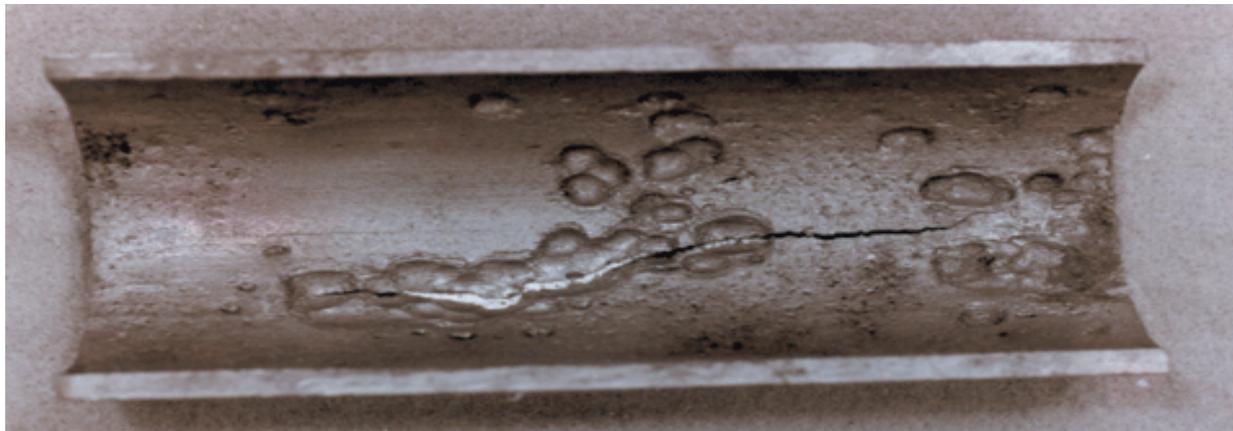


Hydrogen Sulfide and Pipeline Corrosion

Integrated Solution Set Addressing Unpiggable and Difficult Pipelines Through Modern Technology



1. According to the EPA, Infrastructure designed to last 50 – 100 years is failing in as little as 10 – 20 due to hydrogen sulfide corrosion
2. Detecting corrosion areas and targeting repairs is a much more cost effective solution than systematic replacement.
3. Hydrogen sulfide is naturally occurring in many Oil and Gas pipelines and has proven destructive in wastewater infrastructure as well.

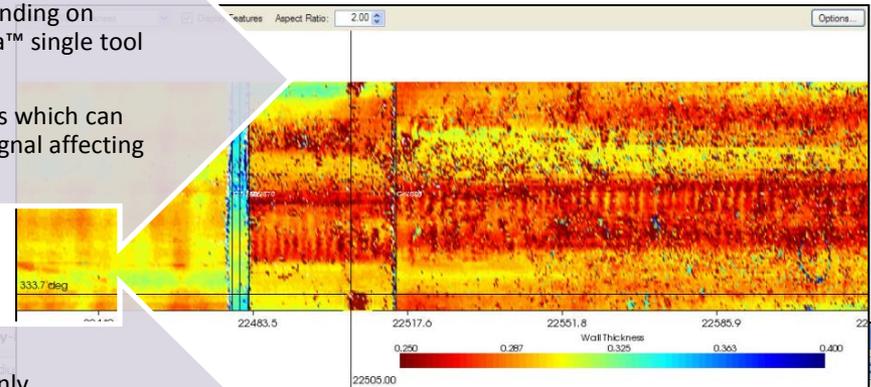


Historical Assessment Methods

Conventional ILI

(includes tethered & BIDI)

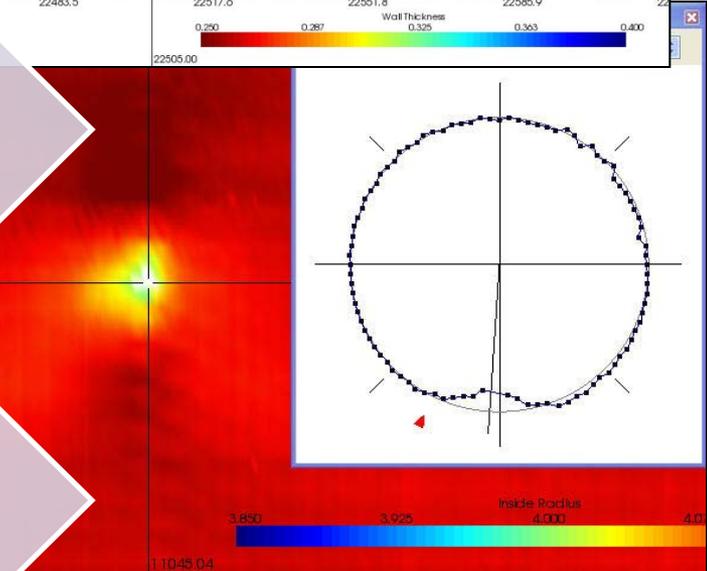
- Conventional ILI tools are more demanding on operator and less capable than InVista™ single tool packaged solution.
- MFL is subject to secondary influences which can mask important components of the signal affecting detection and sizing of defects.



Direct Assessment

(includes guided wave & localized UT)

- Direct Assessment is subjective and only incorporates snapshots of your asset.
- Compare time required for capturing and assimilating field data and decisions based on presumptions against running a tool in 1 day with quantitative report prepared by specialists delivered in about 30 days.



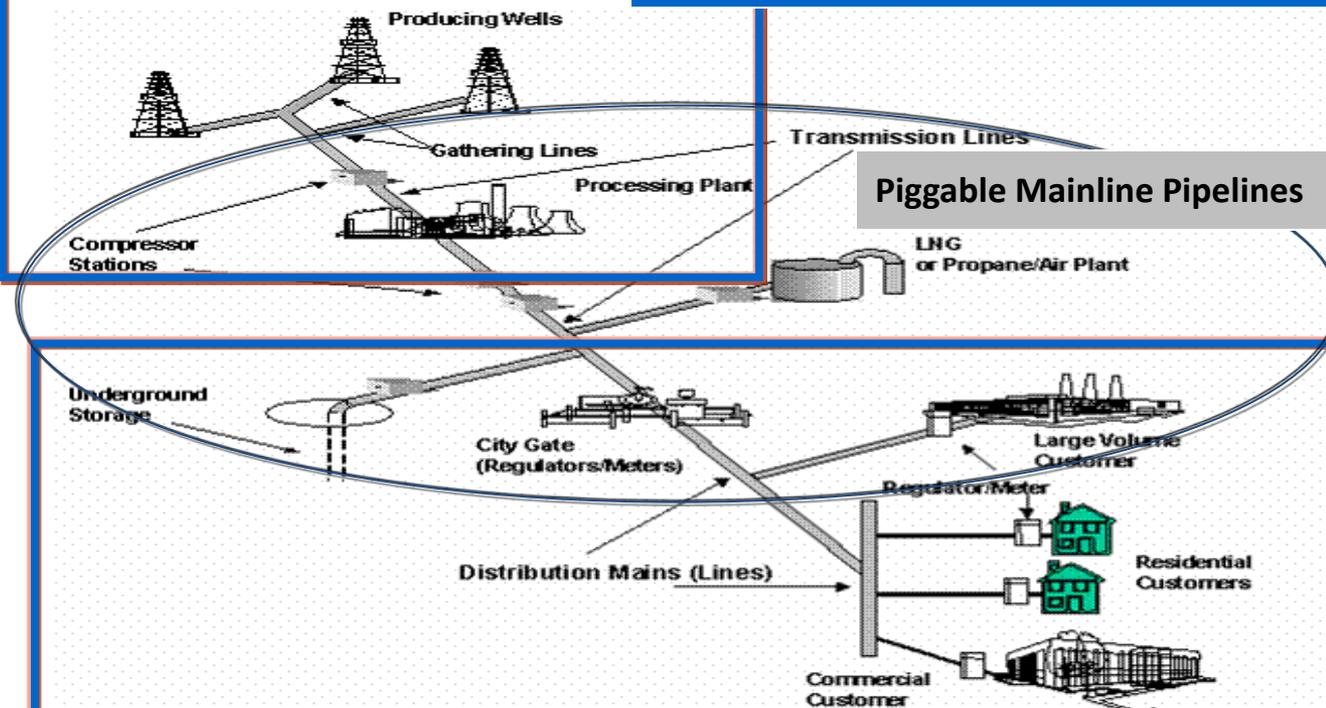
Hydrostatic Testing

- Hydrostatic testing does not deliver value—bursting pipe and increasing failure risk for other locations; does not properly mitigate risk, improve pipeline integrity, or otherwise provide actionable information.
- Operational constraints and limited operator assurance is not sufficient trade-off for reliable, accurate direct pipeline assessment.

- The gold standard for comprehensive data coverage in a pipeline inspection program is through the utilization of In-Line Inspection (ILI) technology
- Much of the existing infrastructure is considered unpiggable by traditional ILI technology which forces operators to consider alternative methodologies that provide limited information. However, new technology has revealed flexible ILI applications that allow operators to re-evaluate the “unpiggable” perception.

Solving Your Pipeline Inspection Challenges

Unpiggable Gathering & Delivery Pipelines

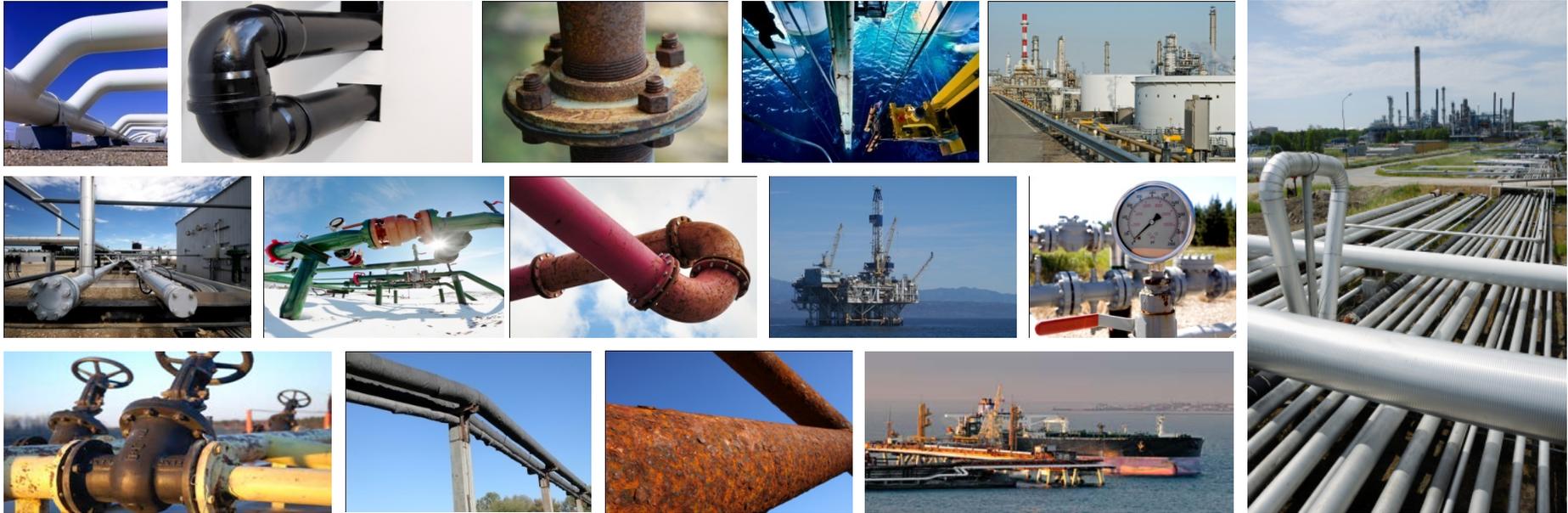


Piggable Mainline Pipelines

- Bidirectional & collapsible to > 50% ID reductions
- Bend radius to $\geq 1D$
- Back-to-back, miters & tight $>90^\circ$ radius turns
- Multi-diameter & dual-diameter capabilities
- Minimal operating pressure requirements-down to 50psi
- Applicable for both ferrous and non-ferrous materials
- Inspection distances of >100 Miles

Unpiggable Transportation & Distribution Pipelines

What Is Unpiggable?



