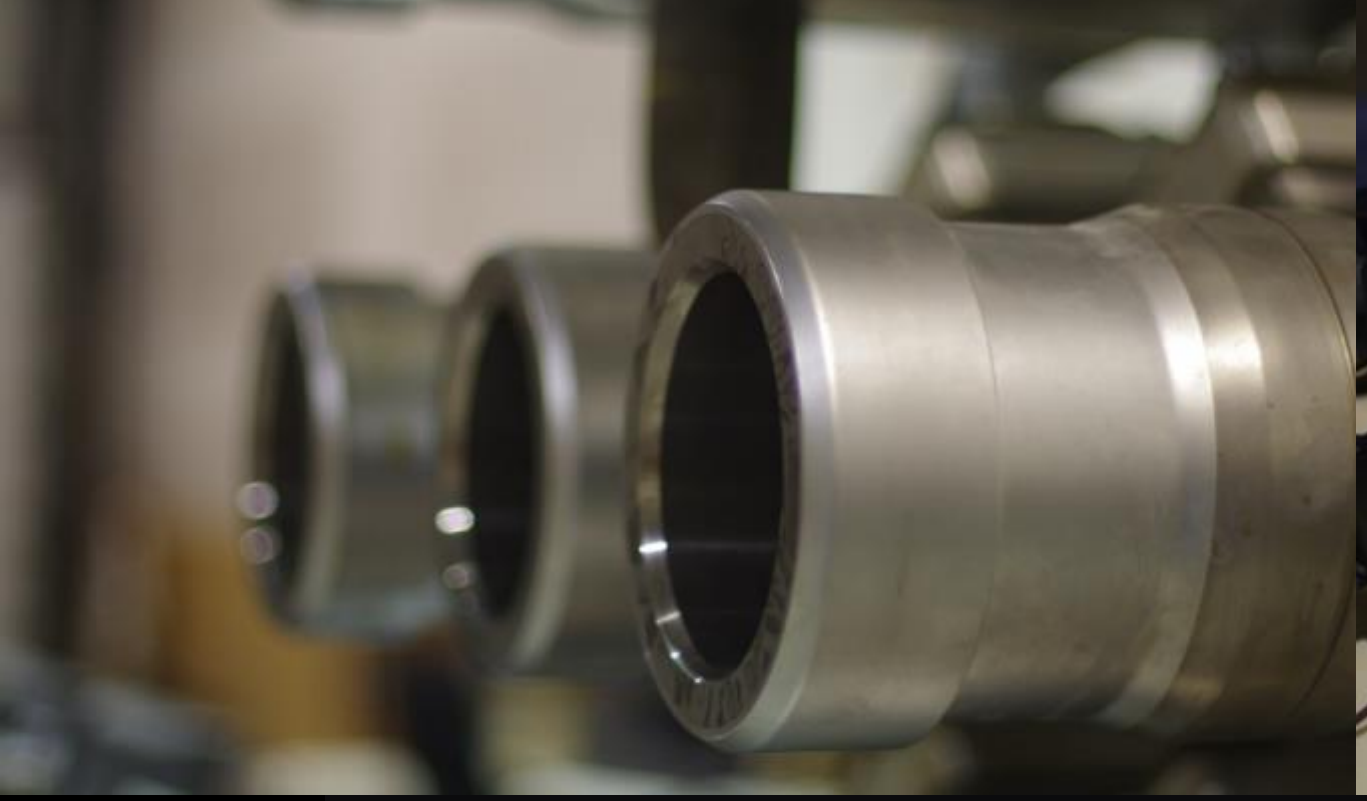

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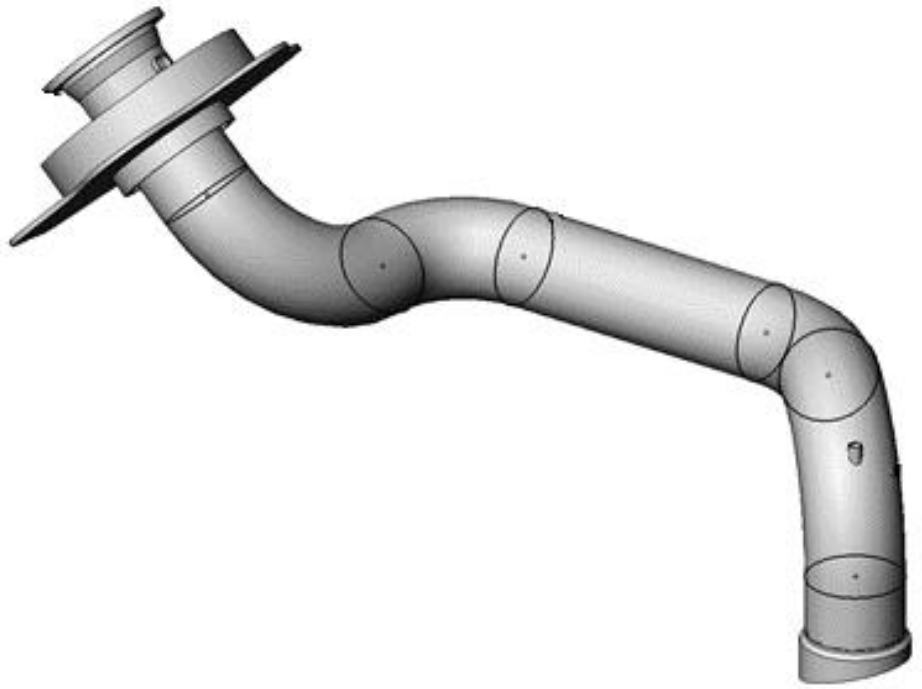
Improved Surface Breaking Flaw Detection and Characterization by Multi-Technique Automated Inspection

Agenda

- **Purpose of the Inspection**
  - Inspection Environment
  - Previous Inspections
    - Manual PAUT
- **NDE Tooling**
  - Delivery System
  - NDE Techniques
- **NDE Development Results**
- **Field Deployment**
- **Conclusion**



Purpose of Inspection

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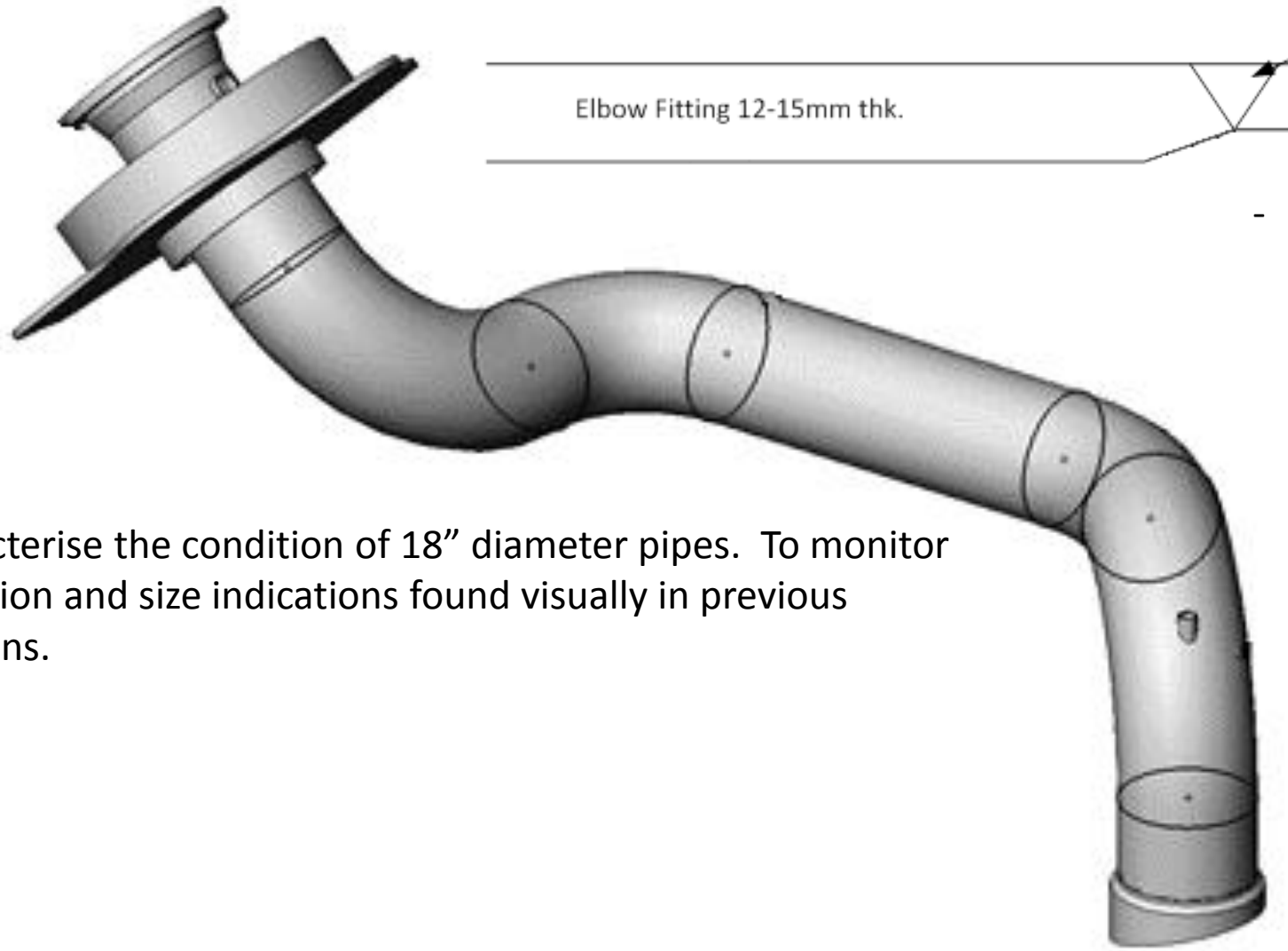
Purpose of the Inspection/Inspection Environment



- **18” diameter 304L SS**
  - Variations in thickness for 9.5mm to 15mm

To characterise the condition of 18” diameter pipes. To monitor degradation and size indications found visually in previous inspections.

Previous Inspections

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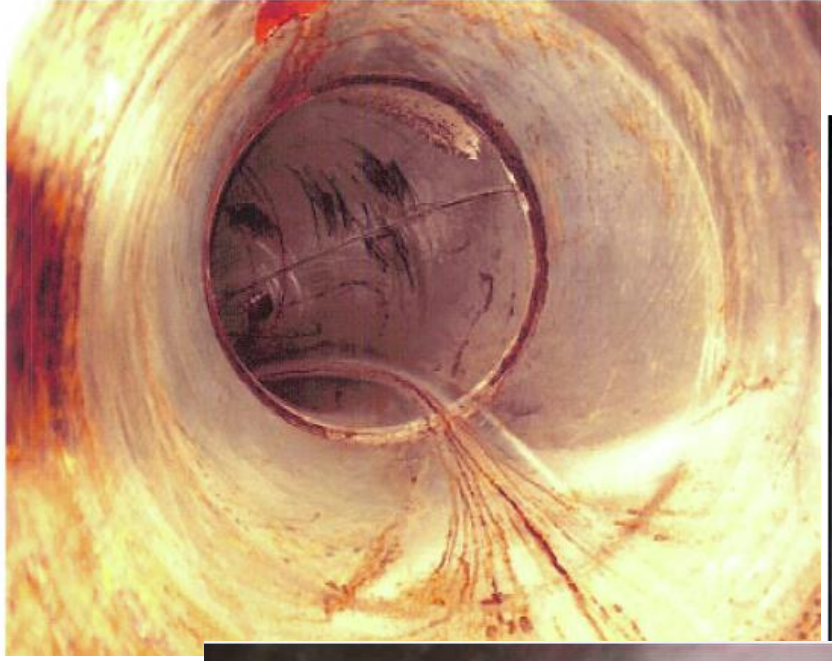
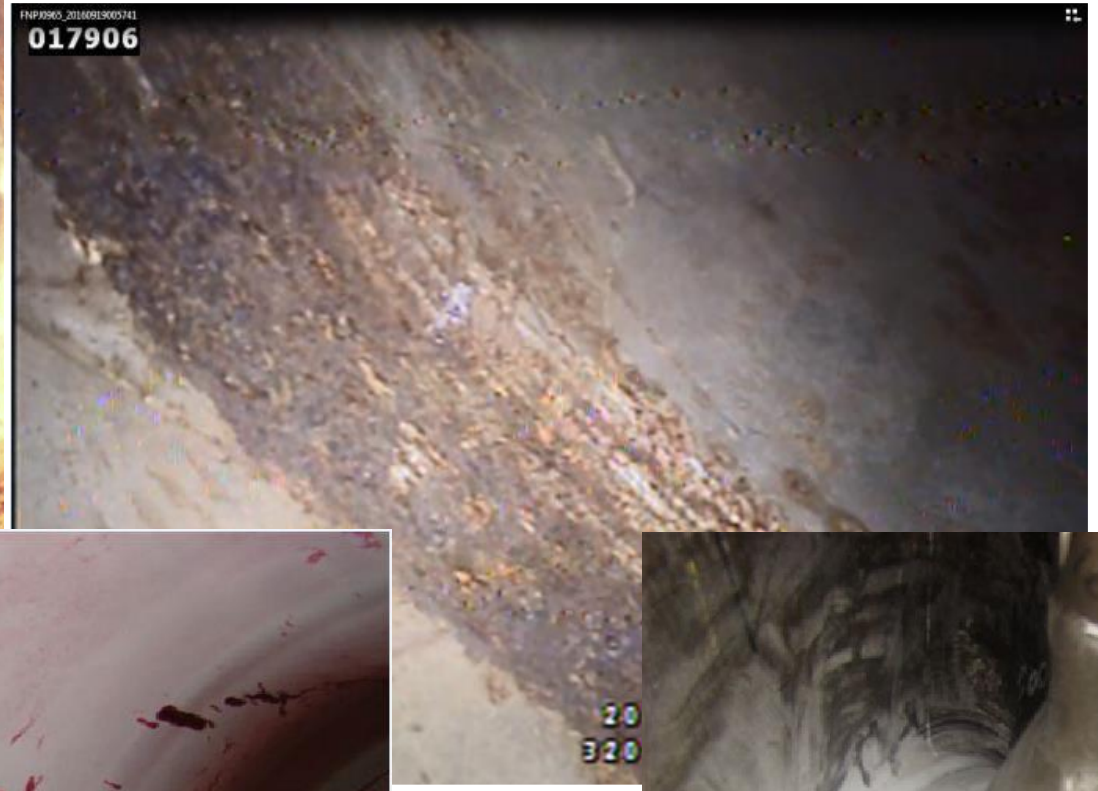
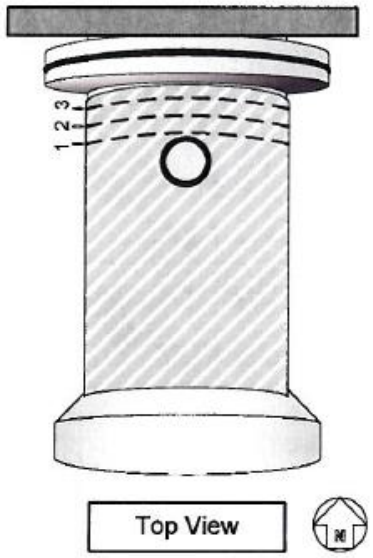
Previous Inspections

