
Defect Parameters	**ILI Results**	**Dig verification results**
Feature	Possible crack	Laminations and crack
Orientation	204°	210°
Length mm	281	300
Nominal wt in feature area	7.1	7.3
Maximum depth mm	1.0	1.1

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

Actual Versus Predicted - Anomaly 2148

Actual Versus Predicted - Anomaly 2149

Excavation Results cont…



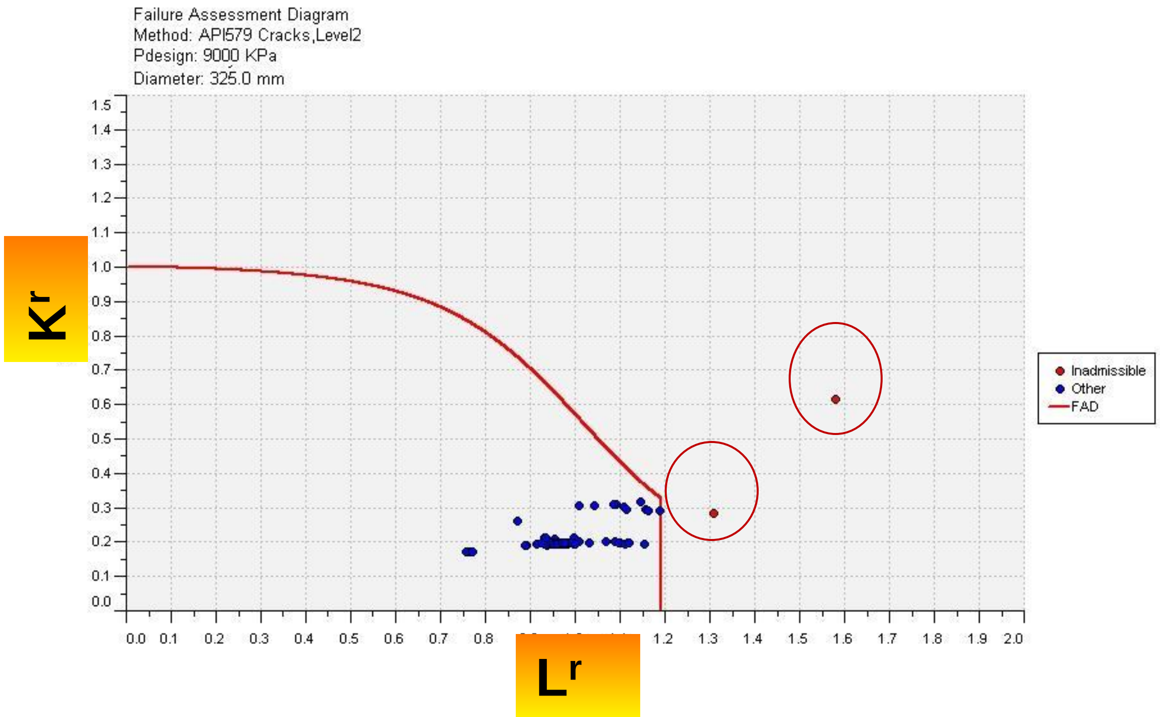
I–View™ Screenshot of Anomalies 2148 and 2149

Photo of pipe joint - Anomalies 2148 and 2149

Crack Assessment

- Crack assessment calculations
  - Performed in accordance with API 579 methodology (LEVEL 2)
  - Example of a Failure Assessment Diagram (FAD)
    - Defects in red 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 or BS 7910.

Example of FAD diagram, API 579 Level 2



Summary of Results with DAF > 1

Below are the results of Anomalies with a Defect Acceptability Factor (DAF) > 1 according to API 579

Anomalies with DAF > 1 – All 4 Sections

	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

Conclusion

- UT CD technology performed well and within specifications
- 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 indicators:
  - Scope was delivered on time
  - Delivered within budget
  - To the client's satisfaction.

Thank you!

Questions?

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