- Bore restrictions, step changes, reduced port valves
- Cased crossings, pipe-in-pipe, vertical support members (VSM)
- Limited or missing launcher/receiver facilities
- Limited or unknown pipeline conditions
- Low flow or limited flow conditions
- Non-standard, bulging, oval, or offset pipe
- Offshore risers
- Significant wall-thickness variations
- Single entry/exit, line stoppage, plugged valves
- Unbarred tees and wyes

What Is Unpiggable?

Check Valve

**Injection Quills
Corrosion Coupons**

Remove check valve internals, quills, and other obstacles.

Non Full Port Valves

Size Changes

Consider using a multidiameter pig.

Dents

Mitre Joints

Consider replacing these as they are a potential source of failure.

Large Diameter Unbarred Tees

Consult with your smart pig vendor.

Fallacy: My line is Unpiggable.
In many cases it may be cheaper to modify the line to be piggable than to do other methods. Once a line is piggable, the cost of smart pigging is less than other methods. No more process shutdowns are required and the inspection data is more accurate.



NDT Tool Technology

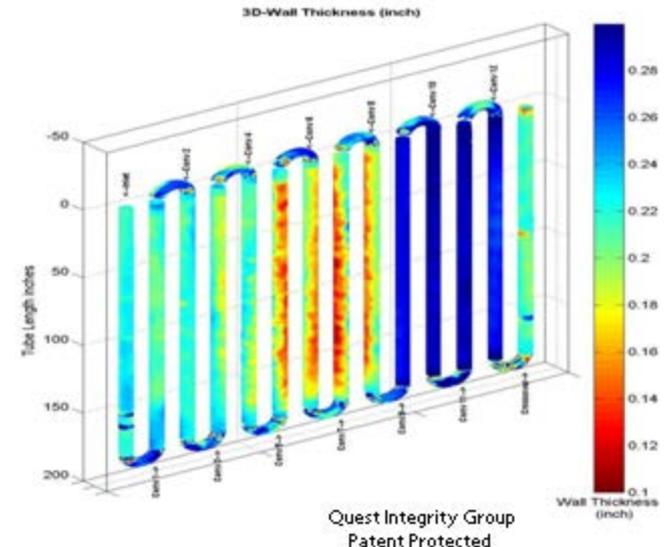
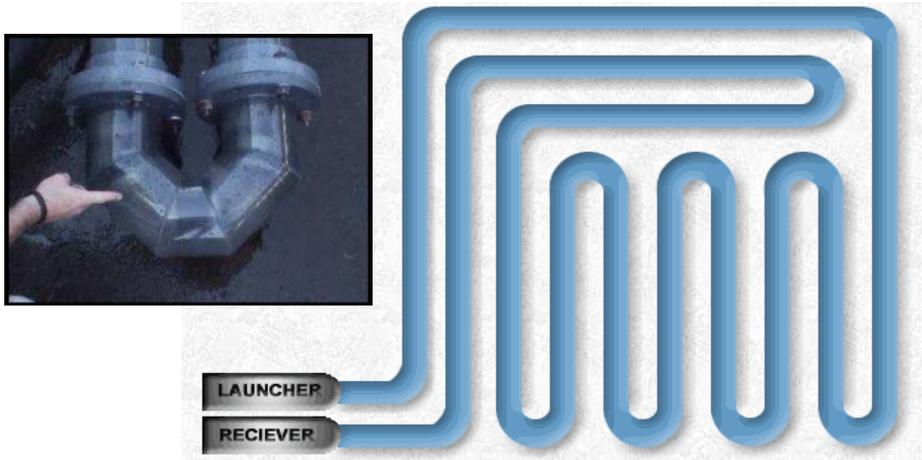
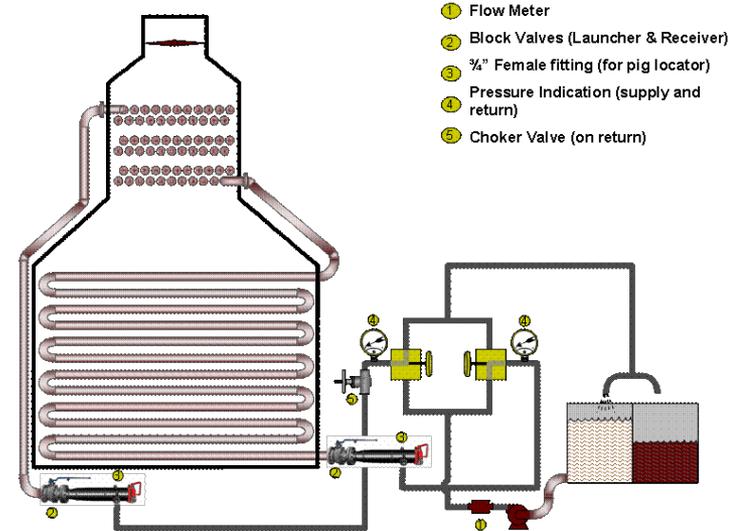
ILI Unpiggable Pipelines

- InVista ILI Technology
 - Leader In *Navigating* Difficult To Inspect Pipelines
 - We're Becoming Recognized as The Go-To Company For Difficult Pipeline Inspections



The Transition of ~~UnPiggable~~ to Difficult to Inspect

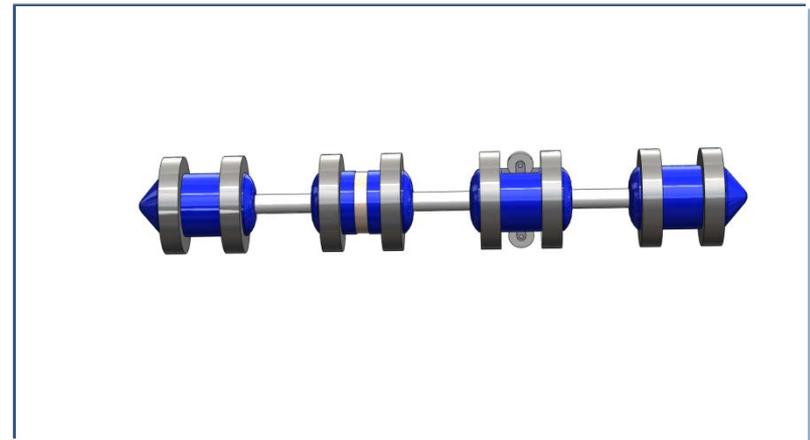
Free Swimming UT Furnace Tube Inspection System – designed to fully navigate short radius - 1D serpentine coils in both radiant and convection sections



Flexible Ultrasonic In-line Inspection

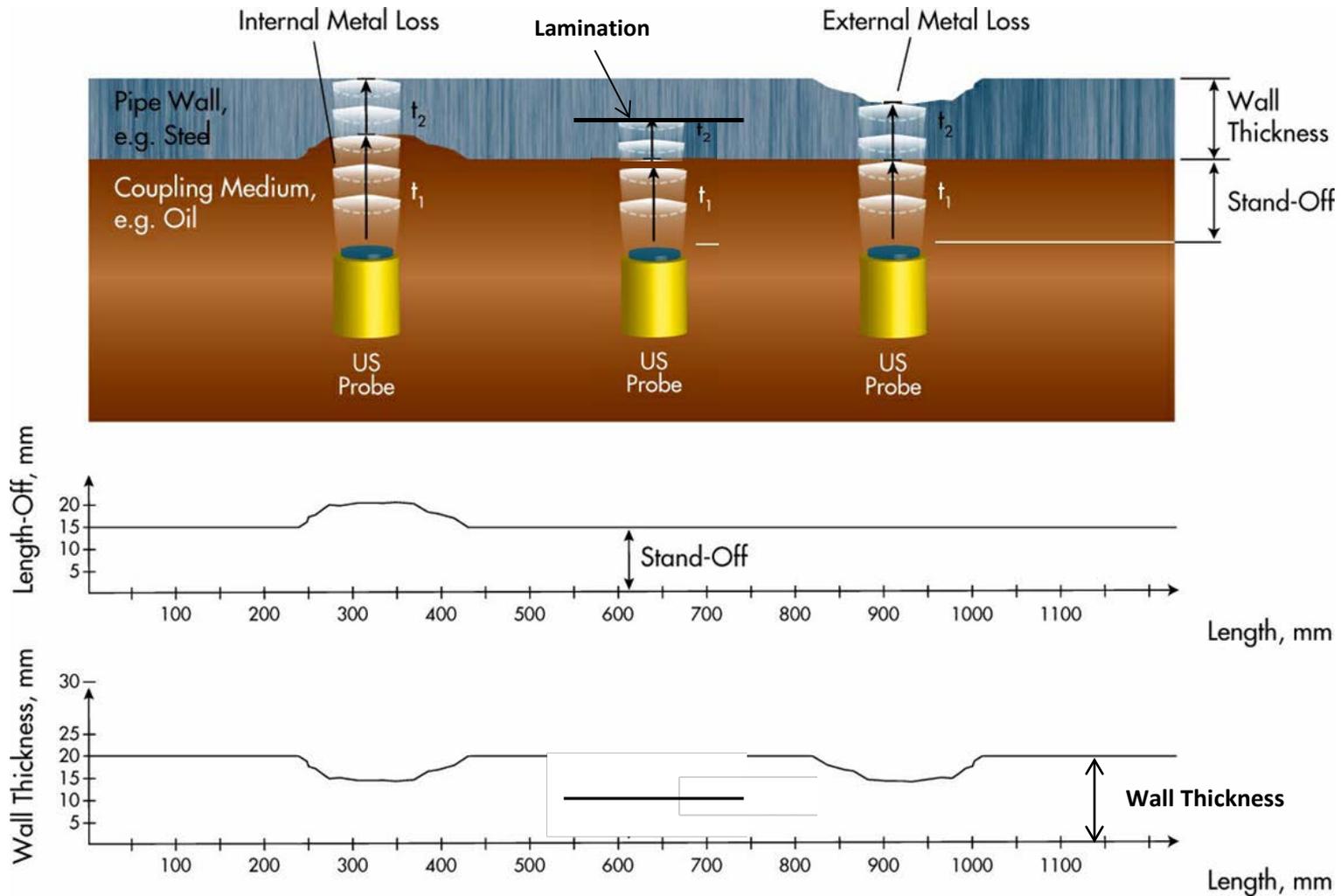


- Ultrasonic inline inspection of unpiggable and difficult pipelines 3" – 24" in diameter
- Combined absolute wall loss and full geometry dimensions in a single pass
- Circumferential, longitudinal and ID/OD location of defects with referencing
- High-density direct measurement ultrasonic technology provides accurate, repeatable results measured to 0.005" precision & 0.030" remaining wall



Immersion Ultrasonic Data Capability

Geometry, Metal Loss, and Lamination



Case Study – Dual-Diameter Lines

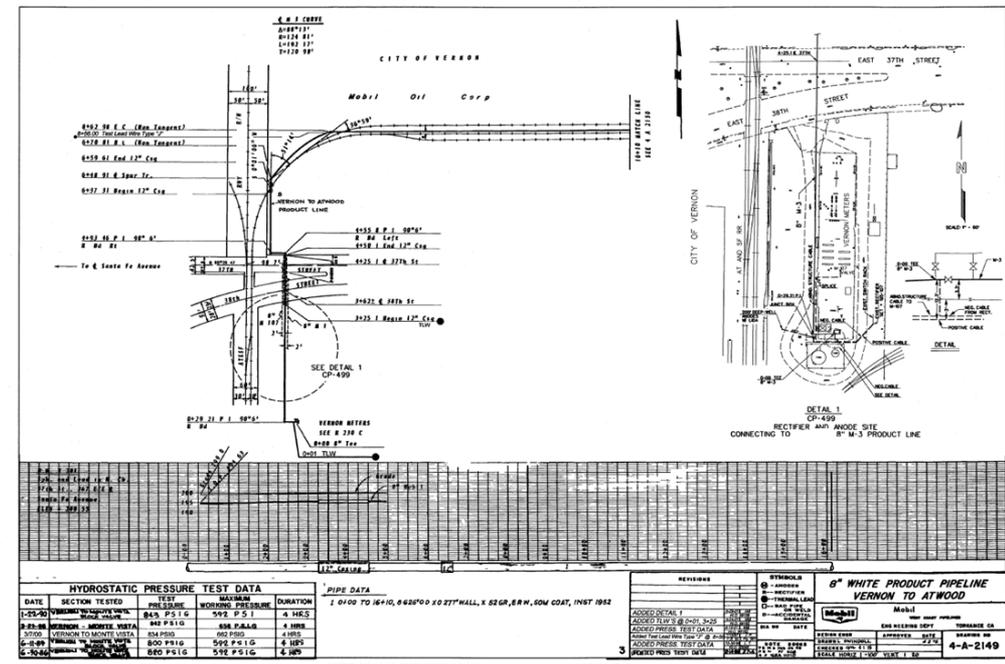


Multiple dual diameter lines have been inspecting in the Los Angeles Greater Metropolitan Area. Ranges span 6”/8”, 8”/10”, 10”/12”

Previous attempts to run MFL failed to navigate all transitions either from SR bends or cup wear.