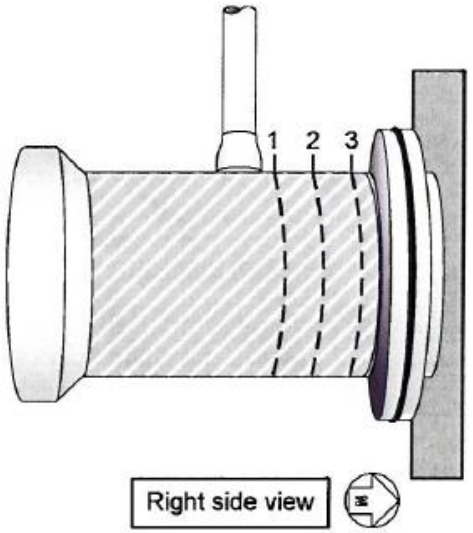


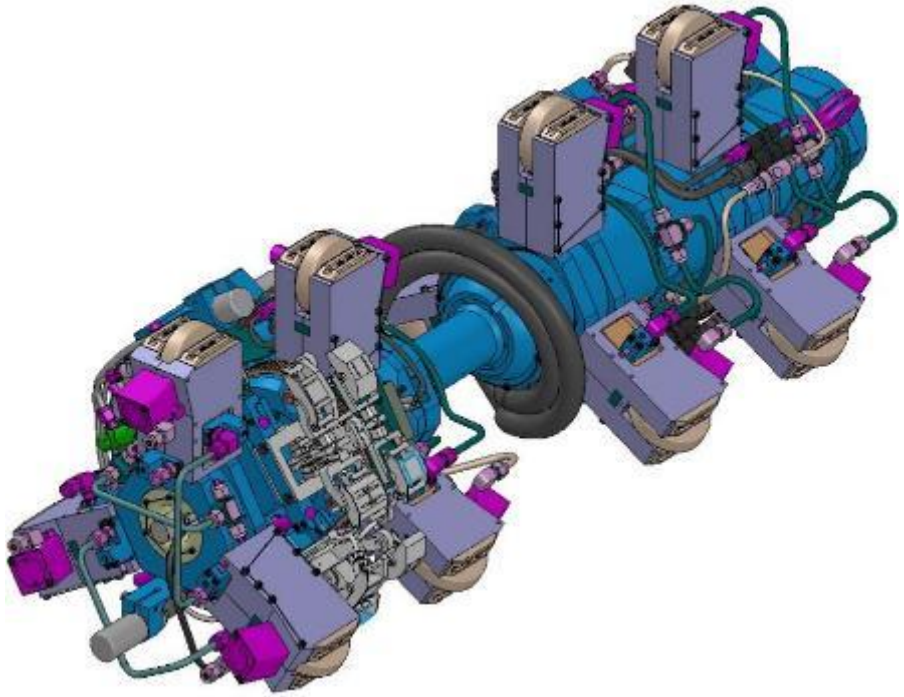


- **Manual PAUT**
  - Omniscan MX 16/128 with a 5L64-A12 transducer on a SA1 45T Wedge
    - 5.0 MHz, 0.60mm pitch, 38.4mm active aperture
  - Numerous linear indications were detected, largest NTW



1) B-reference 80 mm
2) B-reference 90 mm
3) B-reference 100 mm





NDE Tooling

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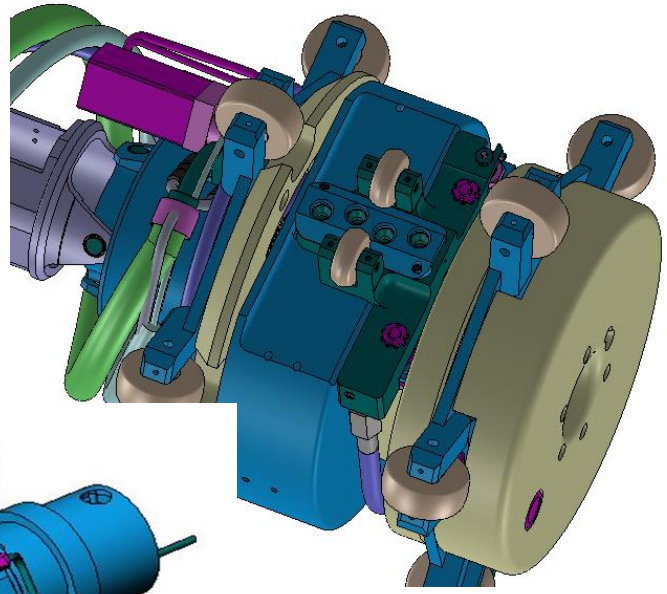
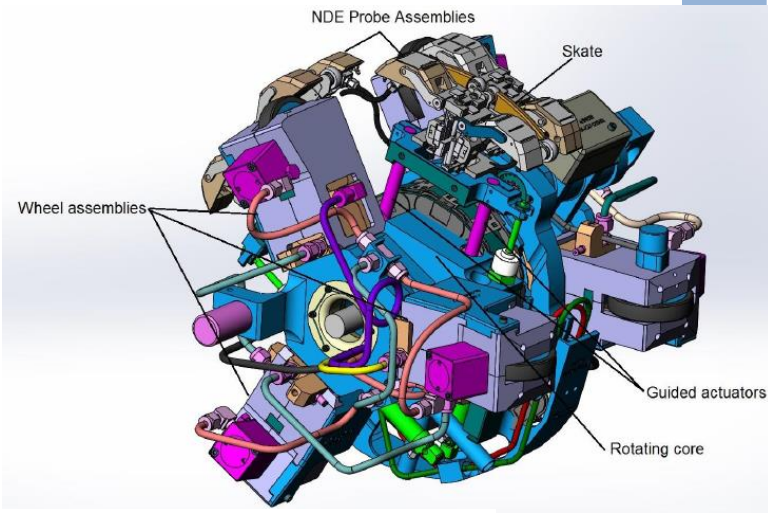
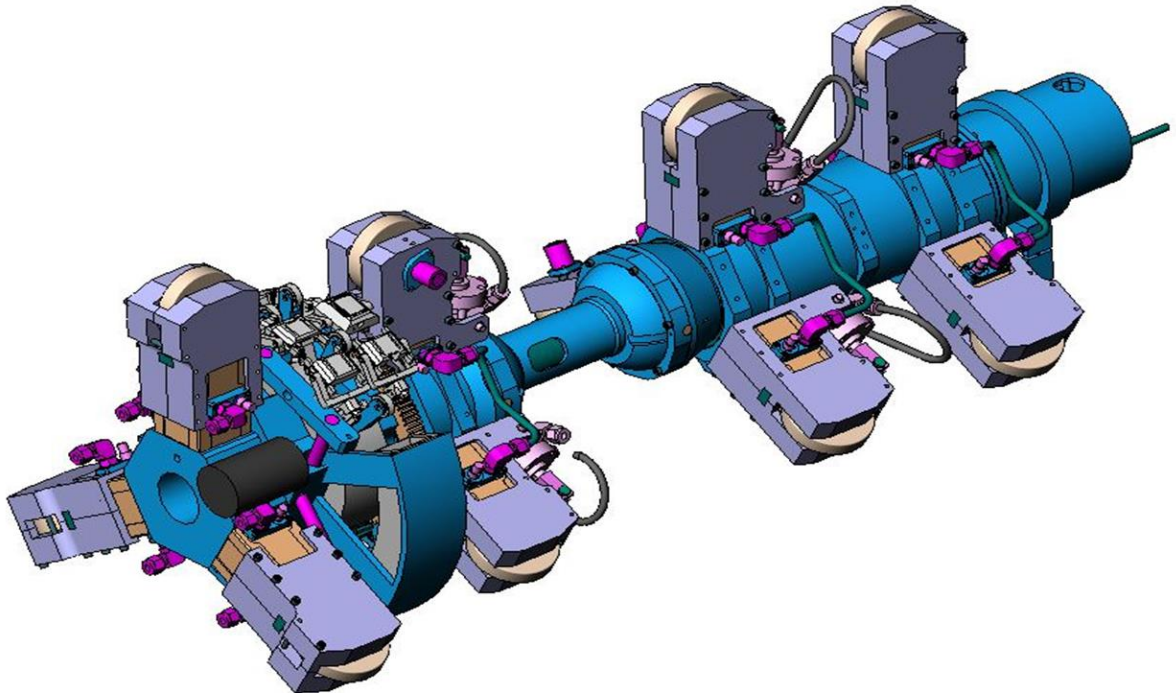
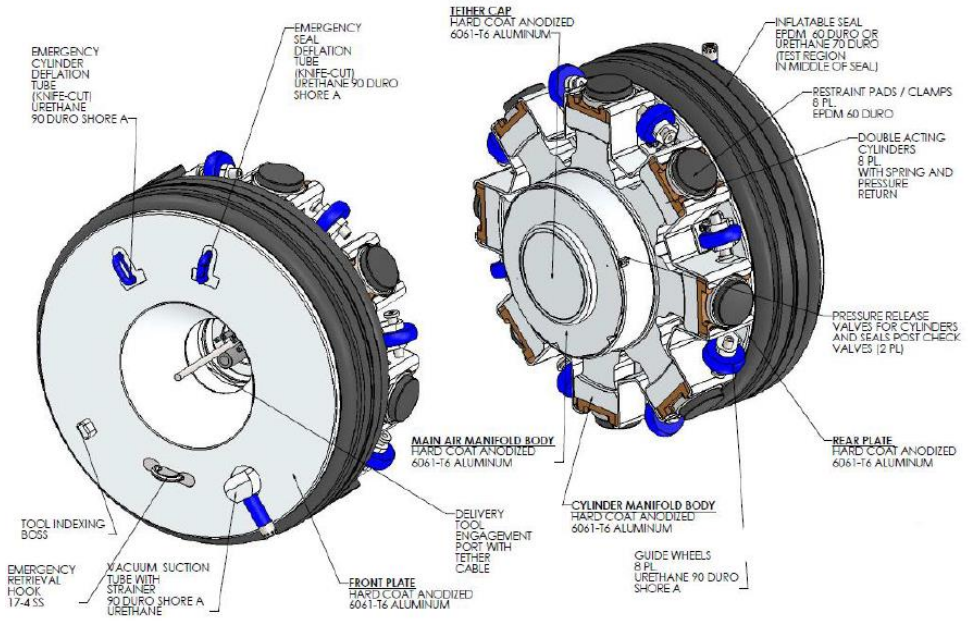
NDE Tooling : Delivery System

- **Tooling Requirements**
  - Navigating crawler
  - Foreign material barrier
  - Cleaning system
  - Inspection head

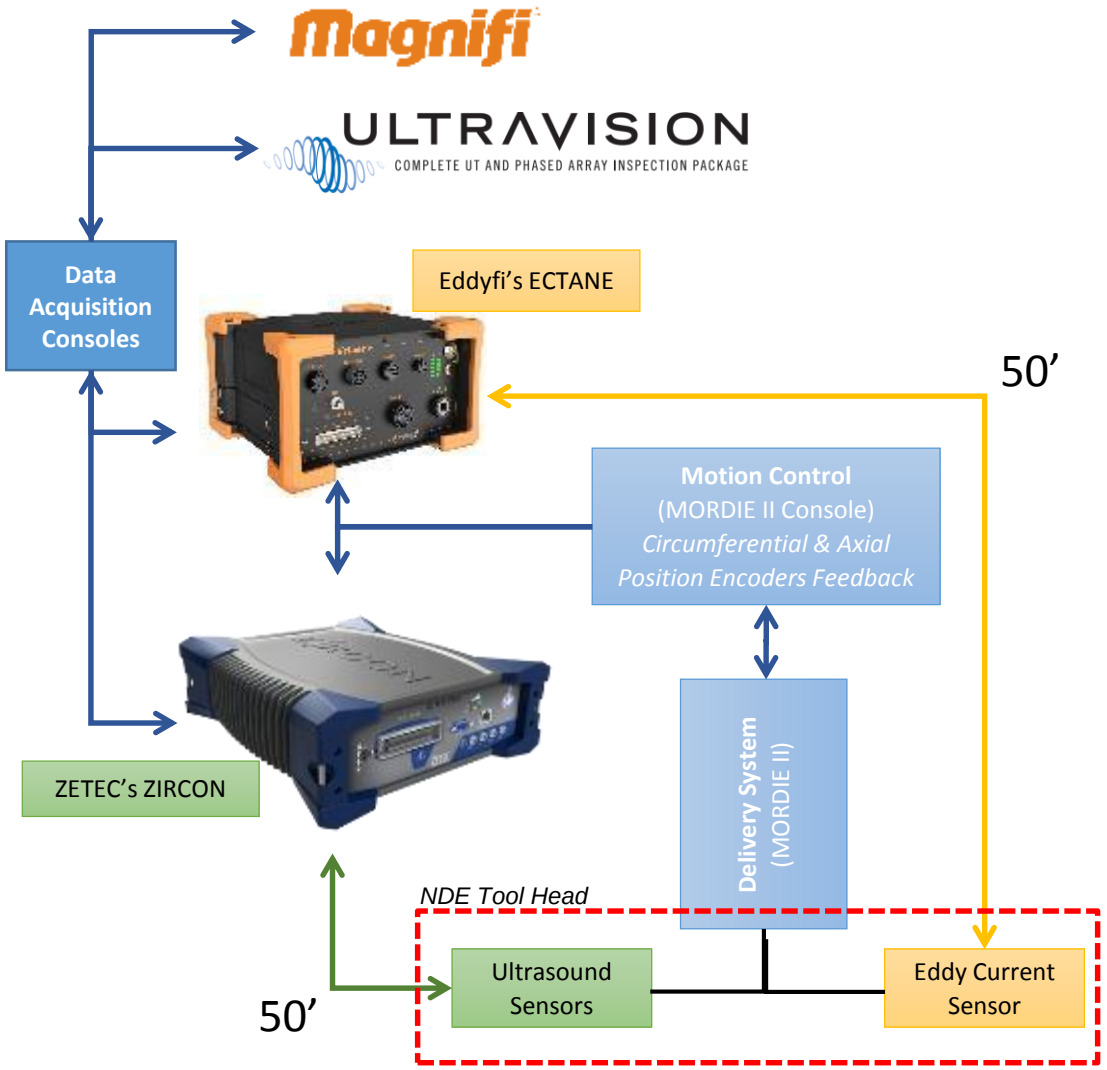






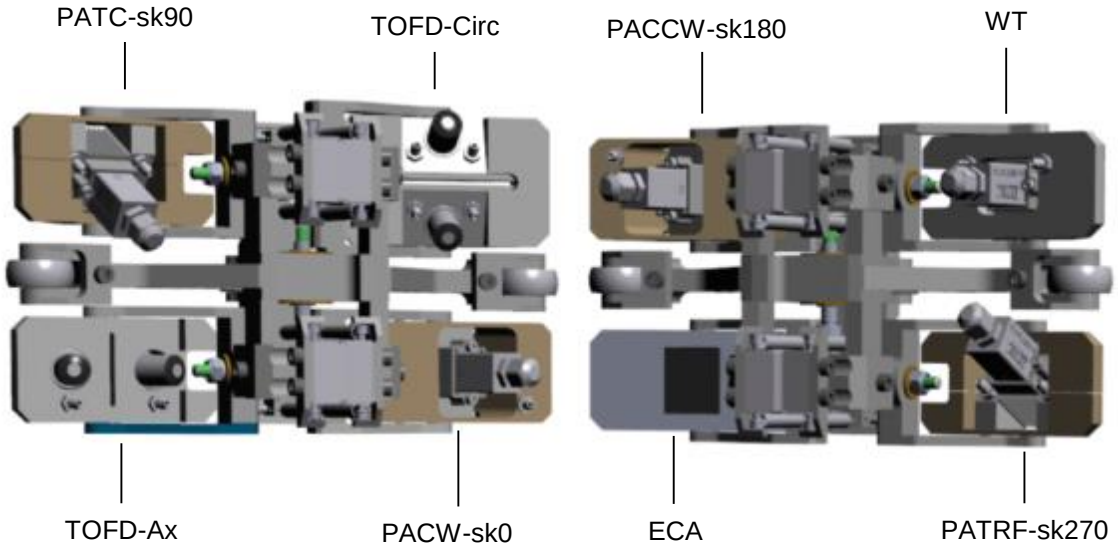


NDE Tooling : Delivery System



NDE Tooling: NDE Techniques

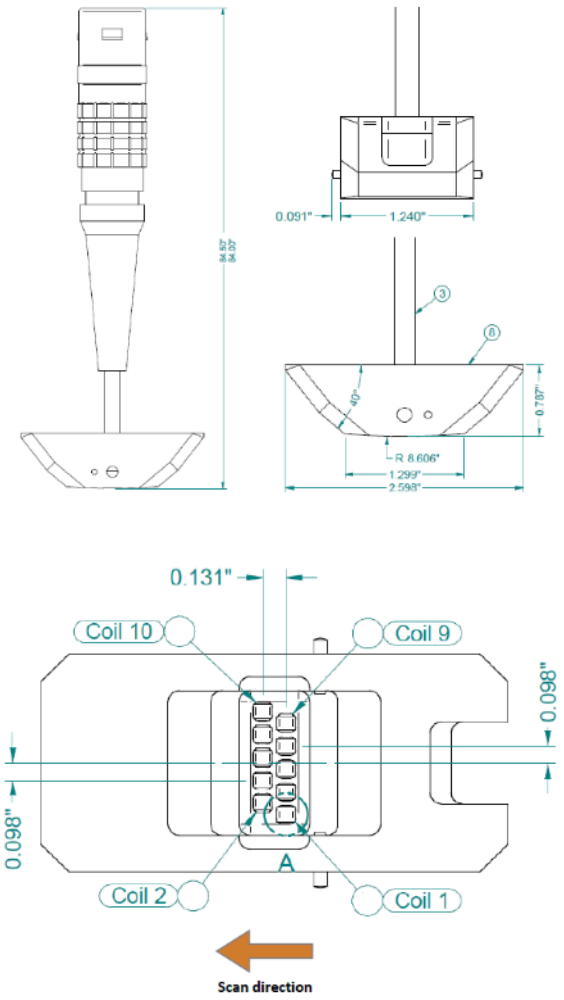
NDE Technique	Description
Eddy current	***Eddy Current Array*** for the detection and length sizing of ID connected flaws.
Ultrasonic	Multiple UT sensors are used to take advantage of different ultrasonic techniques and ensure the volumetric coverage and sizing capabilities of the system: • ***PAUT - thickness measurement***; • ***PAUT - indication detection, sizing and characterization***; • ***TOFD - indication sizing***.



NDE Tooling: NDE Techniques

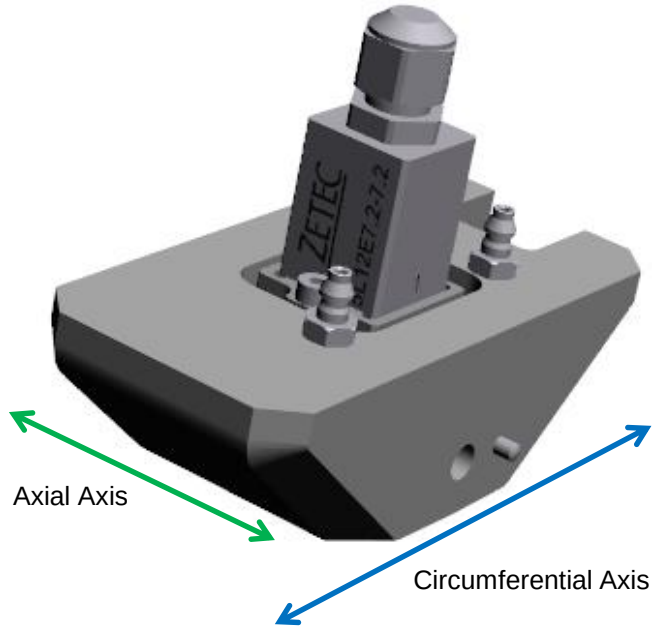
Eddy Current Array

- Orthogonal elements (10 in total)
- Drive frequency: 300 KHz and 500 KHz
- Axial coverage of a single pass: 15mm



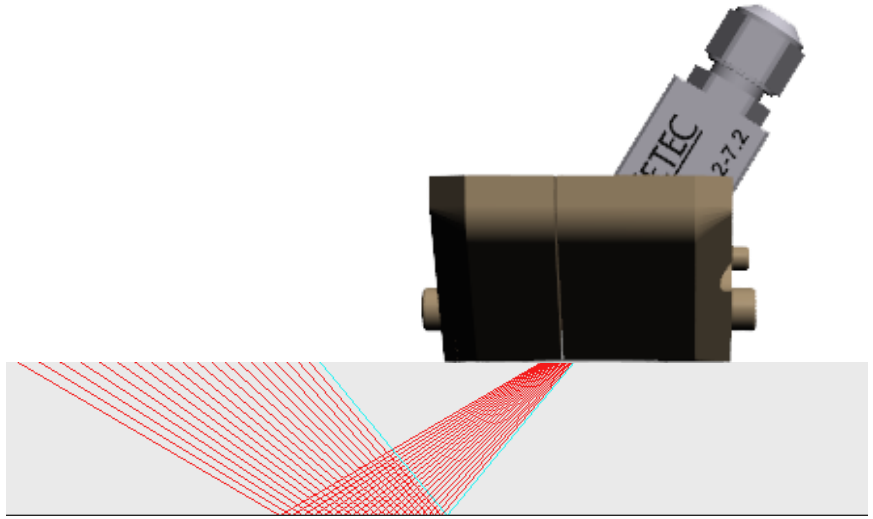
PAUT Probe for Thickness Measurement

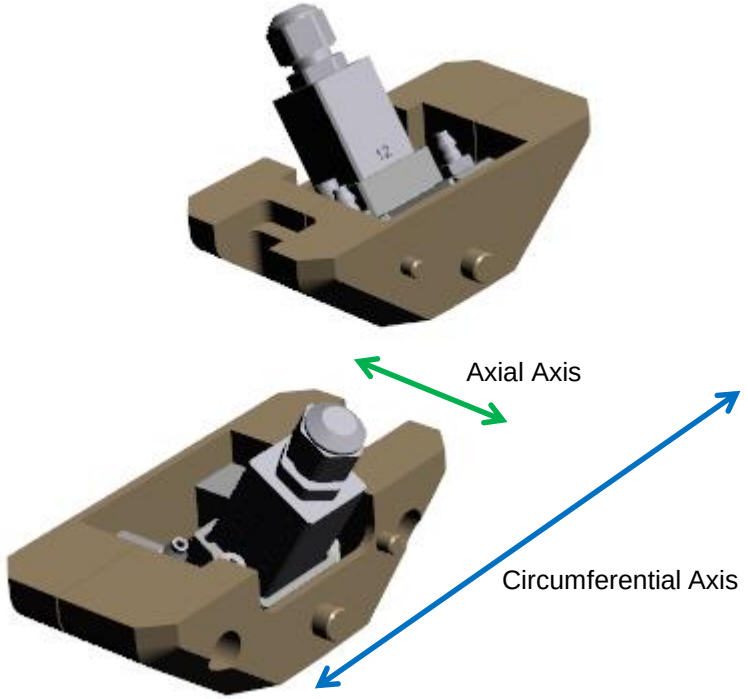
- 5MHz, 12 elements (7.2mm x 7.2mm)
- Sectorial Scanning (-10°LW to +10°LW)
- Linear Scanning (4 el.) for coverage
- Dedicated contoured wedge



PAUT Probe for Circ. Indications

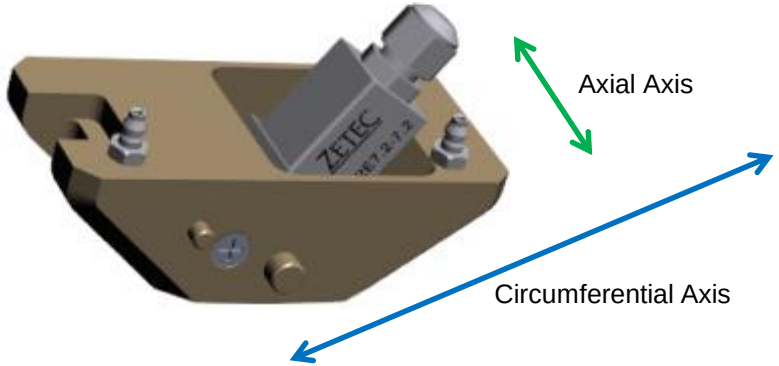
- 5MHz, 12 elements (7.2mm x 7.2mm)
- Sectorial Scanning (40°SW to 60°SW)
- ID and OD surface coverage

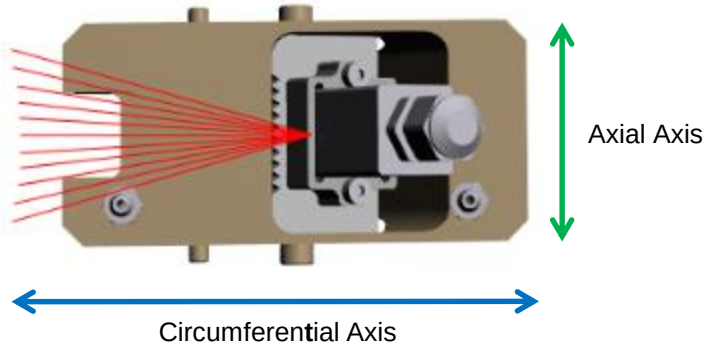


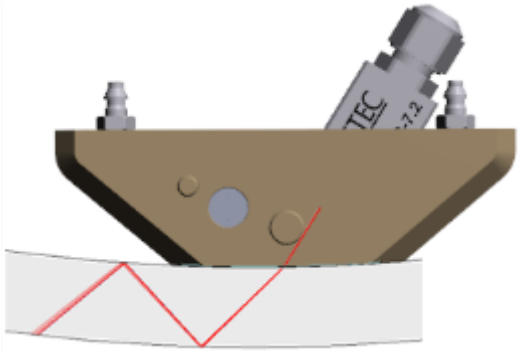


PAUT Probe for Axial Indications

- 5MHz, 12 elements (7.2mm x 7.2mm)
- Nominal Refracted Angle: 45°SW
- Lateral Configuration for Beam Skewing (-28° to +28°)