Low-drag dual-diameter UT tool was able to both navigate and collect complete data.

InVista™ is Successful



HYDROSTATIC PRESSURE TEST DATA				PIPE DATA	
DATE	SECTION TESTED	TEST PRESSURE	WELDER	THICKNESS	DURATION
1-25-20	VERNON TO MOUNTAIN VIEW	800 PSIG	592 P.S.I.G.	4.885	1 0100 TO 16110, 6.625"OD X 0.271" WALL, X 82GR, 8R.H., 50M COAT, INST 1882
8-23-08	VERNON TO MOUNTAIN VIEW	800 PSIG	592 P.S.I.G.	4.885	
6-10-07	VERNON TO MOUNTAIN VIEW	800 PSIG	592 P.S.I.G.	4.885	
6-10-04	VERNON TO MOUNTAIN VIEW	800 PSIG	592 P.S.I.G.	4.885	

REVISIONS		SYMBOLS	
NO.	DATE	DESCRIPTION	BY
1		ISSUED FOR CONSTRUCTION	
2		ISSUED FOR CONSTRUCTION	

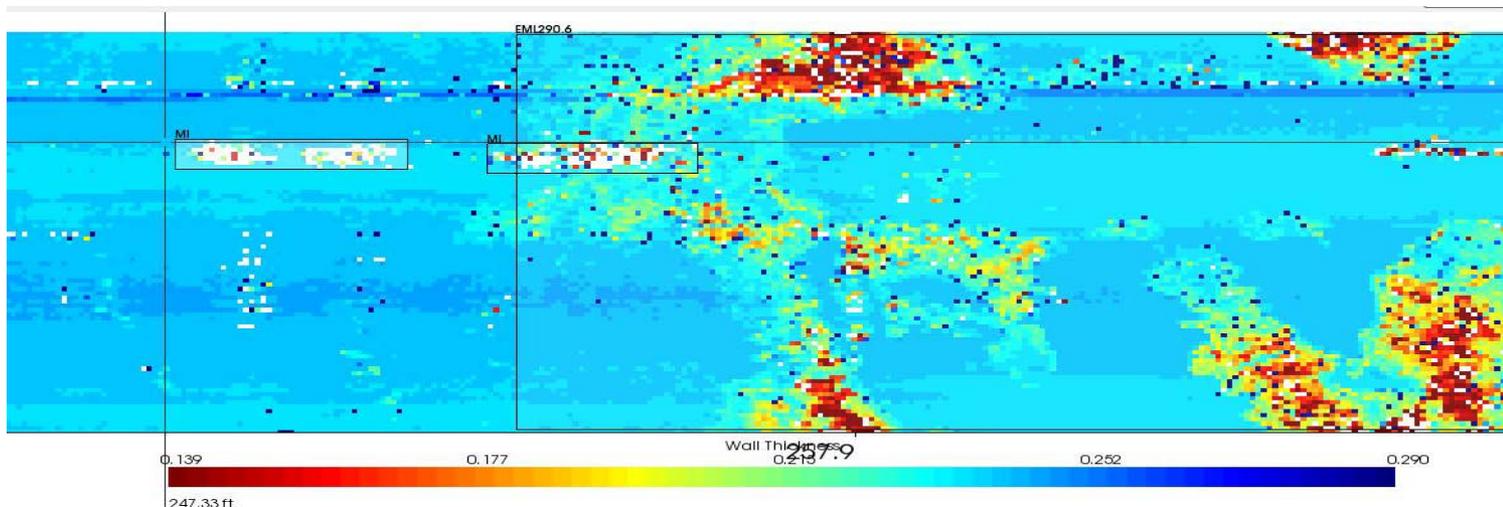
PROJECT	CLIENT	DATE	SCALE
8" WHITE PRODUCT PIPELINE VERNON TO ATWOOD	Mobil	1/11/20	AS SHOWN

NOTE: THIS IS A C.A.D. PRODUCED DRAWING DO NOT MAKE ANY MANUAL CHANGES TO ORIGINAL

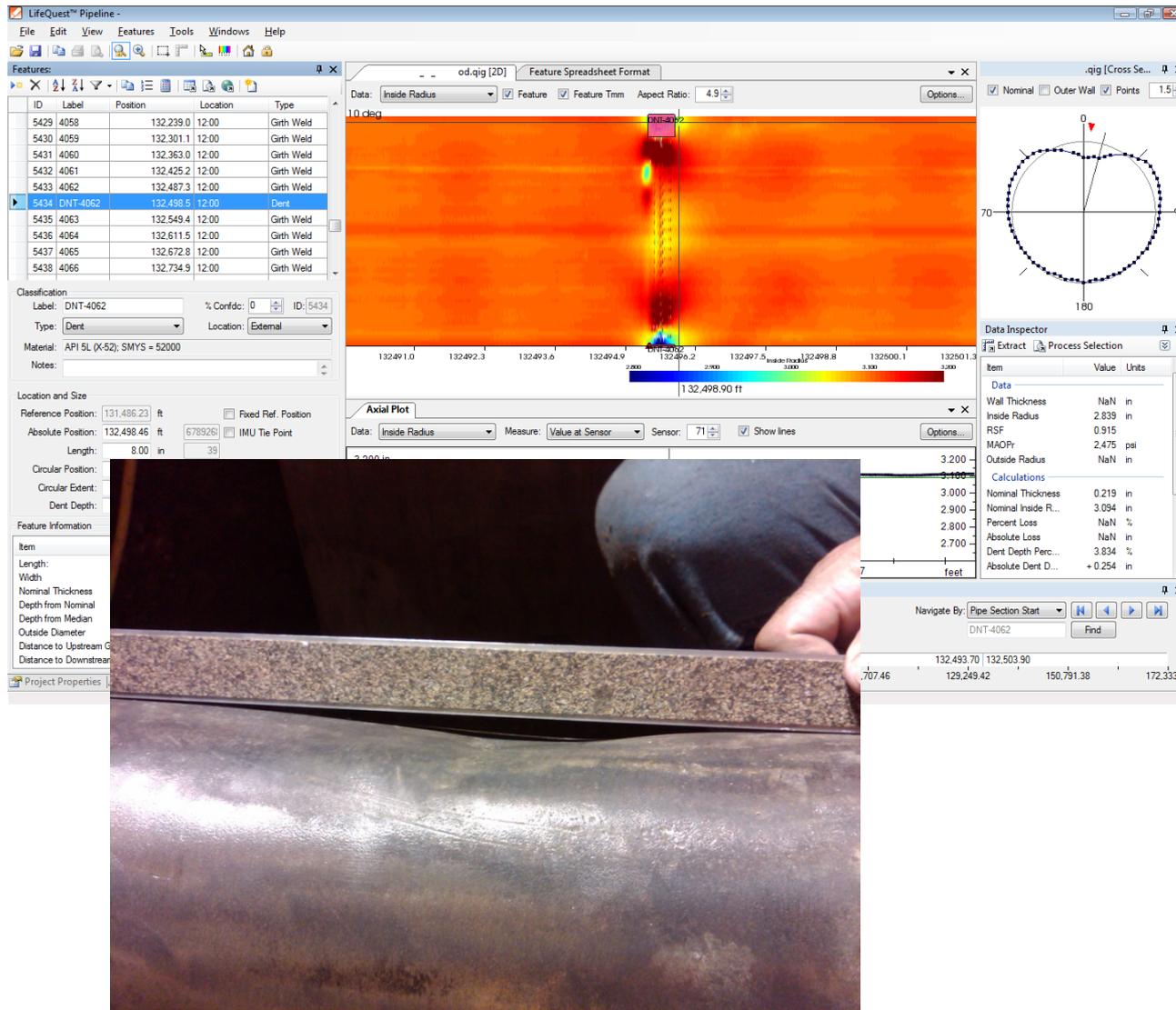
Dual-Diameter Case Study

Localized Internal Corrosion

- Crude pipeline with multiple locations of internal metal loss in an 8"/10" dual diameter line
- Note the excellent data quality despite localized fouling remaining following the cleaning program.



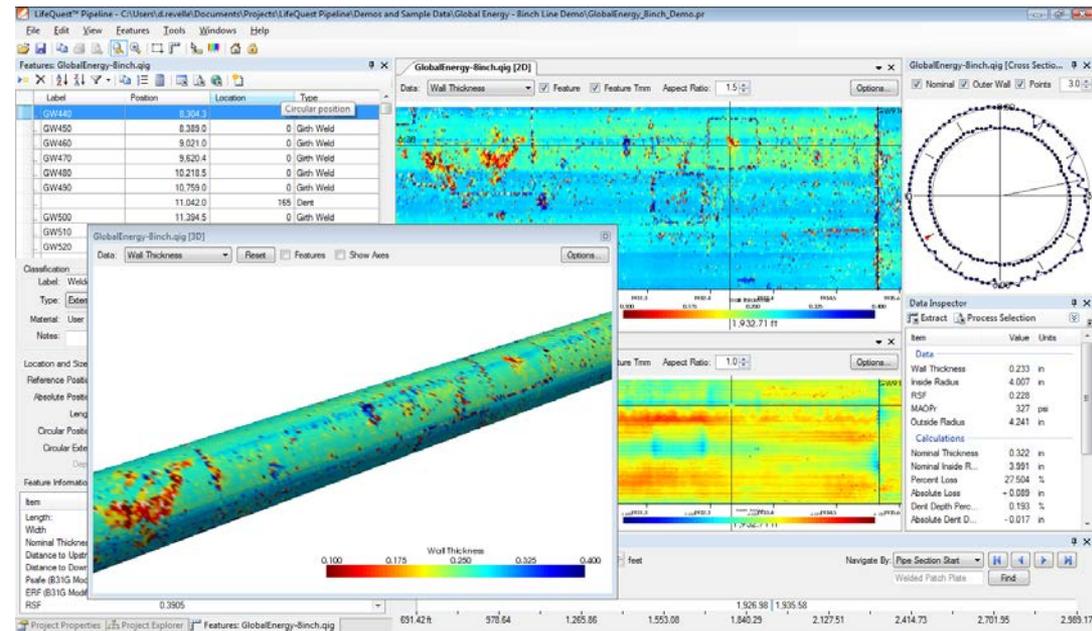
Dual-Diameter Case Study Greater than 6% Topside Dent



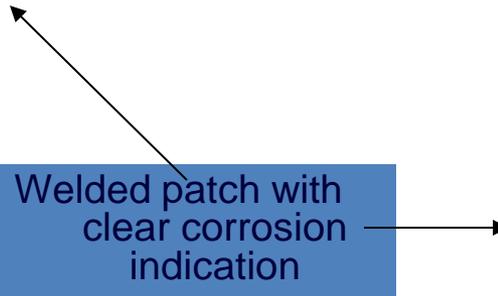
- Quest collected analyzed and performed a full Fitness-For-Service Assessment on nearly 9 GB of data
- Customized reporting to fit client requirements including piping station locations
- Critical defects such as this 6% topside dent were found that would not have been detectable by a hydrotest and could have led to a costly in-service failure

Dual-Diameter Case Study: Large Scale Wall Loss

- Extensive external corrosion found ($T_{mm} < 0.085$ inches Over 80% wall loss)
- Large scale wall loss at a location in the pipeline that was not readily accessible.
- High consequence area if there had been a leak.
- High resolution UT measurement provides a clear picture of previous repairs (patch plates).



Welded Patch with Corrosion

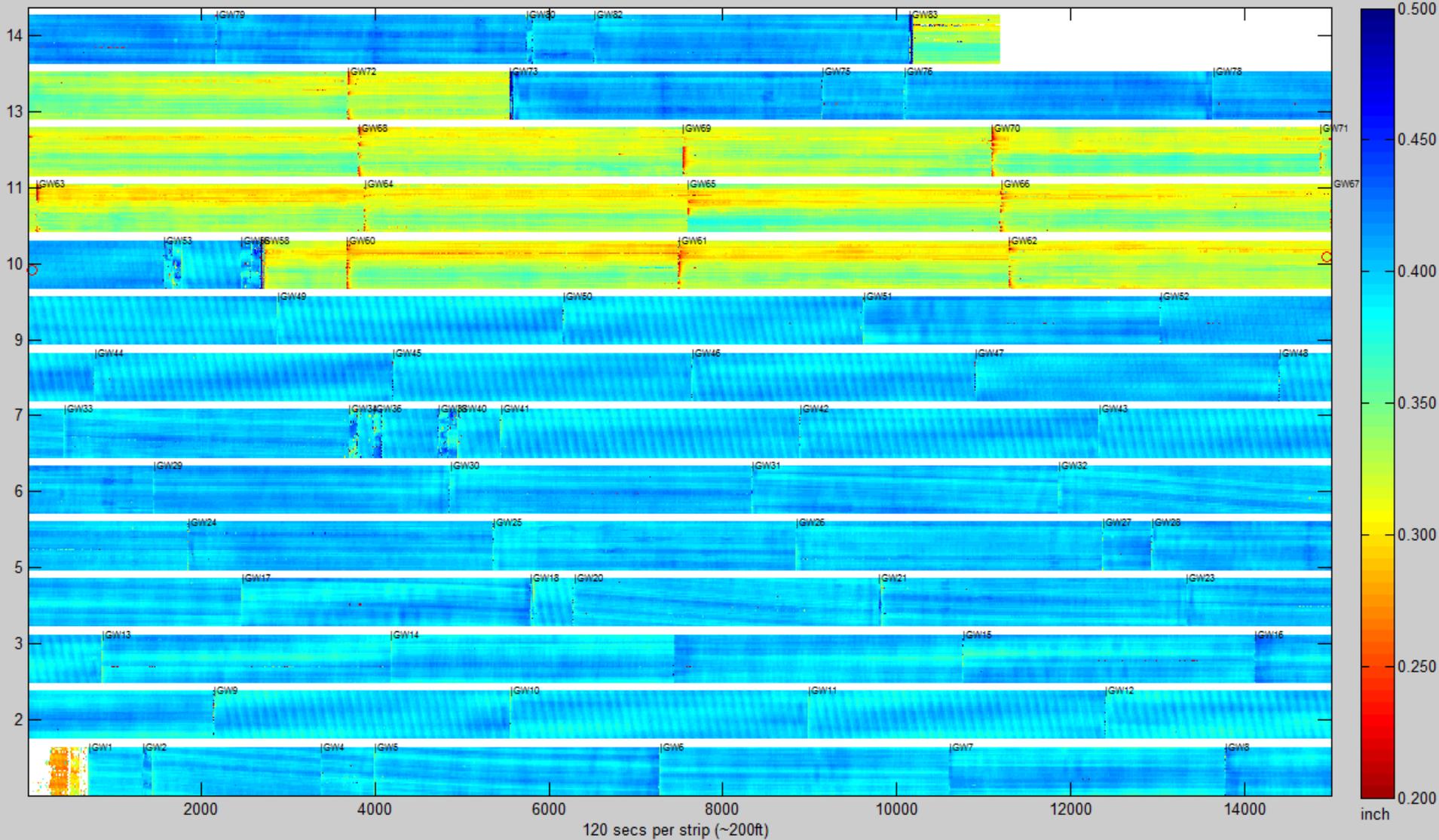


Case Study - Sulfuric Acid Pipeline

- Refiner operated a 6” Diameter Sulfuric Acid Pipeline which had failed.
- Plant hired Quest to see if the pipeline was salvageable.
- The pipeline contained multiple repairs which had occurred over its lifetime.
- InVista™ inspection detected and quantified severe areas of erosion damage on the downstream side of several circumferential welds.
- Inspection results provided justification for refiner to building a new replacement pipeline.
- Customer then hired Quest to inspect the new acid pipeline, both as a baseline to accurately monitor future damage and to ensure proper Q/C on root weld penetration

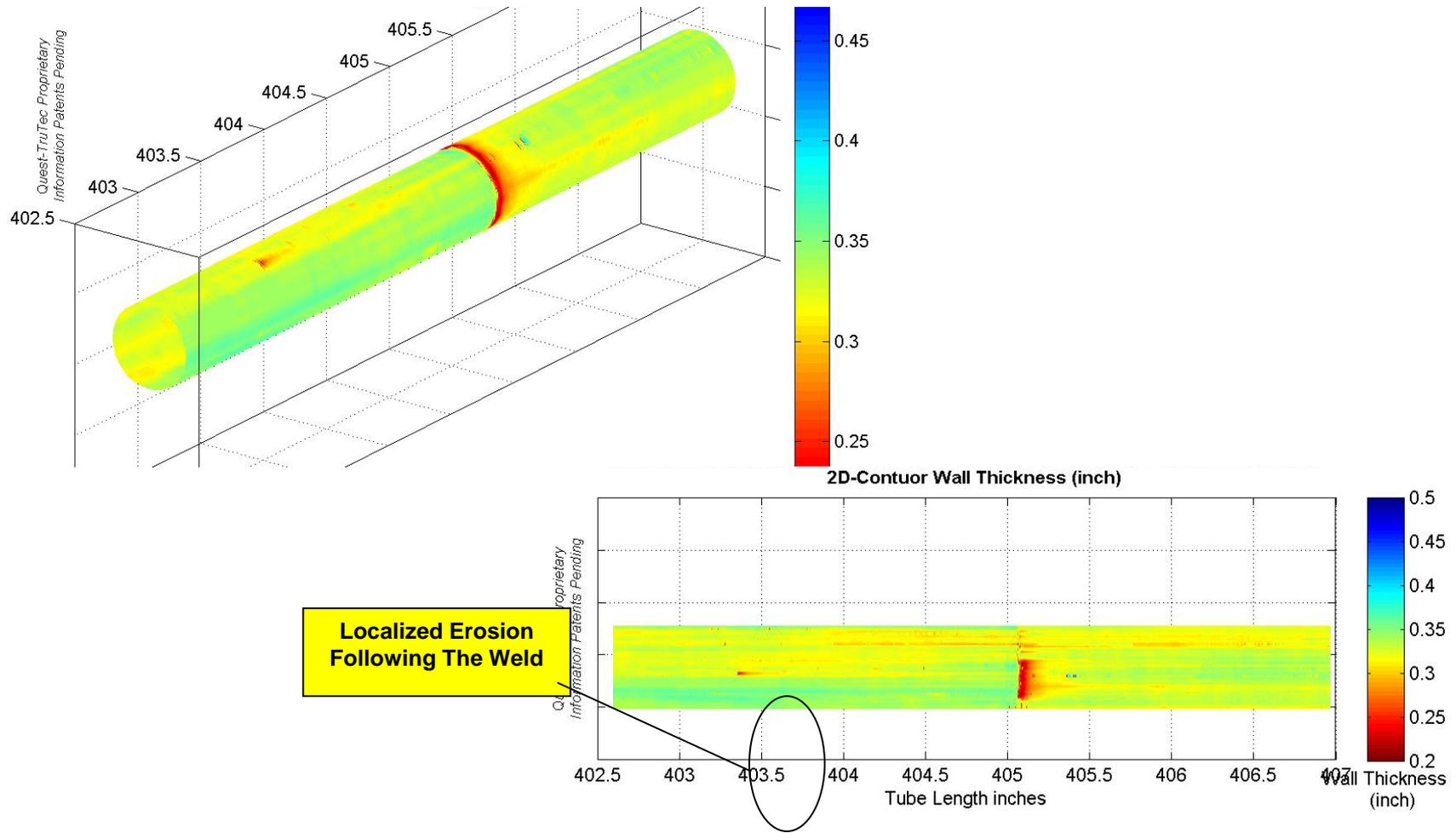
Case Study - Sulfuric Acid Pipeline

Wall Thickness Data
generated with QUEST proprietary technology (patents pending)



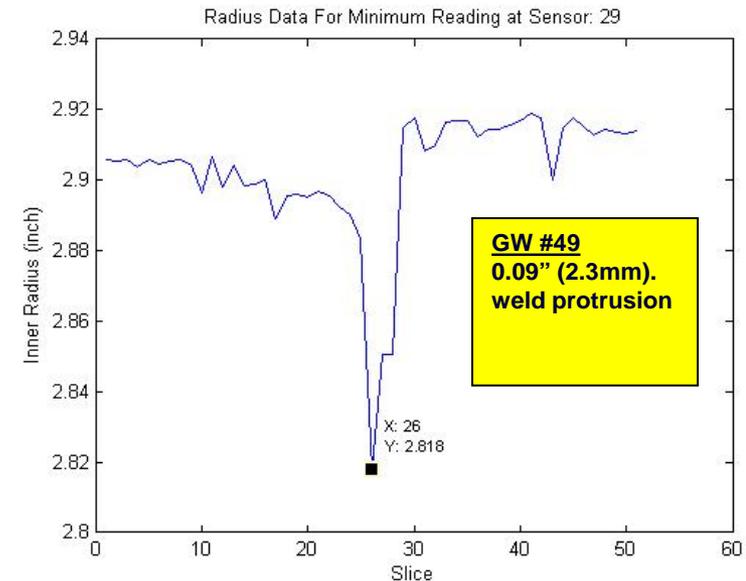
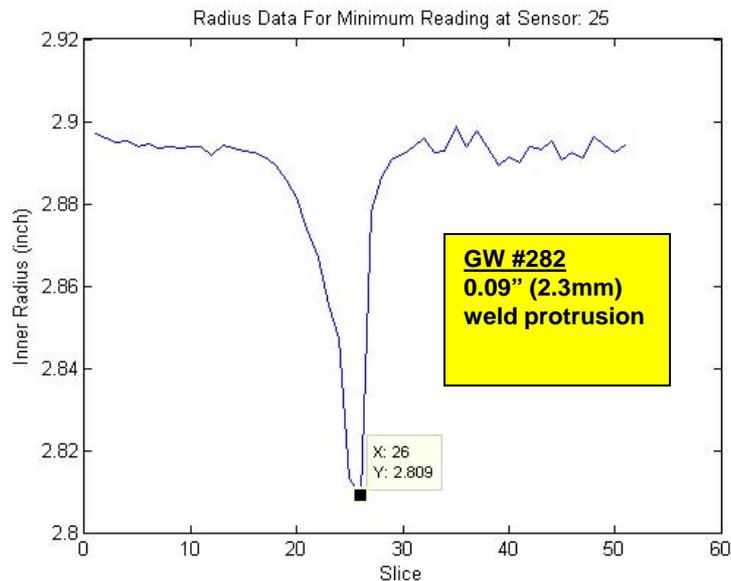
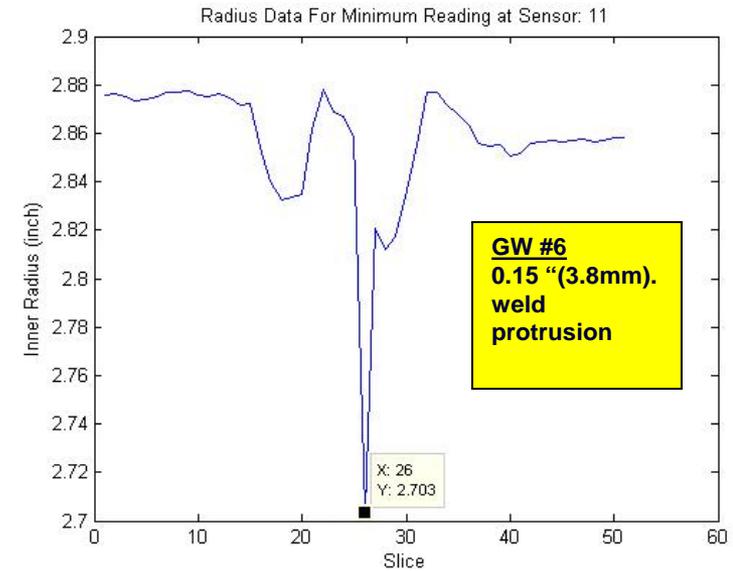
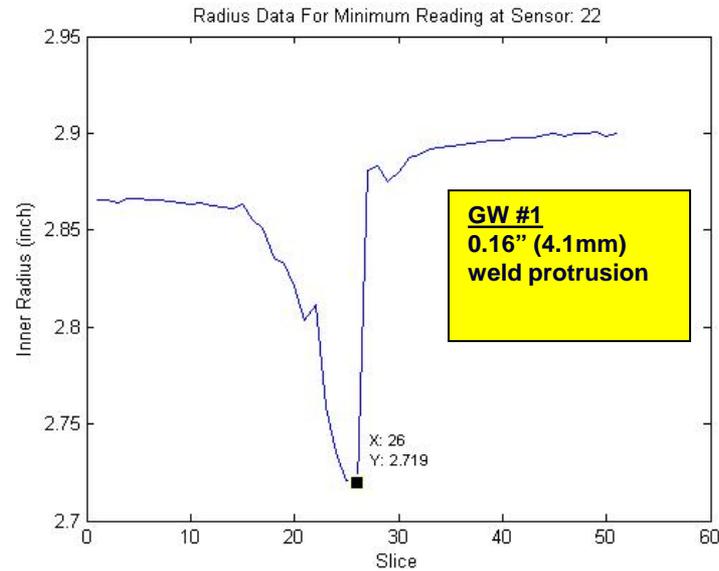
Case Study - Sulfuric Acid Pipeline