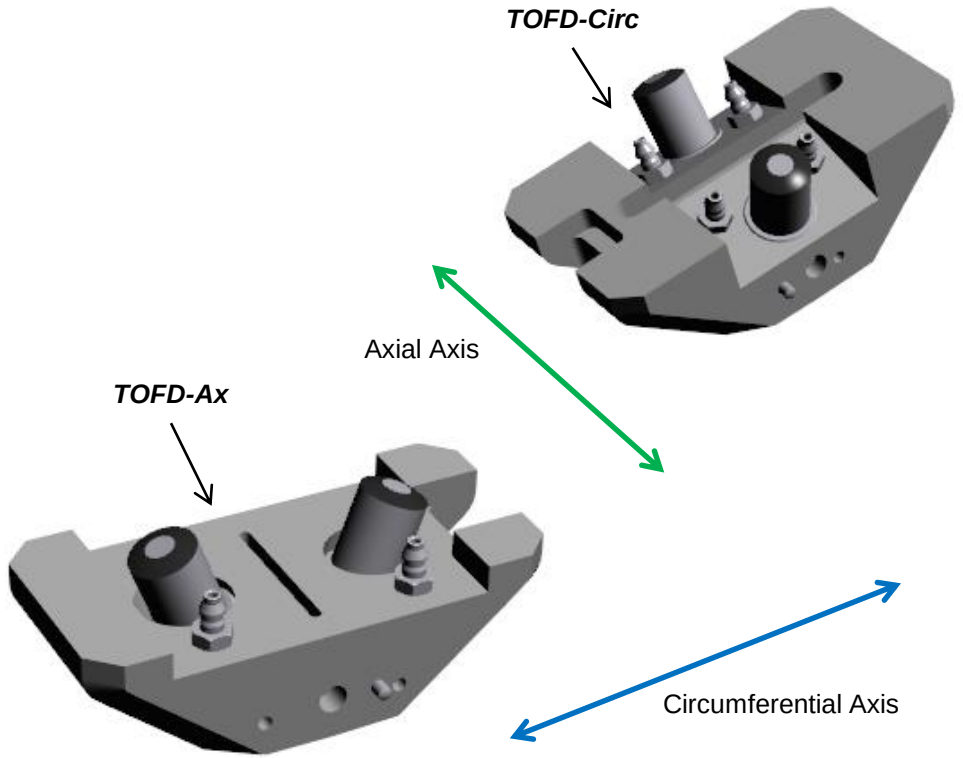




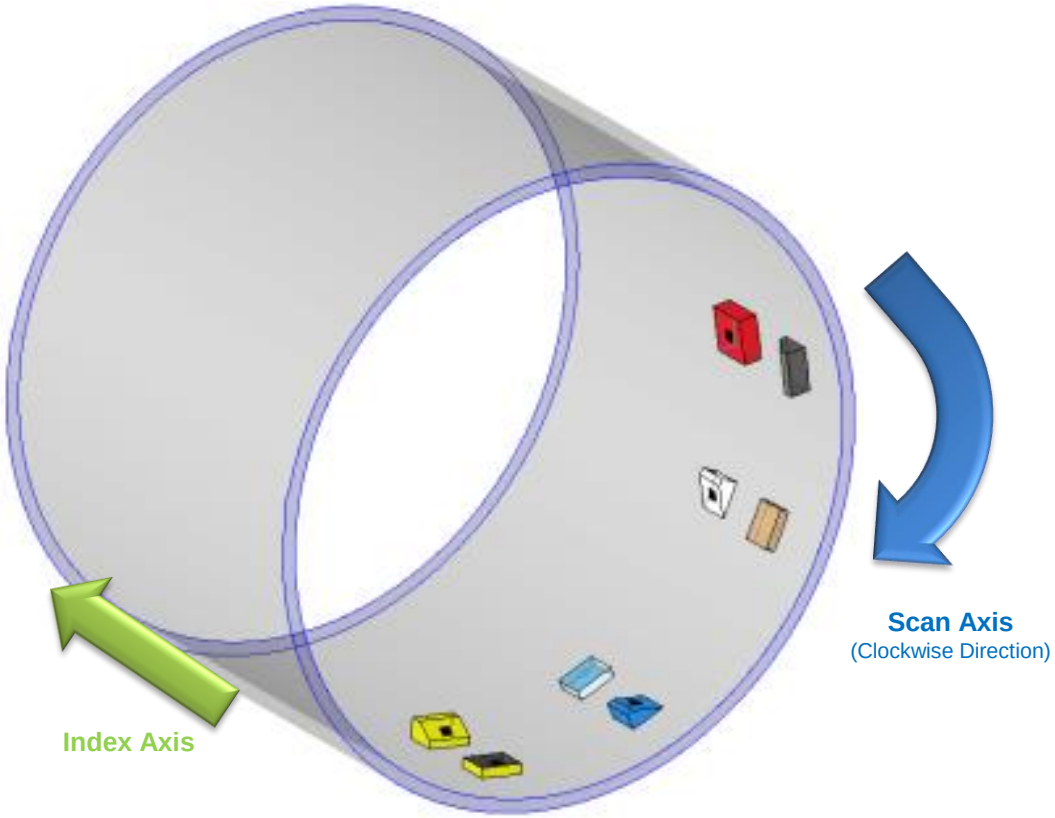


TOFD Probes for Axial and Circ. Indications

- 5MHz, ϕ: 6mm
- Nominal Refracted Angle: 70°LW
- PCS $\Rightarrow$ Near Surface/Surface Breaking indications



NDE tooling: NDE Techniques



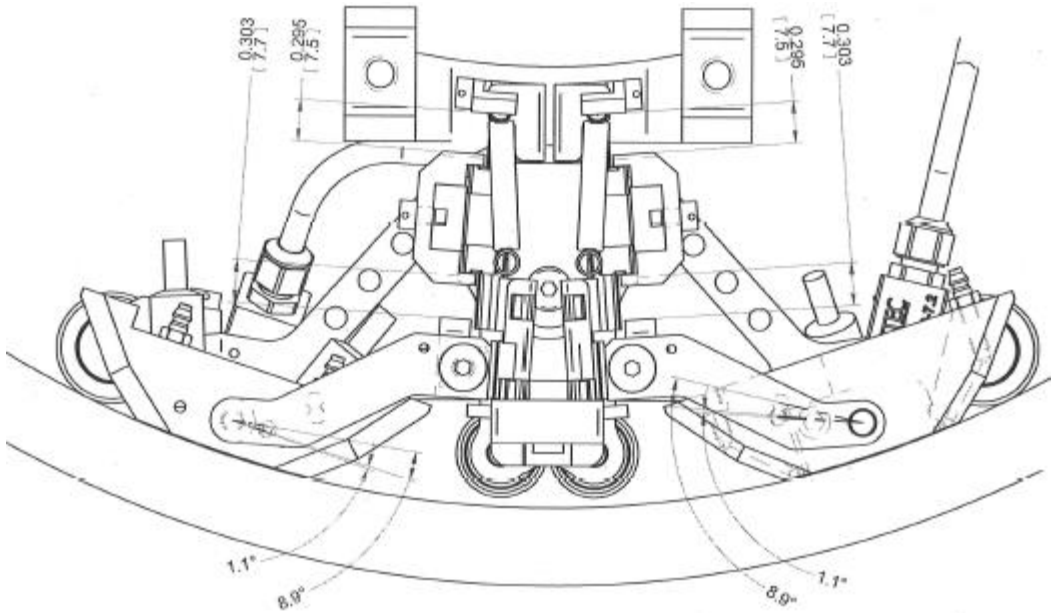
	Red	WT probe
	Grey	PATRF-Sk270 probe
	White	PACCW-Sk180 probe
	Light Brown	ECA probe
	White and Blue	TOFD-Circ probes
	Blue	PACW-Sk0 probe
	Yellow	PATC-sk90
	Grey and Yellow	TOFD-Ax probes

Why Multiple NDE Techniques?

- Increase PoD and Reduce False Calls
- Tackled the Various Geometries (Thickness Variations, Bends, Openings)
- "Single Scan"

Scan Performance?

- Rotational Speed: 25mm/s (1mm Resolution)
- Axial Increment: 5mm or less (Varies with Geometry)
- Inspection Duration (Continuous): ~24 hours
- *~3 TB of Data*



NDE Development Results

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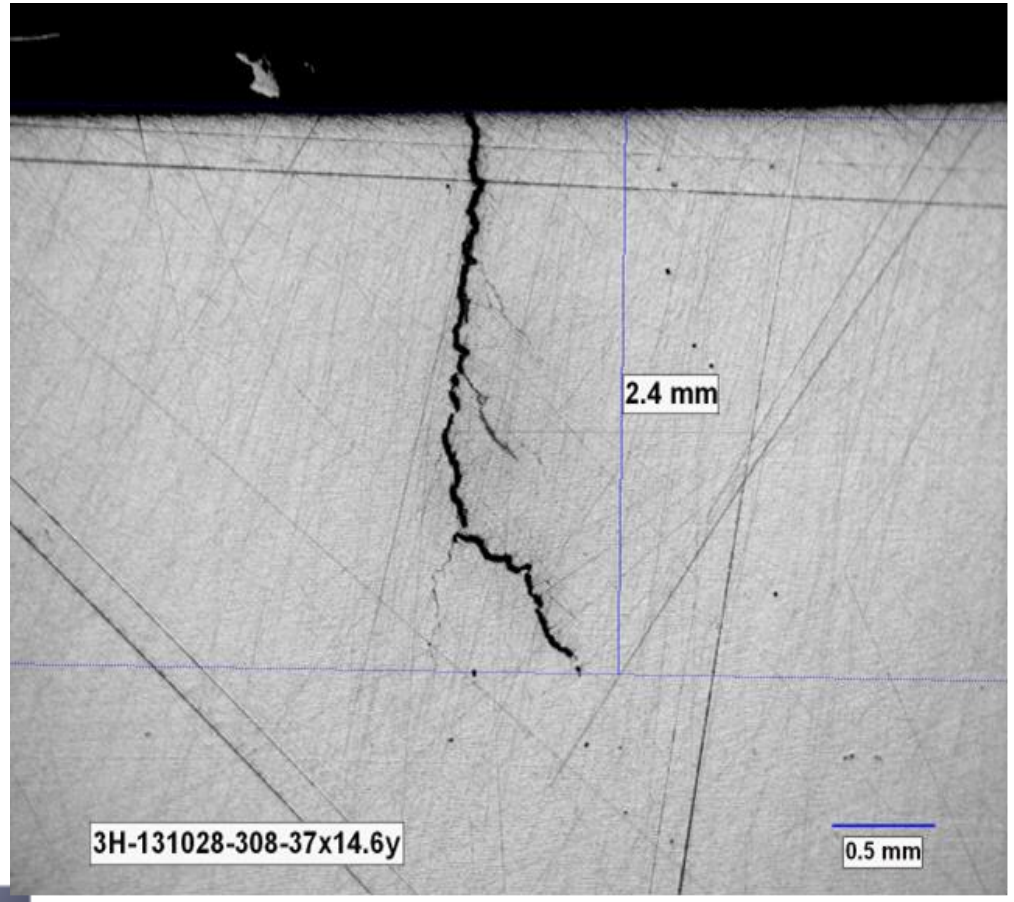
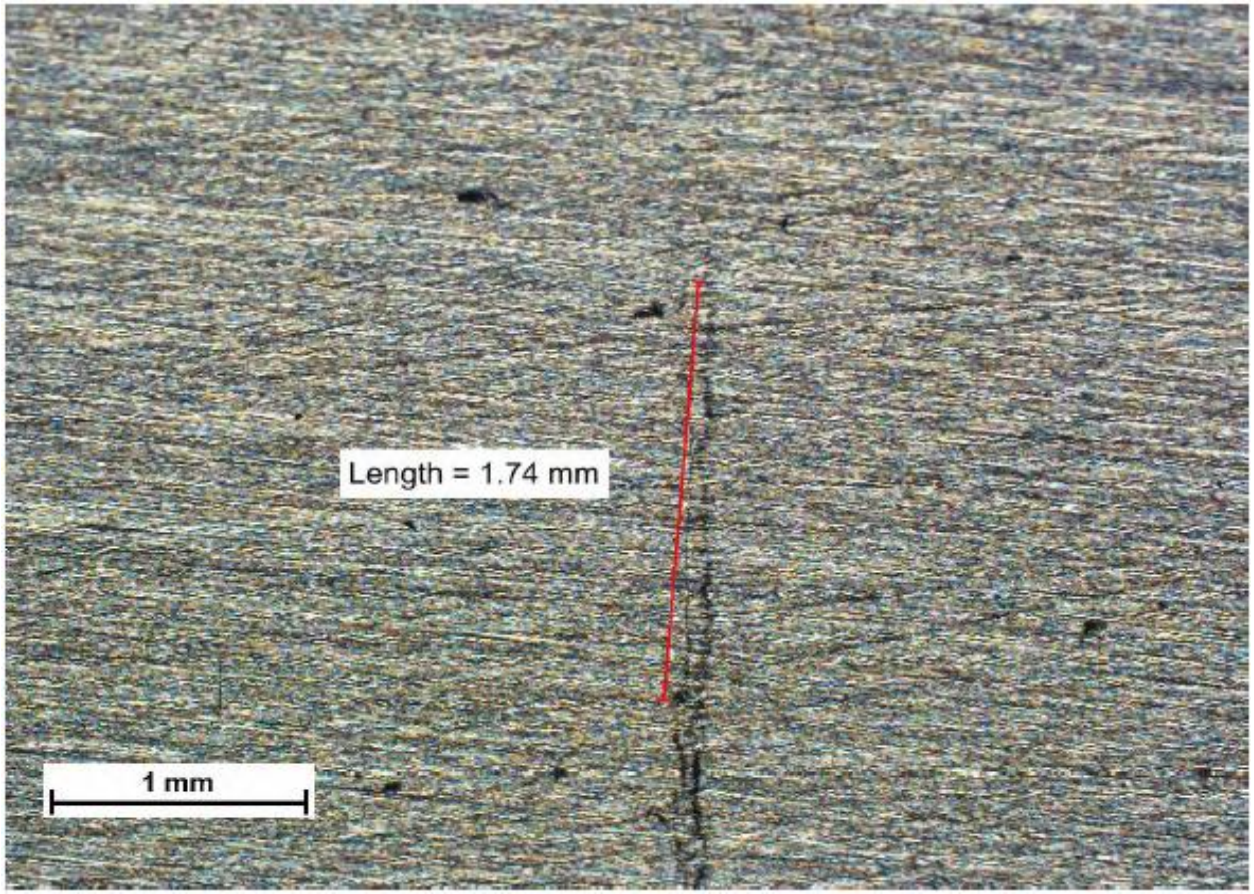
Goal of the Inspection:

- Detection of TGSCC

Real TGSCC

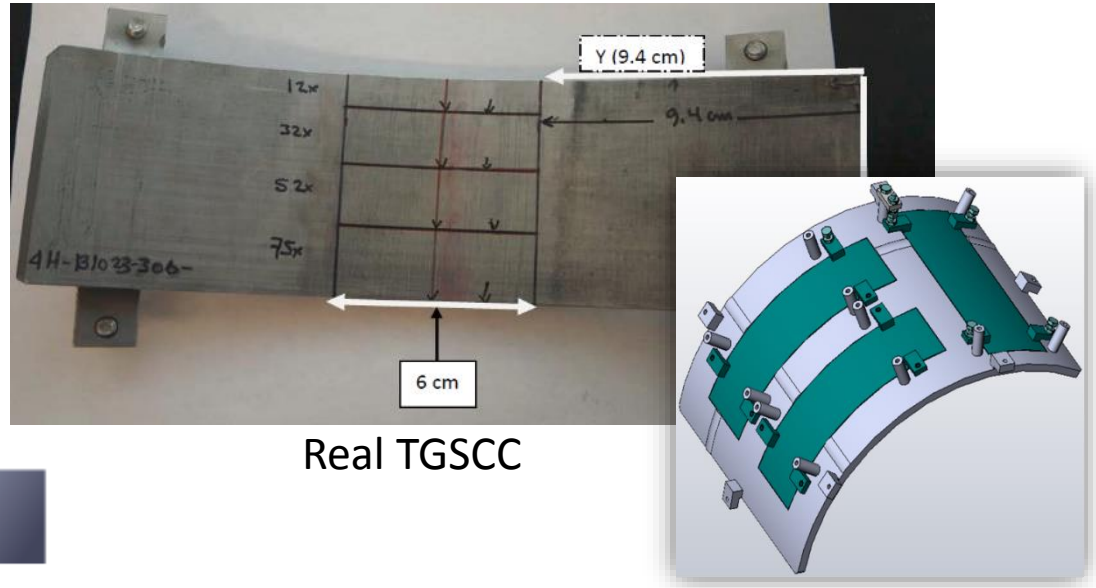


Simulated TGSCC



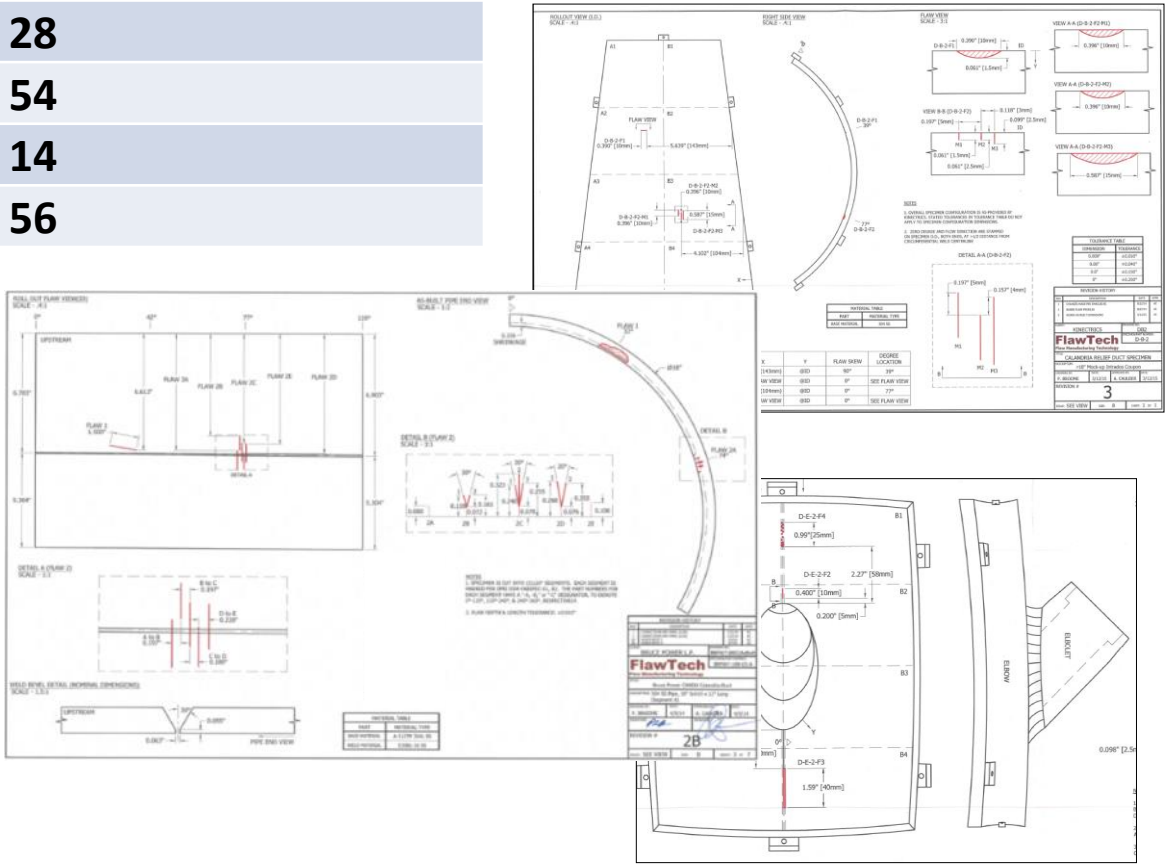
NDE Development Results

Demonstration Coupons	
Description	
Number of Coupons	17
TGSCC Flawed Grading Units	22
Weld Flaws	11
Saw Cut Notches	28
EDM Notches	54
Pitting Flawed Grading Units	14
Unflawed Grading Units	56