Erosion Damage after Excessive Weld Penetration



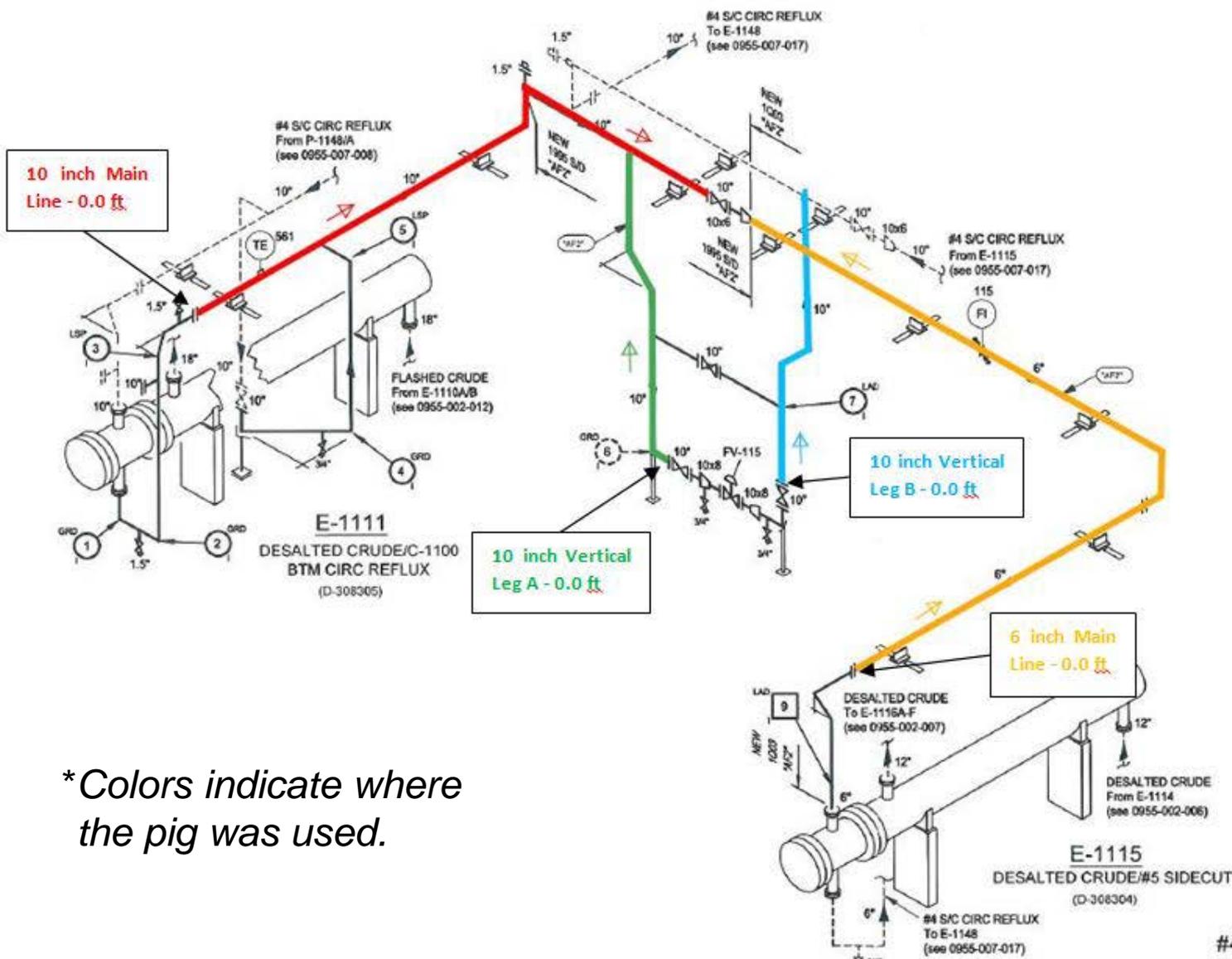
Damage was found downstream of the welds which was a big surprise to the client.

Special Weld Penetration Analysis

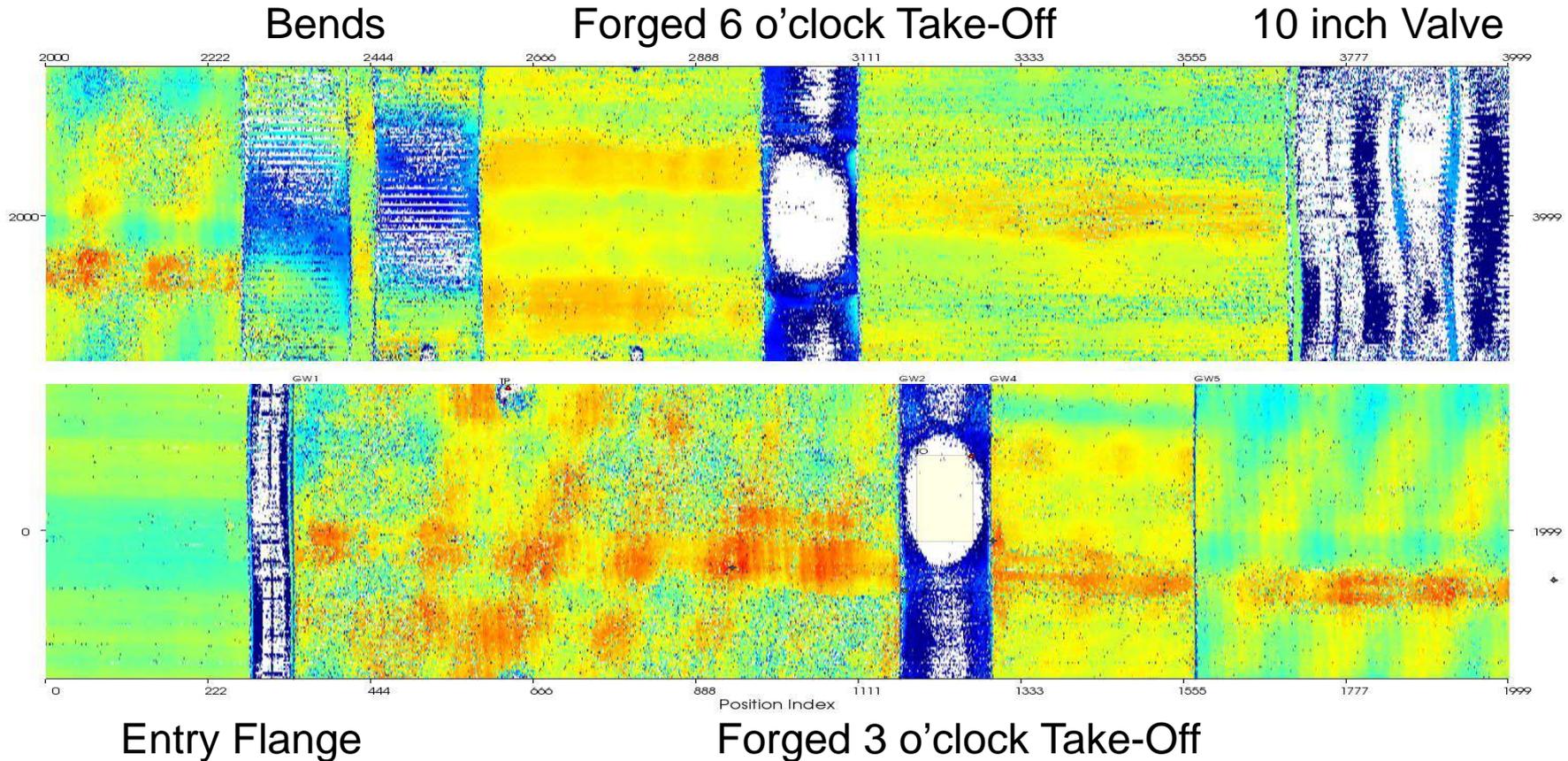


Case Study

High Temperature Sulfidation



*Colors indicate where the pig was used.



The plots illustrate the pipe in a 2-Dimensional (2D) plot, as if the pipe is cut down the axial length and rolled out flat so that all 360-degrees of the pipe can be viewed from one (1) image. The pipe is presented in continuous rows in order to maximize the axial pipe length per page. The color coding corresponds to the associated thickness (red = thinnest pipe).

Push Behind the Project:

- Operator required to hydrostatic test all lines with missing records
- Locating small leaks on lines that fail said tests is prohibitively expensive
- Lines have never been pigged before
- ILI would provide areas of immediate concern for pressure test as well as a full picture of the integrity of the line

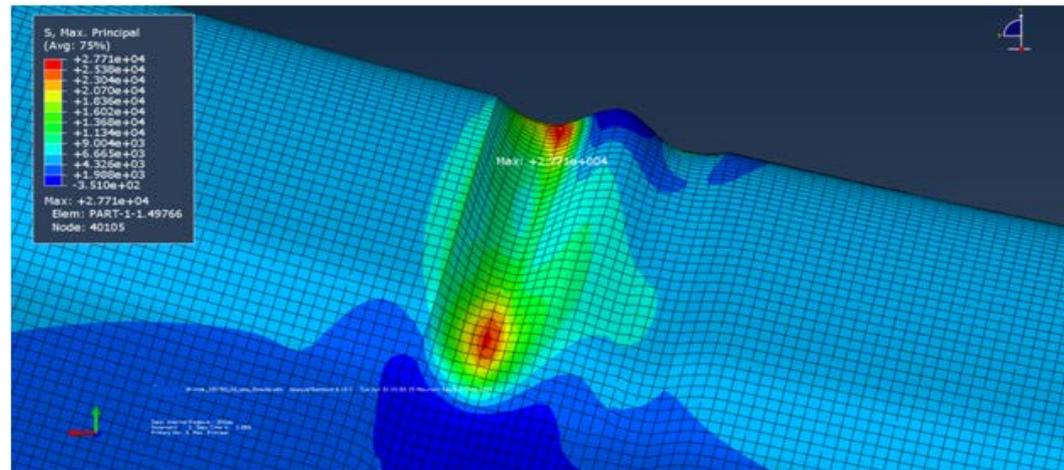


Program Targets

48-hour data turnaround for immediate calls prior to hydrostatic test including GPS coordinates of anomalies.

Pilot project used to demonstrate potential to use InVista as part of hydrostatic test program in 2014

Found anomalies requiring immediate remediation, that would not have been detected by the hydrostatic test alone.

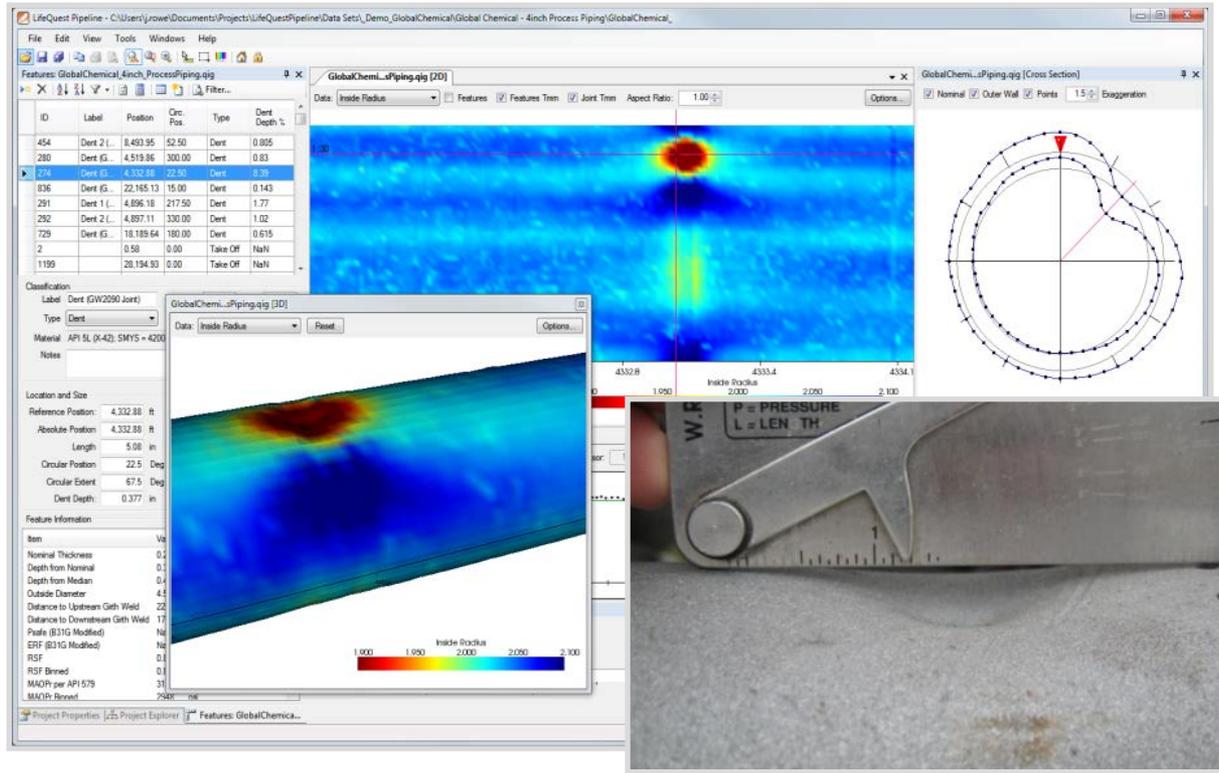


Expanded 2014 Program

- Program tripled in size with only one week's notice for two of the projects
- Six of the lines were completed in two weeks alone; each with a 48hr deliverable
- Multiple anomalies have been identified and repaired prior to hydro (Dents, Buried flanges, External/Internal Wall loss, etc.)
- Truly difficult to inspect lines with SR bends, multiple diameters and Miters

Segment Name	Diameter (in.)	Length (mi.)	Wall Thickness (in.)	Pipe Specification
Line 1	6"/8"	8.42	Unknown	Not Provided
Line 2	12"	2.41	Unknown	Not Provided
Line 3	6"/8"	4.84	Unknown	Not Provided
Line 4	10"	1.14	Unknown	Not Provided
Line 5	3"/4"	4.22	Unknown	Not Provided
Line 6	16"	3.05	Unknown	Not Provided
Line 7	12"	1.38	Unknown	Not Provided
Line 8	12"	0.28	Unknown	Not Provided
Line 9	10"	2.9	Unknown	Not Provided
Line 10 Test A	8"	0.85	Unknown	Not Provided
Line 10 Test B	12"	0.50	Unknown	Not Provided
Line 11	6"/8"	3.75	Unknown	Not Provided
Line 12	12"	1.68	Unknown	Not Provided
Line 13 Test A	12"	1.59	Unknown	Not Provided
Line 13 Test B	12"	2.10	Unknown	Not Provided

Dents



Dent Assessment.

New software tools allow for rapid engineering assessment of the severity of the dents. Have standing proposals with per dent pricing so engineers can get B31.8S strain assessments on any dent within 24 hours. Complete FEA models can be rapidly generated using geometry data directly imported from the InVista inspection

Case Study – Technology is Bi-Directional

Louisiana , USA

This 4" (100mm) line developed a leak and regulators mandate that the line be taken out of service and inspected for repair.

Adding to the operator's sense of urgency was the fact the crude was selling around \$130 per barrel.

“We need this pipeline back in service ASAP...”

InVista™ is Successful



Launcher

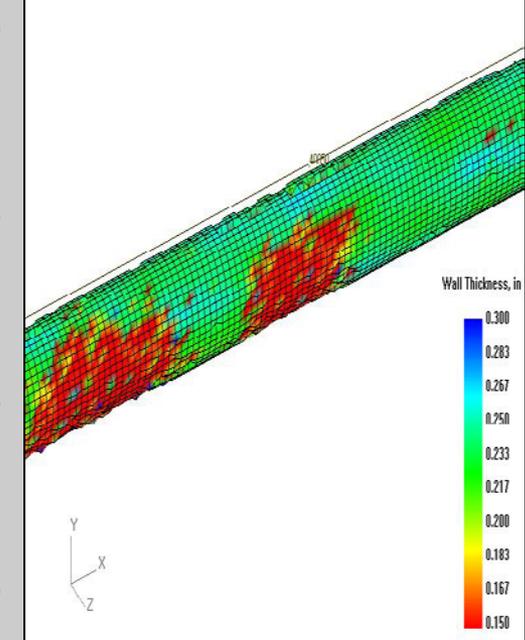
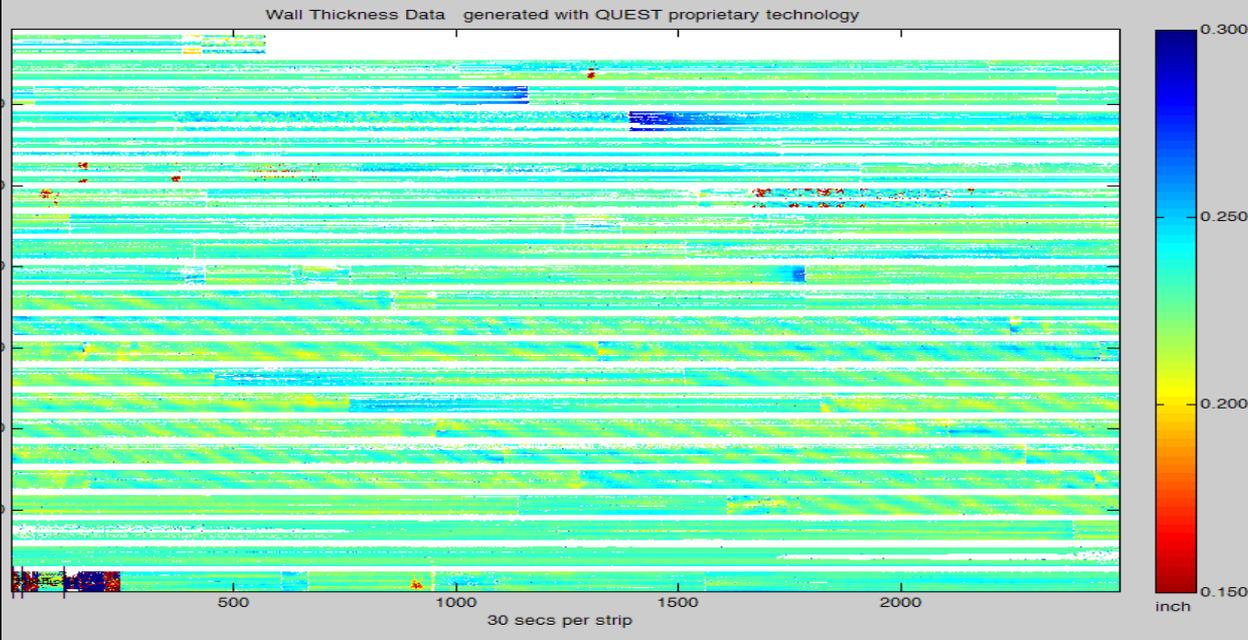
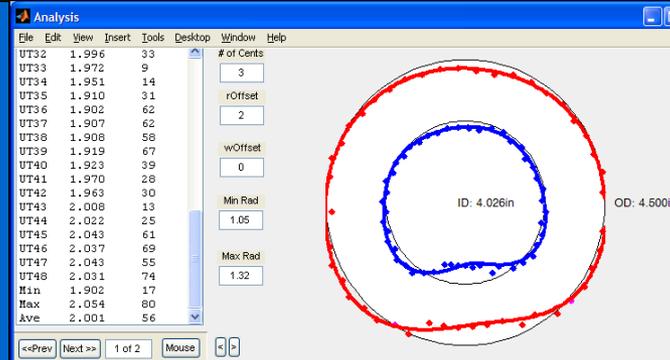
- Minimal working area
- Minimal trap length
- Unbarred 6" x 6" (150mm) tee at 6 o'clock

Receiver

- Minimal nominal pipe after valve
- Minimal trap length
- Line was not properly cleaned prior to ILI