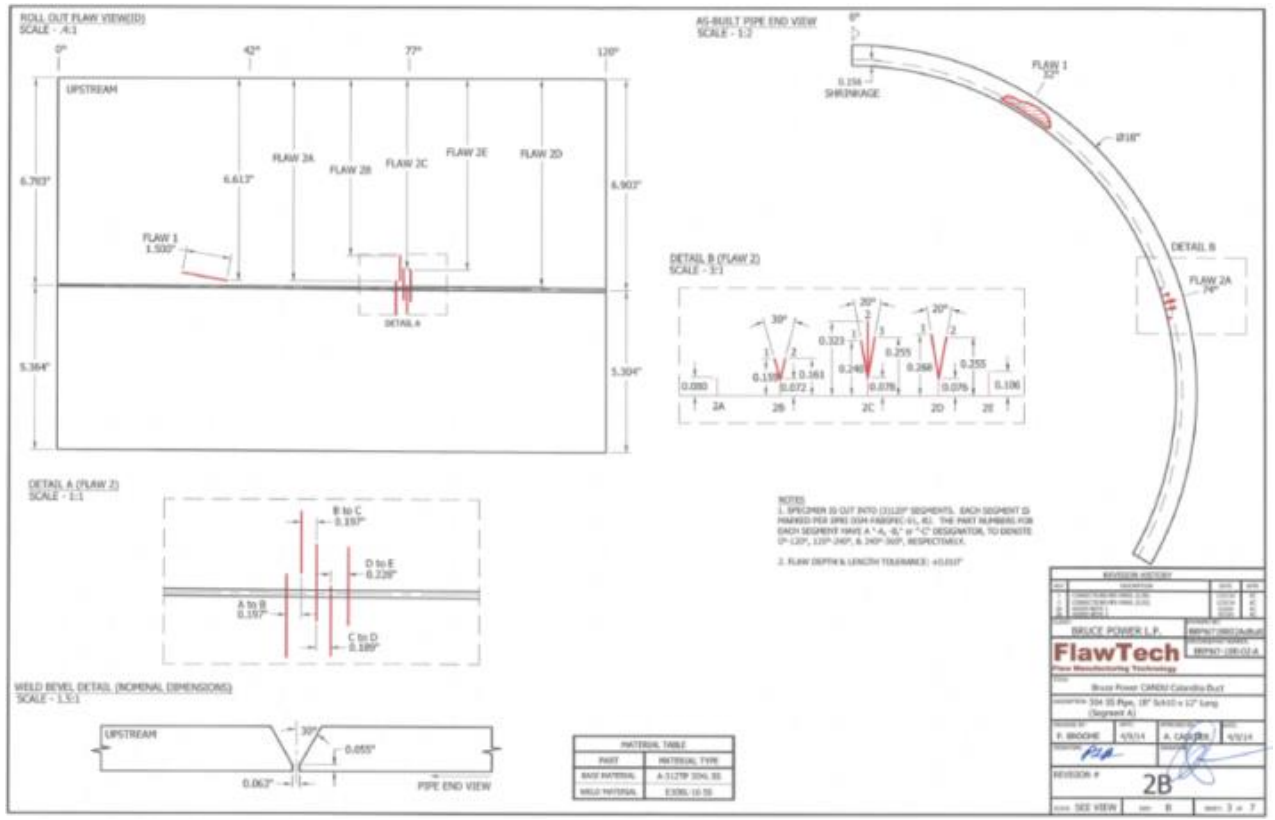


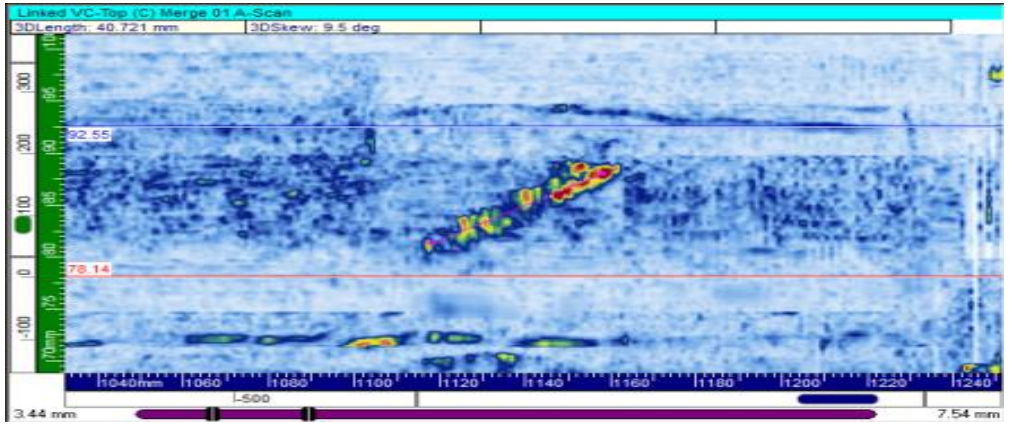
Real TGSCC

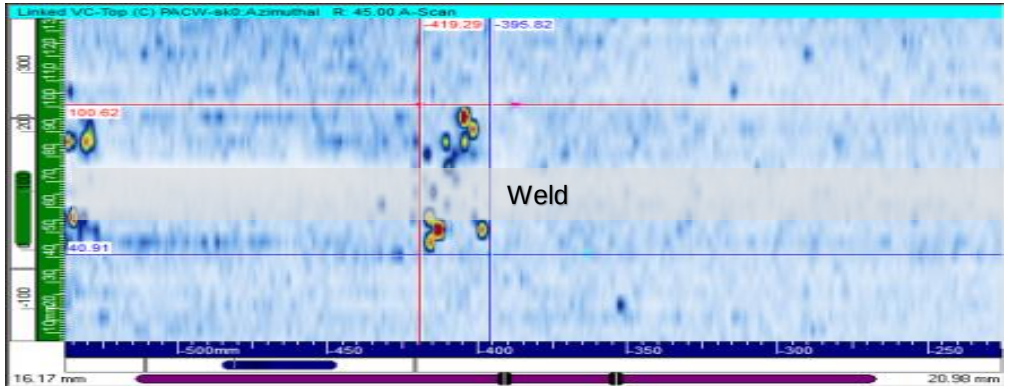
Simulated TGSCC

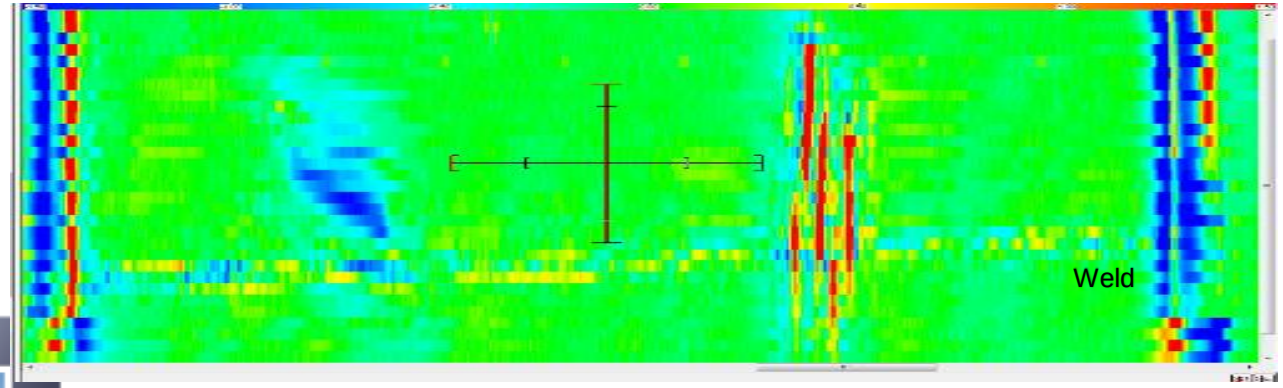


NDE Development Results





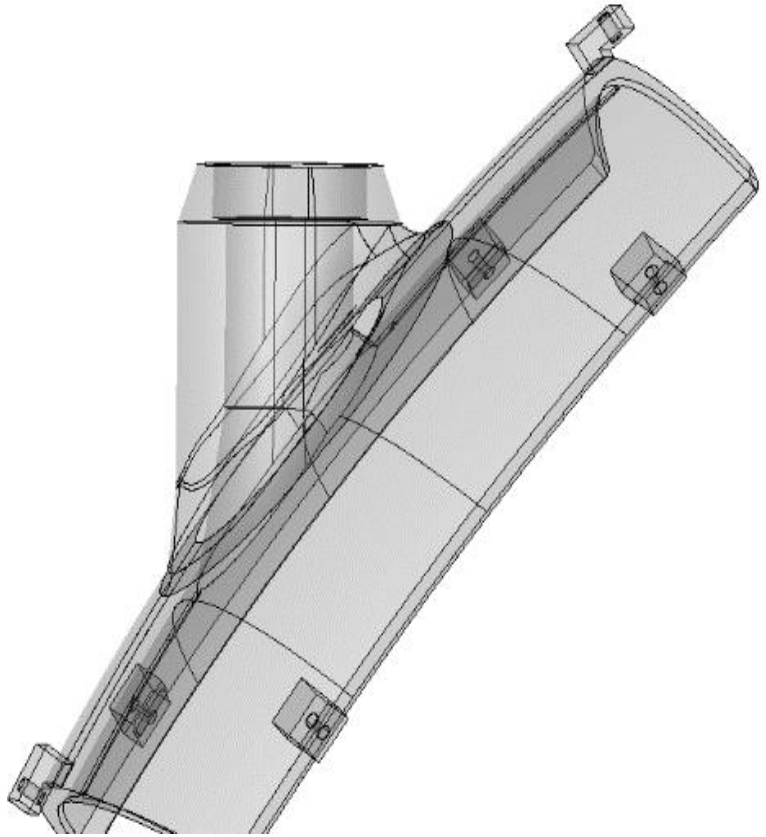


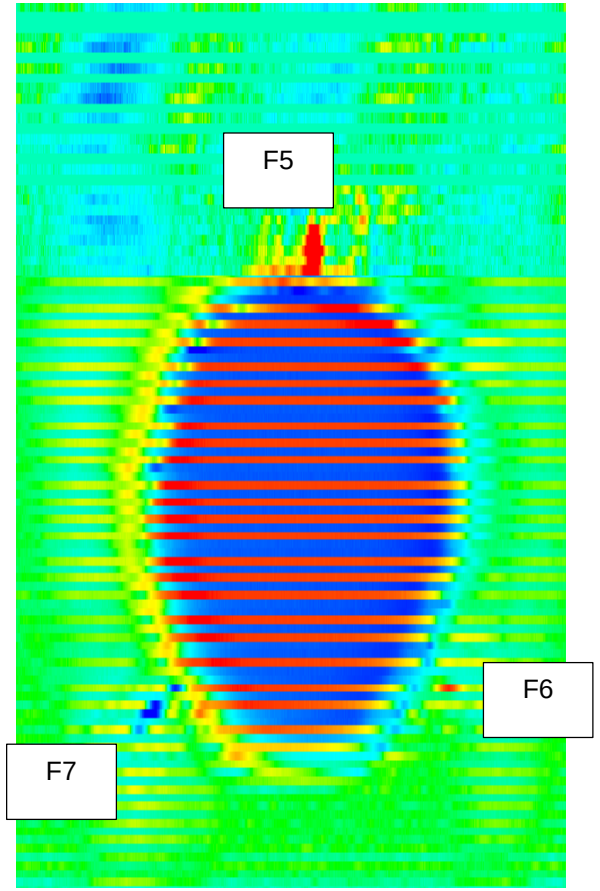


Simulated TGSCC (Straight Coupon):

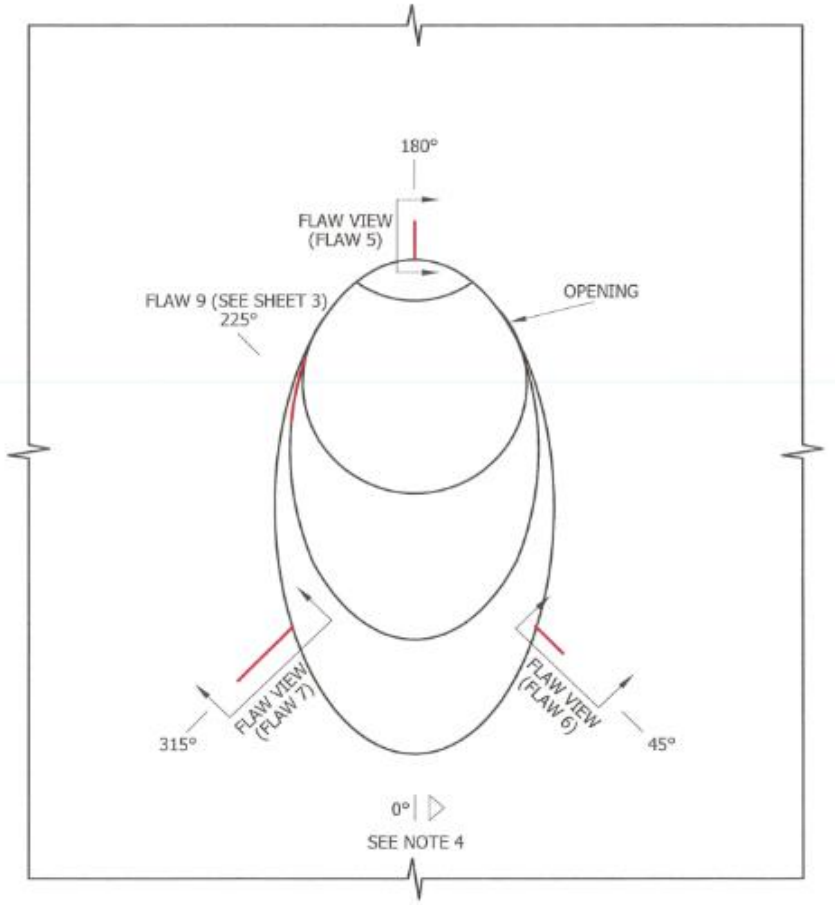
- 100% Detection
  - Both UT and ECA

Simulated TGSCC (Bend with Opening)

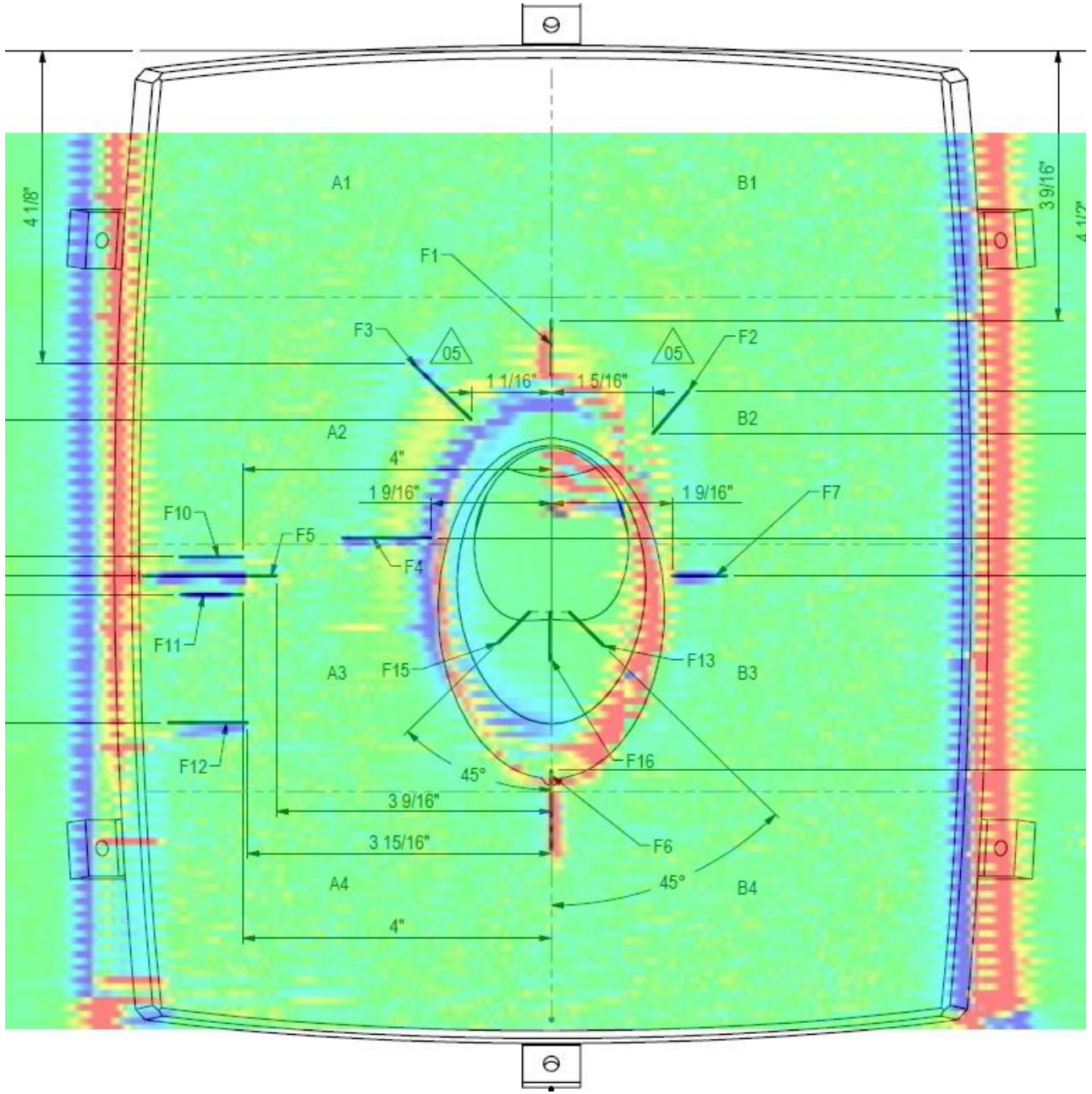




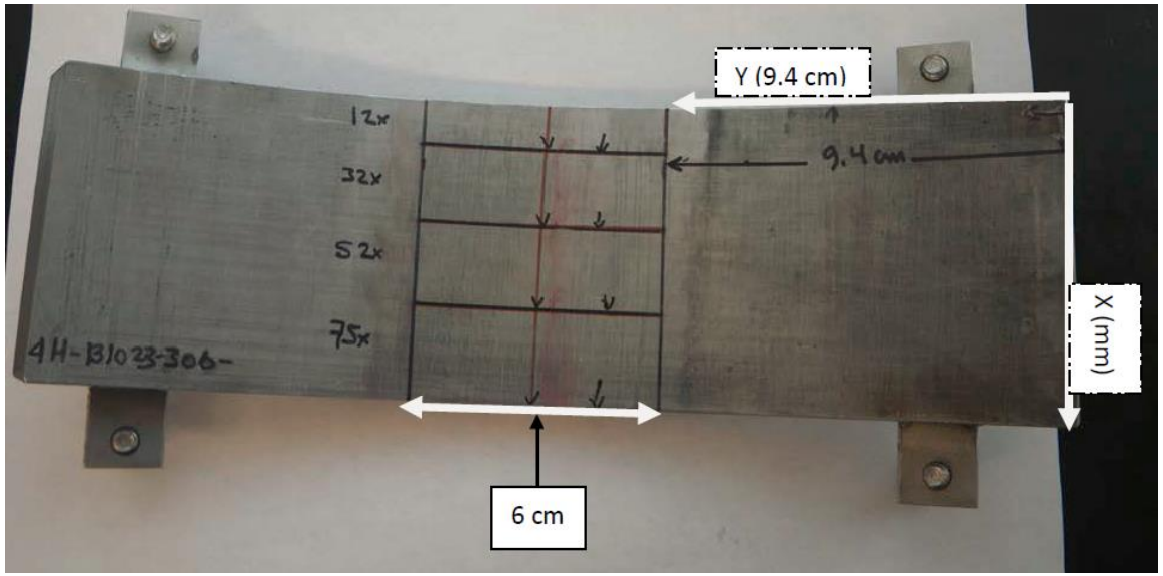
ECA Results

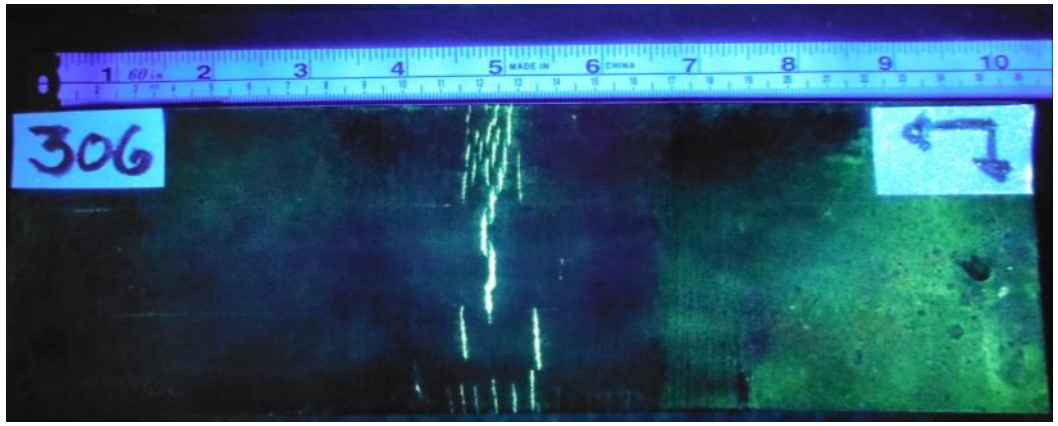


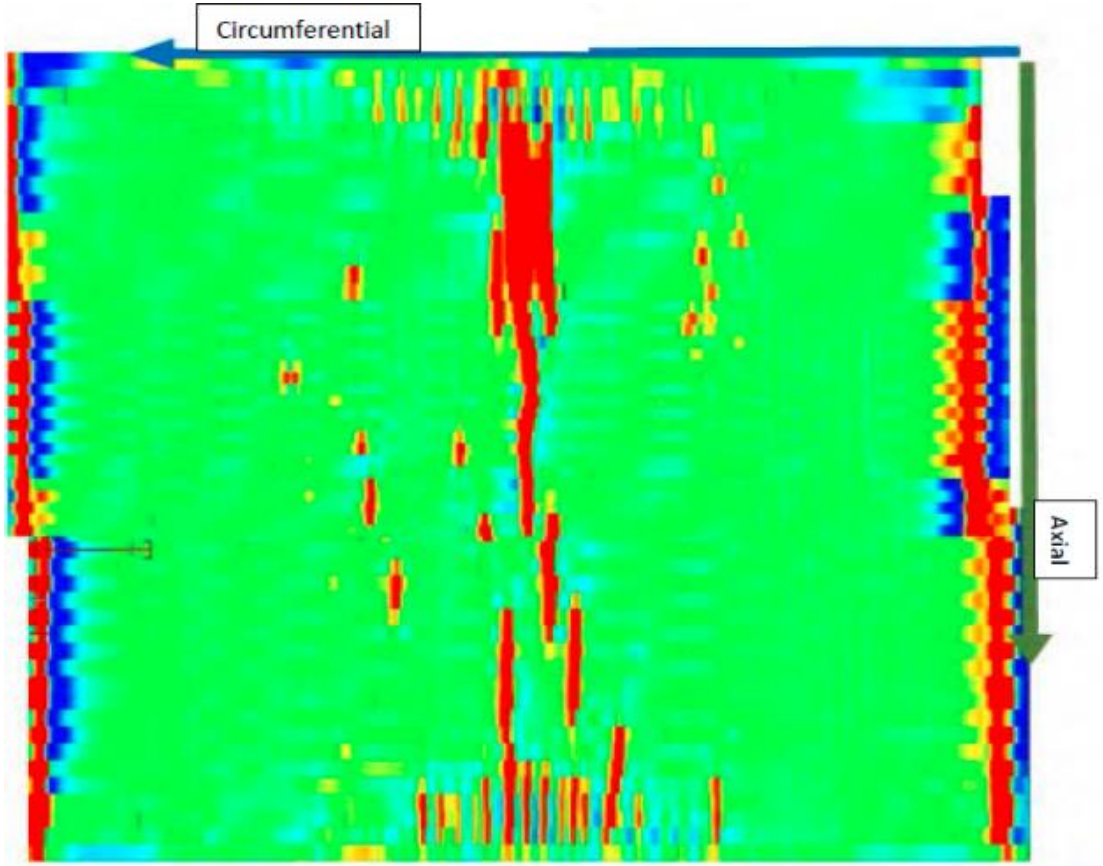
ECA Results


A1
B1
A2
B2
A3
B3
A4
B4
F1
F2
F3
F4
F5
F6
F7
F10
F11
F12
F13
F15
F16
05
05
1 1/16"
1 5/16"
4"
1 9/16"
1 9/16"
45°
3 9/16"
3 15/16"
45°
4"
4 1/8"
3 9/16"