Case Study – Bi-Directional Results

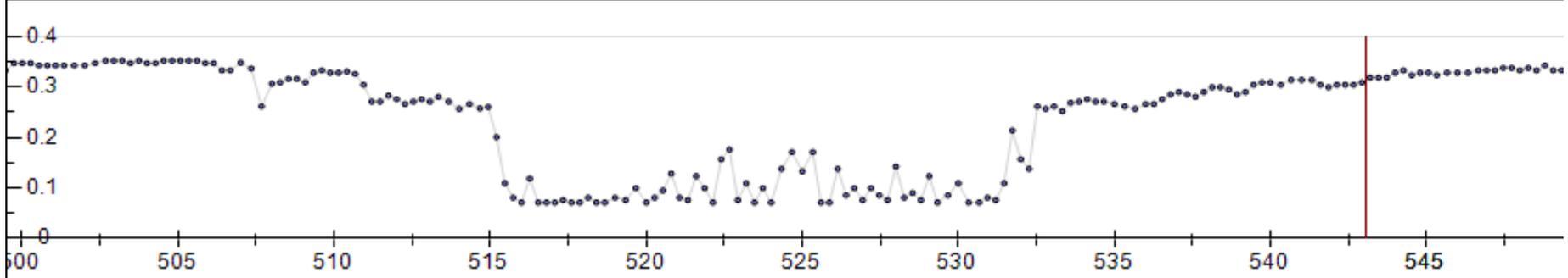
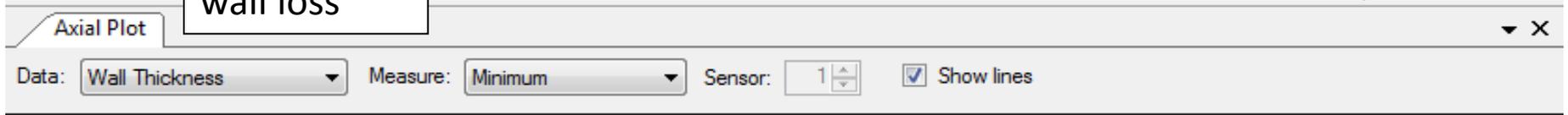
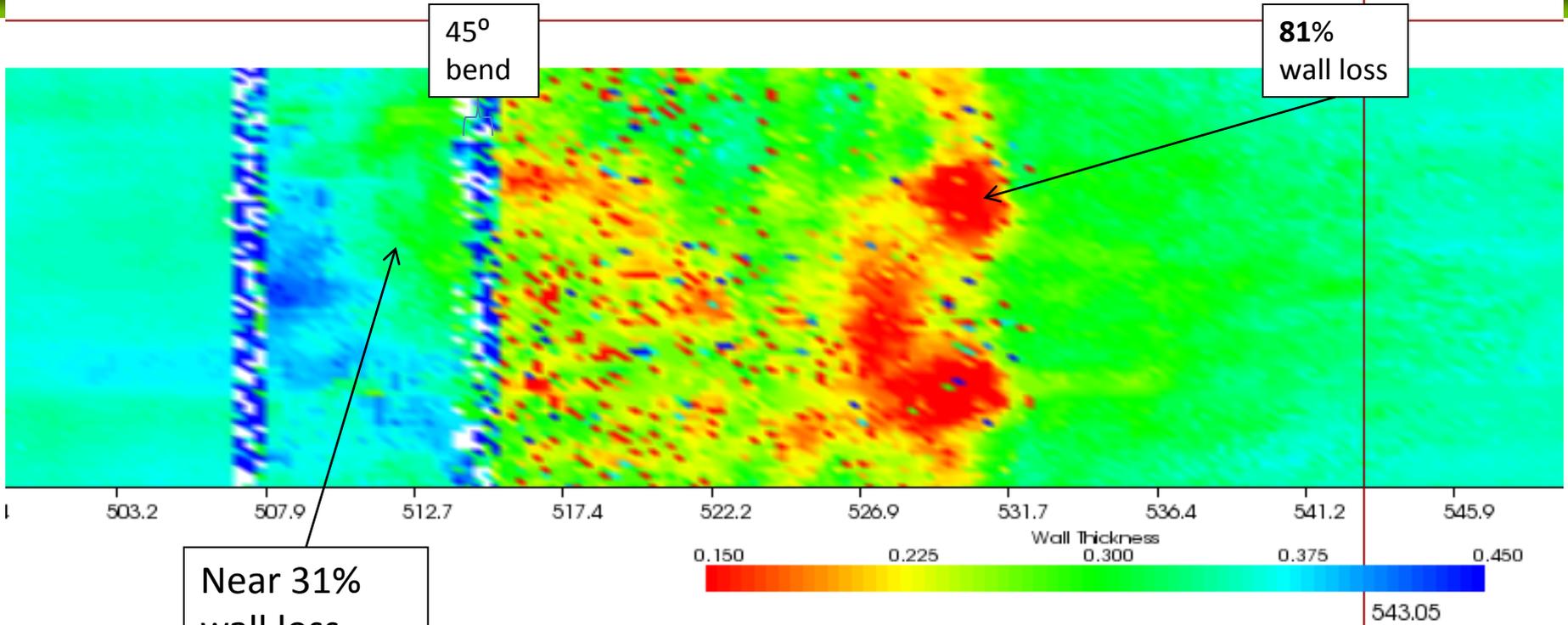
- 7 major corrosion and pitting flaws detected
- Client verified each flaw with alternate manual NDT method (i.e. pit gauge and/or manual ultrasonic scope)
- Repairs were made to all areas based upon InVista™ inspection results



Benefits of InVista™ tool:

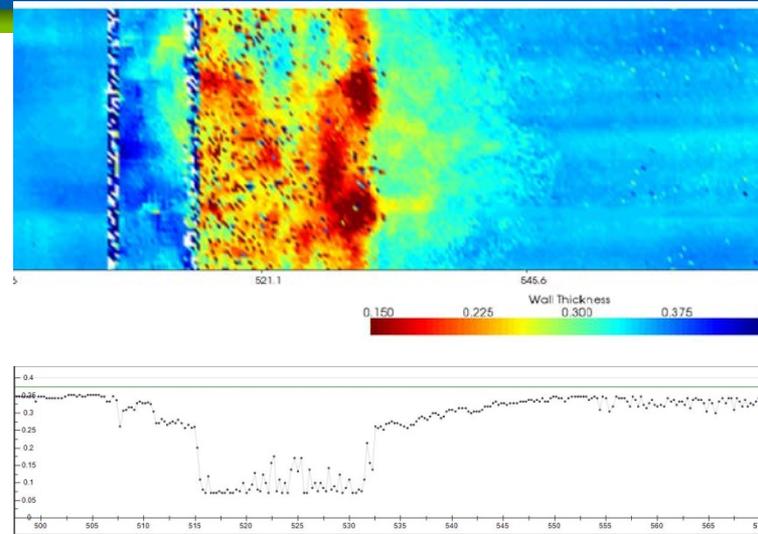
- Quest Integrity was able to deliver the inspection results in one day
- Bi-directional tool was able to collect 100% of the data even though the line was not clean

Case Study - Corrosion under insulation:



Case Study: External Wall Thinning

- 81.1% Wall Loss
- RSF = 0.278
- MAOPr = 986 psi
- Pipe section replaced following inspection.

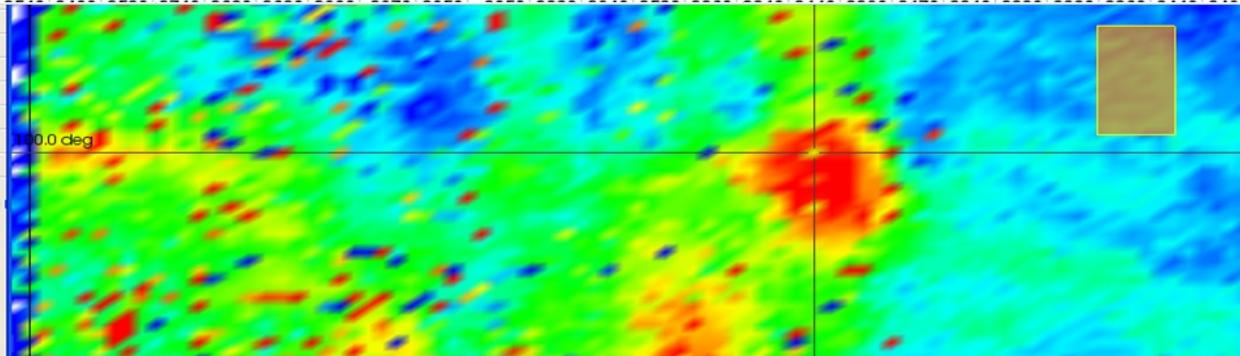


External Corrosion
Area

Case Study: Prove-Up Results

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X
210	230	280	280	310	330	310	300	330	310	300	320	300	270	240	210	240	300	320	310	320	330	320	340
250	250	250	280	300	310	300	300	350	290	280	310	310	280	290	210	250	320	320	320	310	320	320	330
190	250	220	260	260	240	310	330	330	300	290	300	290	270	280	210	250	330	320	320	320	320	290	310
160	140	170	200	230	250	300	310	330	280	290	310	310	230	190	140	160	300	300	310	310	310	310	300
190	140	180	200	200	210	250	310	310	250	270	260	260	220	160	110	120	300	300	300	300	320	310	330
230	210	210	230	190	200	240	290	280	270	270	260	200	220	180	120	120	200	290	320	310	310	310	320
250	230	240	240	240	190	250	260	270	280	250	210	210	210	180	150	250	300	290	320	310	320	320	340
280	260	260	260	230	250	240	280	250	280	250	250	190	180	200	220	220	270	280	280	280	270	330	320
280	260	240	260	250	230	230	240	220	270	240	230	160	170	170	230	250	300	300	300	290	280	300	300
220	220	220	250	230	230	230	180	200	260	230	230	160	160	190	230	240	290	280	270	300	300	310	300
250	210	260	250	240	240	240	170	180	260	210	230	140	150	200	250	290	310	300	310	320	290	290	300

Manual UT Results



InVista UT Results



Manual Inspection Grid



High-Fidelity Ultrasonic ILI Survey

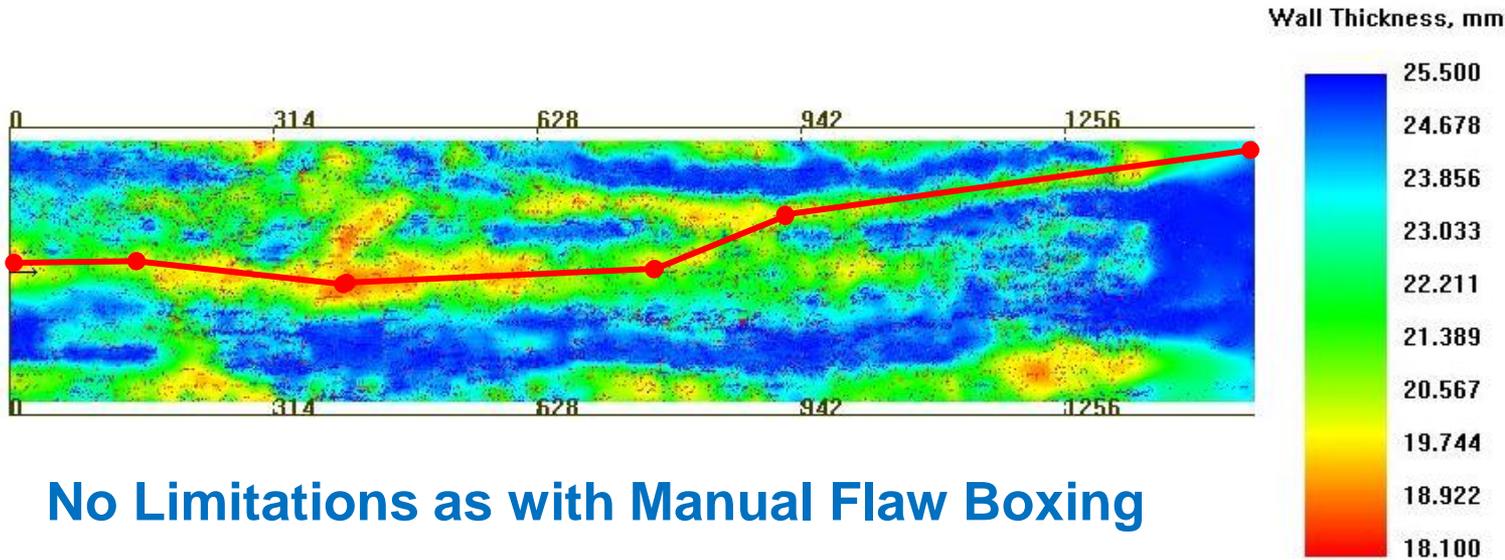
- Onsite technician certified NDT L II or greater.
- Report immediate conditions as defined by you and provided within 7 days standard, customized final report provided with approximately 30 days standard.

Fitness-for-Service Engineering Assessment

- Provides remaining strength and maximum allowable operating pressure (MAOPr) for entire length of pipe vs. limited locations only.
- Follows API 579-1/ASME FFS-1 local thinning assessment methodology (accepted Level 2 methodology in ASME B31G-2009).

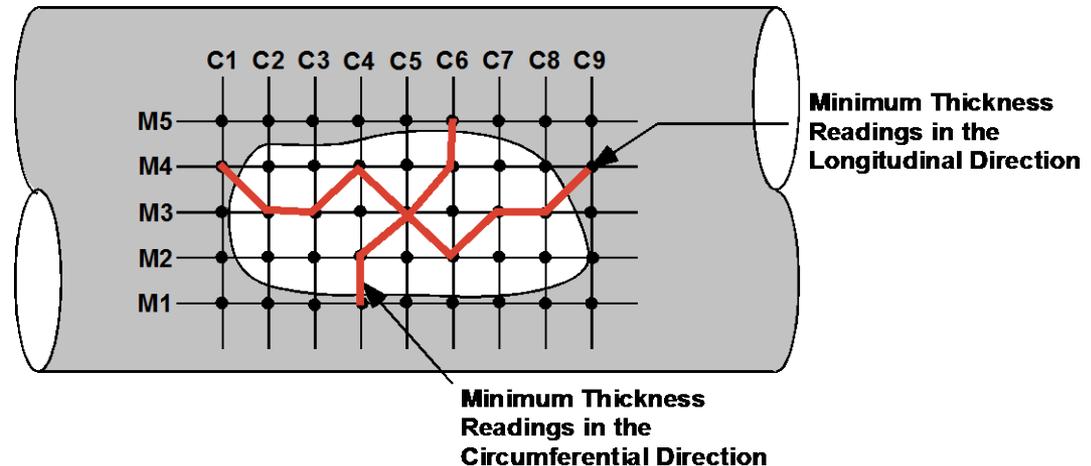
LifeQuest™ Visualization and Analysis Software

- High resolution 2D and 3D views of wall-thickness and inner profile for 100% of your data.
- Fully synchronized data display windows for rapid examination of your inspection results.
- Client configurable feature table compatible with GIS systems and exportable to Microsoft Excel®.



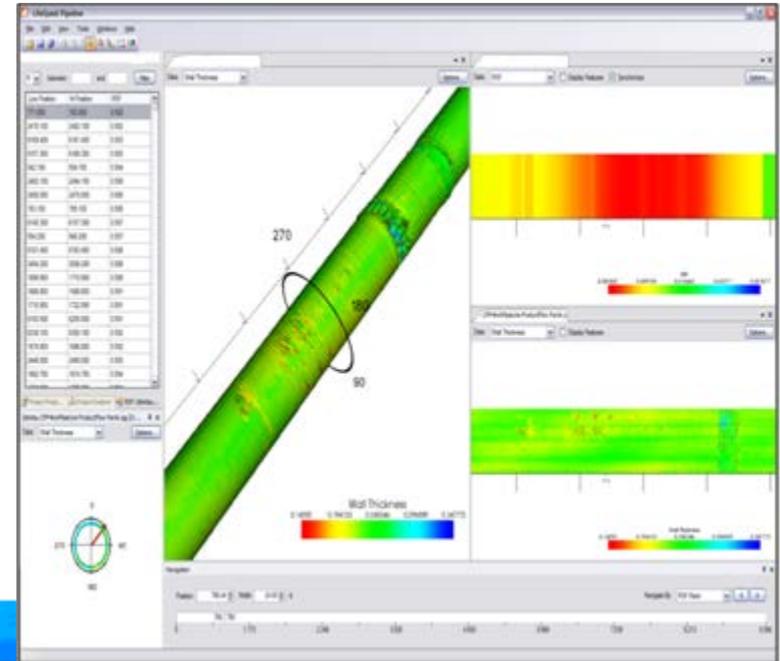
No Limitations as with Manual Flaw Boxing

- Obtain thickness data from inline inspection
- Compute RSF at short segments
- Rank corrosion damage over various segments

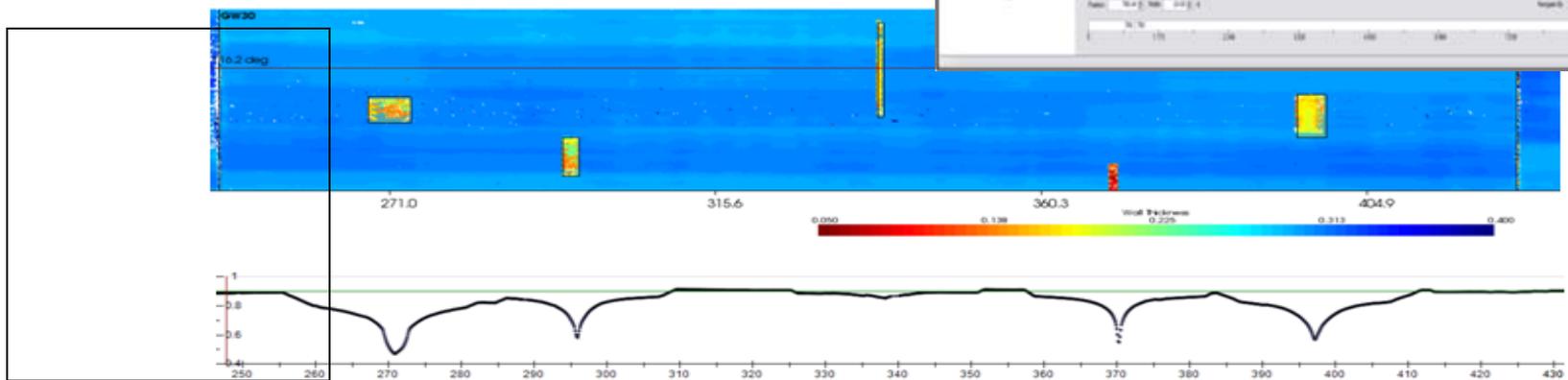


Converts ILI data sets into synchronized 2D and 3D views

- Better defect characterization
- Simultaneous visualization of multiple data values
- More accurate defect growth models
- Visualization allows operators to improve mitigation
- Advanced analysis improves Fitness-for-Service assessment

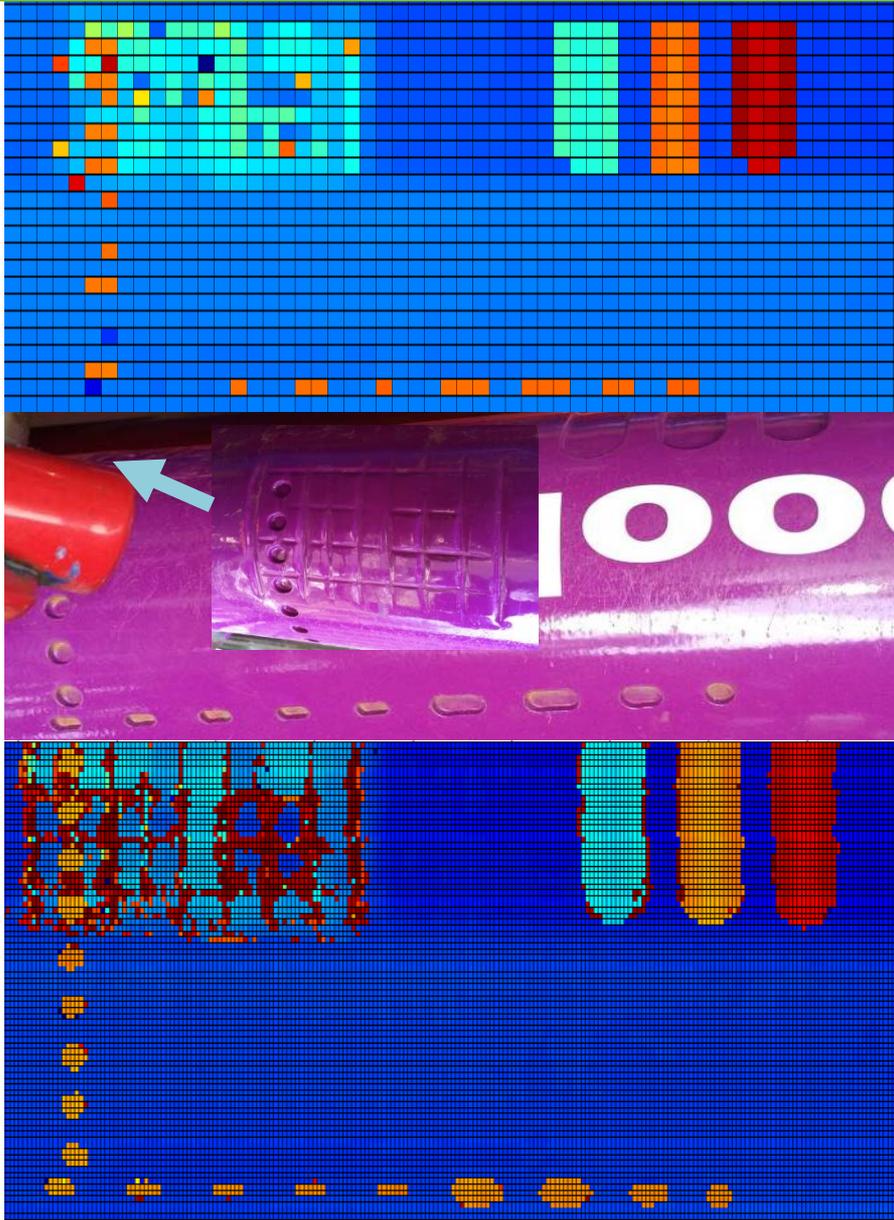


Measured Wall Thickness



Calculated RSF

Breakthrough Developments: October 2014 – 10X



Current technology

- Industry leader in navigation
 - 1D & Back-2-Back Bends
 - Multiple Diameter
 - Un bared Ts
- Top-Tier Resolution – ¼" x ¼" Grid

Spool Piece

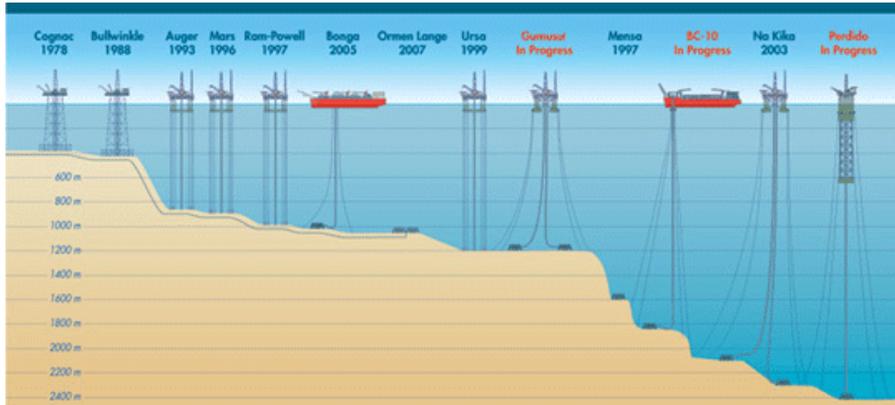
72 Sensors
18,247,680 readings/mile

256 Sensors
194,641,920 readings/mile

10X Development

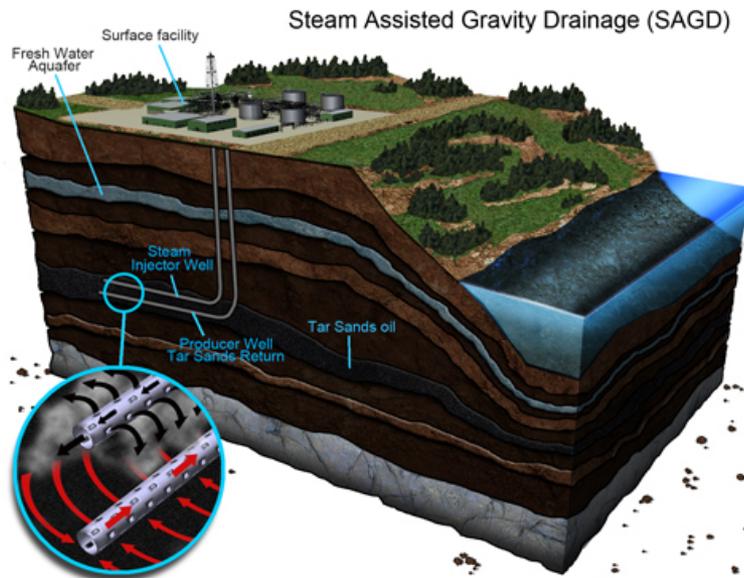
- Industry Leader in navigation (same as above)
- Industry Leader in data resolution
 - Order of Magnitude Improvement in Resolution
 - 1 MP camera → 9 MP camera

Breakthrough Developments: 5000 psi technology & 2" tools



High Pressure Technology – 5000 psi

- Deep Sea Off-Shore Assets
- High Pressure Wells / Water Injection



2" Tool Development

- Steam Generation (HRSG) and SAGD
- Distribution

Conclusion: Hydrogen Sulfide Corrosion in the Petroleum Industry

Cause of corrosion-related failure in petroleum-related industries

Type of failure	Total Failure (%)
CO ₂ related	28
H ₂ S related	18
Preferential weld	18
Pitting	12
Erosion	9
Galvanic	6
Crevice	3
Impingement	3
Stress Corrosion	3

In Summary:

1. InVista™ ultrasonic inline inspection overcomes challenges associated with pipelines that until now have limited the capabilities of conventional pigging systems.
2. LifeQuest™ data delivers more actionable and timely information that is as reliable and regulatory credible when **compared to** today's cumbersome, conventional analytical approach.
3. Quest Integrity Group offers an unmatched global pool of engineering talent, cutting-edge assessment technologies, and a culture of client responsiveness, understanding and **professionalism**.



InVista™ Gives You Options

Thank you for your attention.

Questions or Comments?

Brett Covey

b.covey@QuestIntegrity.com – (405) 822-5257