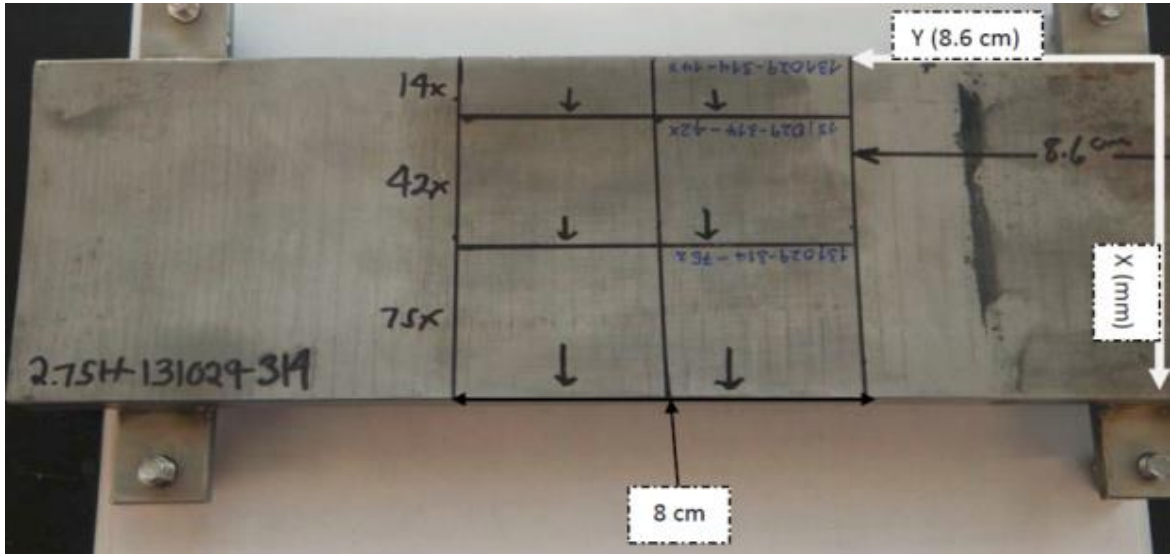
Real TGSCC

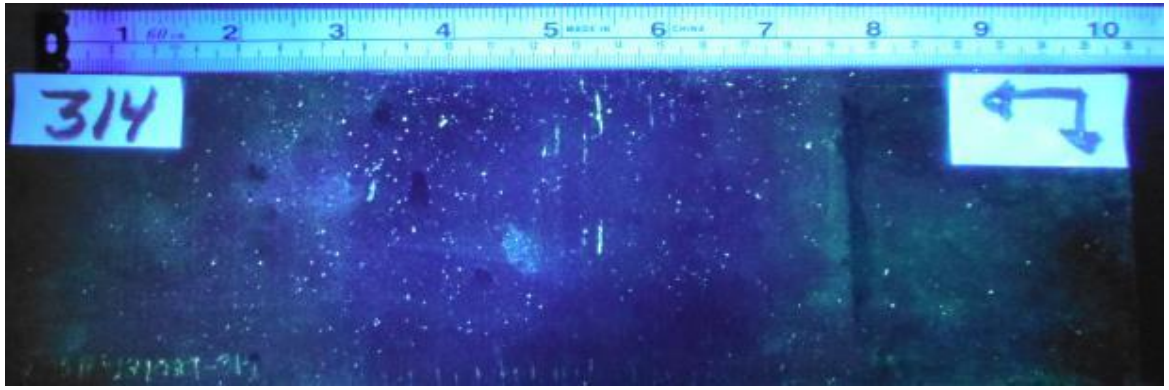

Y (9.4 cm)
9.4 cm
X (mm)
6 cm
12x
32x
52x
75x
4H-B1023-306-

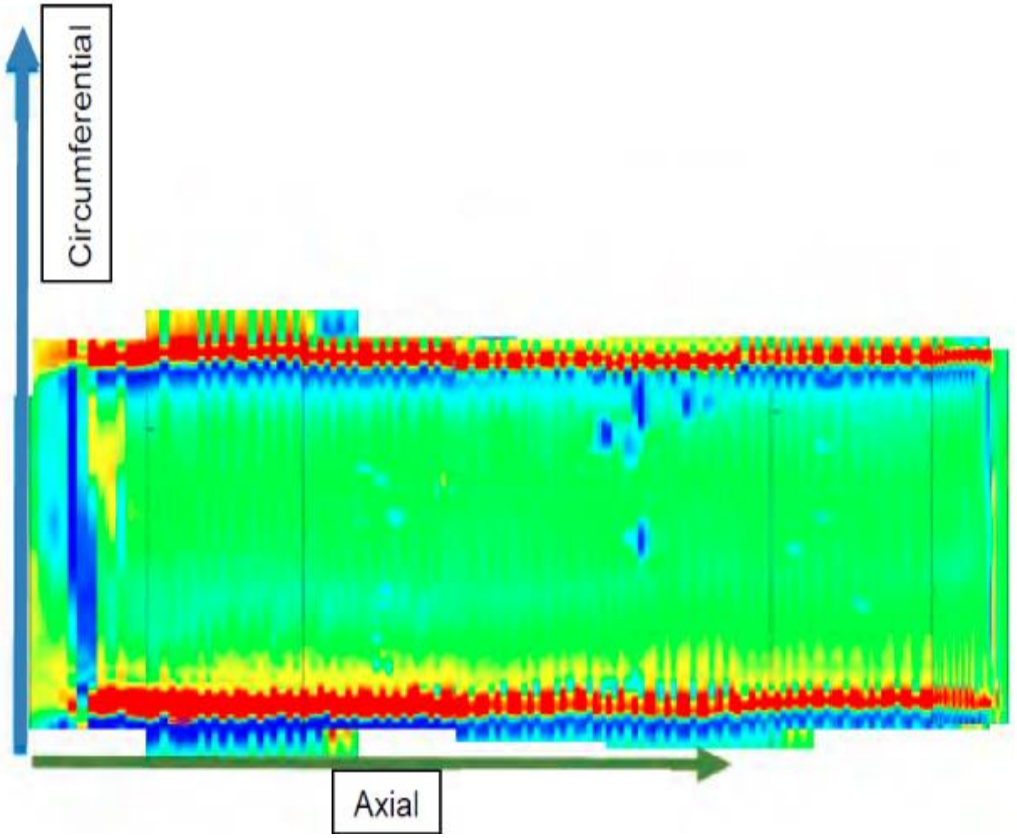

306


Circumferential
Axial

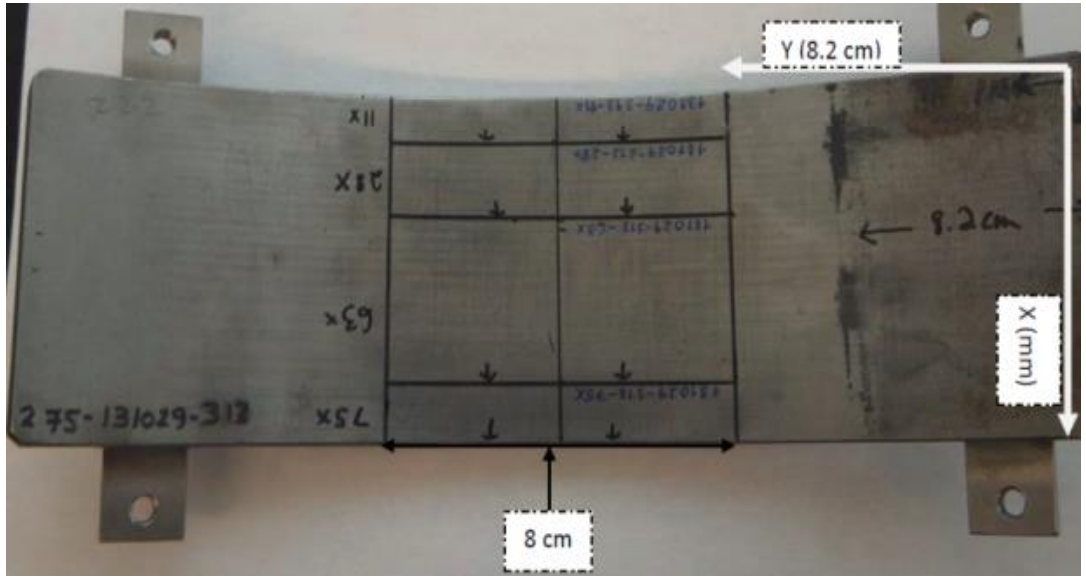
Real TGSCC

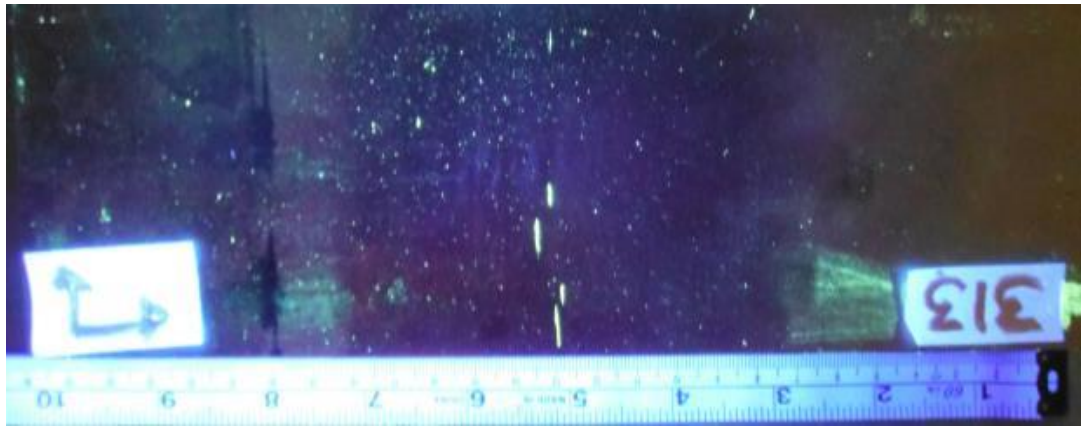

Y (8.6 cm)
14x
42x
75x
8.6 cm
X (mm)
2.75H-131029-314
8 cm

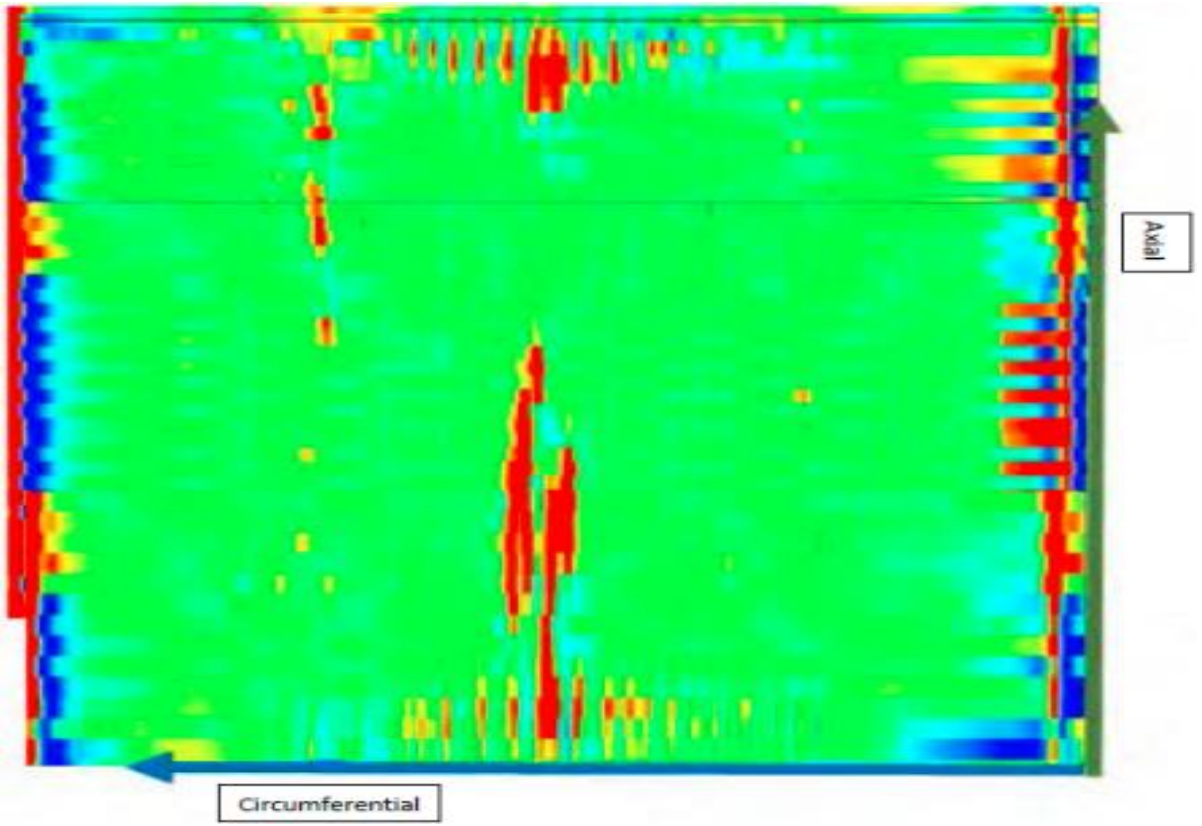

314


Circumferential
Axial

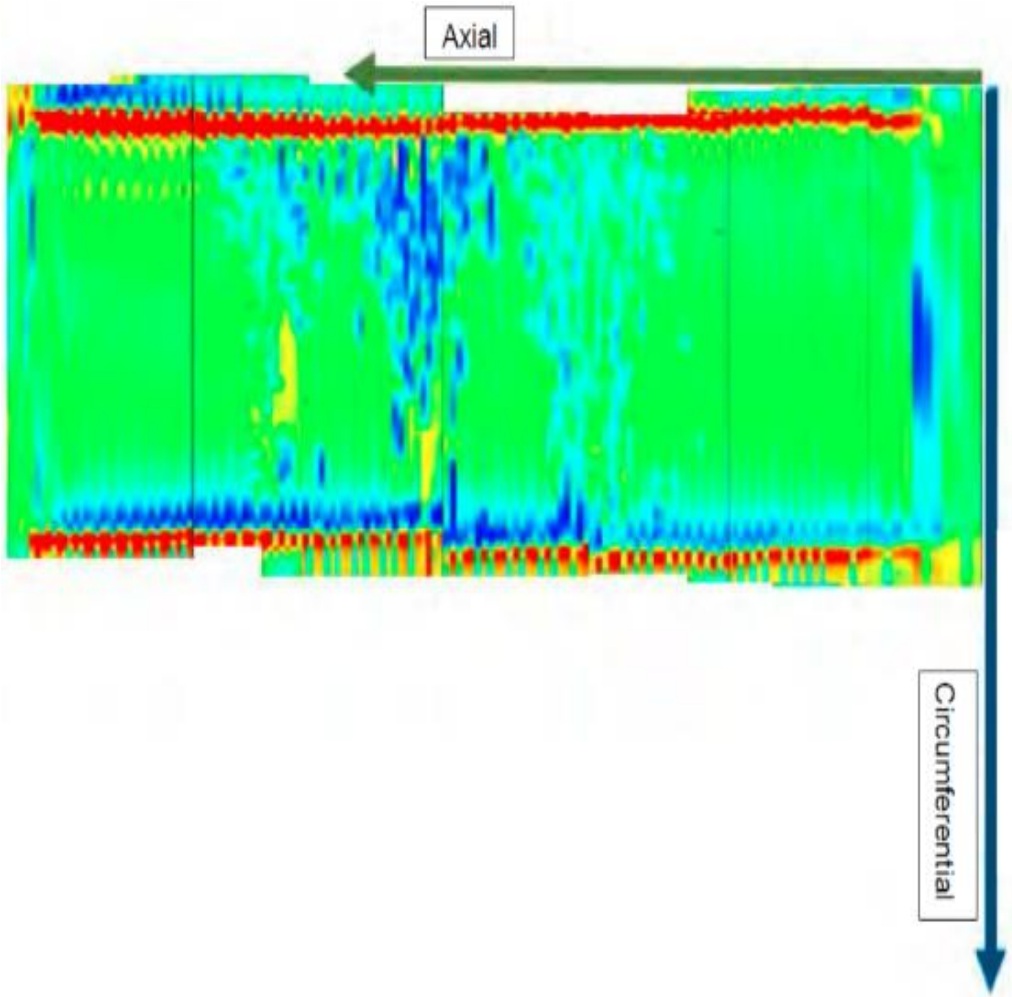
NDE Development Results

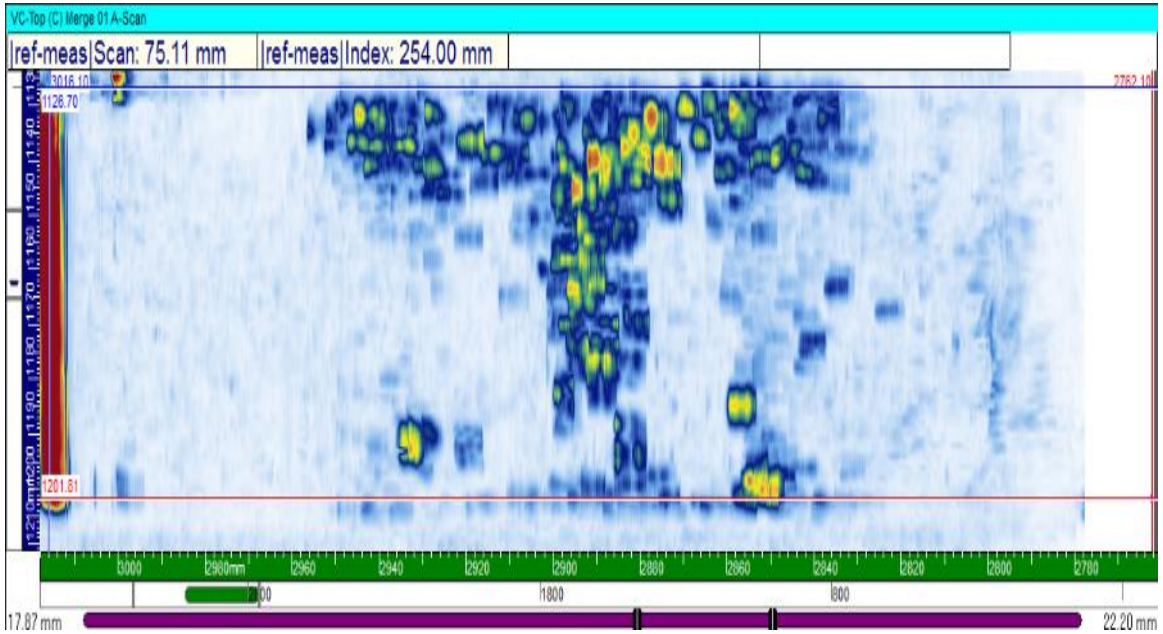






Real TGSCC


Axial
Circumferential


VC-Top (C) Merge 01 A-Scan
|ref-meas|Scan: 75.11 mm
|ref-meas|Index: 254.00 mm
17.87 mm
22.20 mm

NDE Development Results

80% PoD
90% C.L.
(10mm x 2.5mm)

Coupon Id	Flaw #	Orientation	Nominal Flaw Values (mm)		Hit/Miss Status		Measured Depth Extent (mm)			Measured Length (mm)		
			Depth Extent	Length	UT	ECA	Channel	Value	Delta	Channel	Value	Delta
D-B-1	F1	Axial	2.1	10	Hit	Hit	PACW	2.39	0.29	ECA	8.4	1.6
	F2	Circ	5	31	Hit	Hit	PATRF	5.39	0.39	ECA	48	17
D-B-2	F1	Axial	1.5	10	Hit	Hit	TOFD	1.5	0	ECA	12	2
	F2-M1	Circ	1.5	10	Hit	Hit	PATC	1.5	0	ECA	11	1
	F2-M2	Circ	1.5	10	Hit	Hit	PATC	1.7	0.2	ECA	12	2
	F2-M3	Circ	2.5	15	Hit	Hit	PATRF	2.42	0.08	ECA	14	1
D-B-3	F1	Axial	1.5	12.4	Hit	Hit	PACCW	1.61	0.11	ECA	13.3	0.9
	F2	Circ	2.3	10	Hit	Hit	PATRF	2.41	0.11	ECA	9	1
	F3	Axial	3.1	17.7	Hit	Hit	PACW	3.3	0.2	ECA	17	0.7
D-S-1	F1	Circ	2.3	10	Hit	Hit	TOFD	2.44	0.14	ECA	9.5	0.5
	F2	Axial	1.7	12.4	Hit	Hit	TOFD	1.75	0.05	ECA	11.7	0.7
	F3 SLAG	Circ	3	40	Hit	Miss	PATC	3	0	PATC	37	3
D-S-2	F1	Axial	2.2	10	Hit	Hit	PACCW	2.15	0.05	PACCW	10	0
	F2	Axial	2.3	12.5	Hit	Hit	TOFD	2.33	0.03	PACCW	11	1.5
	F3	Circ	3.2	15	Hit	Hit	PATC	3.6	0.4	ECA	14	1
	F4	Circ	3	17.6	Hit	Hit	PATC	3.04	0.04	PATC	17	0.6
	F5-M1	Axial	1.5	10	Hit	Hit	PACCW	1.4	0.1	PACCW	11	1
	F5-M2	Axial	2.4	15	Hit	Hit	PACCW	2.39	0.01	ECA	15	0
	F5-M3	Axial	1.7	10	Hit	Hit	PACCW/PACW	1.84	0.14	ECA	10	0
D-S-3	F1	Circ	5	25	Hit	Hit	PATRF	5.1	0.1	PATRF	24	1
	F2	Axial	2.2	10	Hit	Hit	PACW	2.07	0.13	ECA	10	0
	F3	Axial	3.1	15	Hit	Hit	TOFD	3.02	0.08	ECA	15	0
	F4	Axial	1.7	10	Hit	Hit	PACW	1.84	0.14	ECA	10	0
	F5 LoF	Circ	3	25	Hit	Hit	PATC	3.38	0.38	PATC	25	0
D-E-1	F1	Circ	2.7	15	Hit	Hit	PATC	2.6	0.1	PATC	14	1
	F2	45deg	2.5	15	Miss	Hit	N/A	N/A	N/A	ECA	13	2
D-E-2	F1-M1	Circ	2.5	15	Hit	Miss	PATC	3.3	0.3	PATC+PATRF	22	3
	F1-M2	Circ	3.6	20	Hit	Miss						
	F1-M3	Circ	2.5	15	Hit	Miss						
							Depth Extent – RMS Error:		0.17	*Length – RMS Error:*		3.33

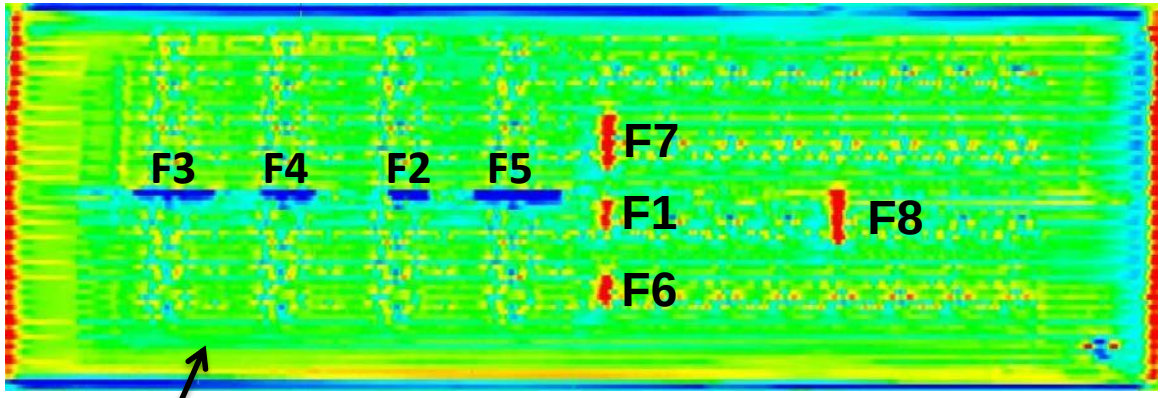
EDM Notches in Simulated Pitting (Up to 1.5mm)

Flaw Id.	Length (mm)	Depth Extent (mm)	Width (mm)	Orientation
F1	10.0	2.5	0.19	Axial
F2	10.0	2.5	0.15	Circumferential
F3	18.0	7.5	0.23	Circumferential
F4	12.0	5.0	0.21	Circumferential
F5	20.0	9.5	0.26	Circumferential
F6	12.0	5.0	0.26	Axial
F7	20.0	8.6	0.23	Axial
F8	18.0	7.5	0.21	Axial

100% Detection (2 Techniques)

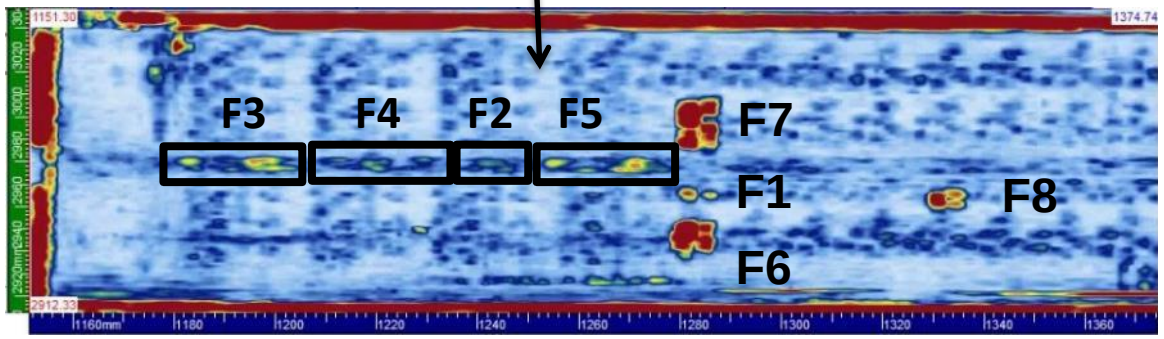
Measurement Impact (Error)

- Depth Extent: -0.3mm to +0.78mm
- Length: -1.98mm to +0.37mm



Eddy Current

Ultrasound



Field Deployment

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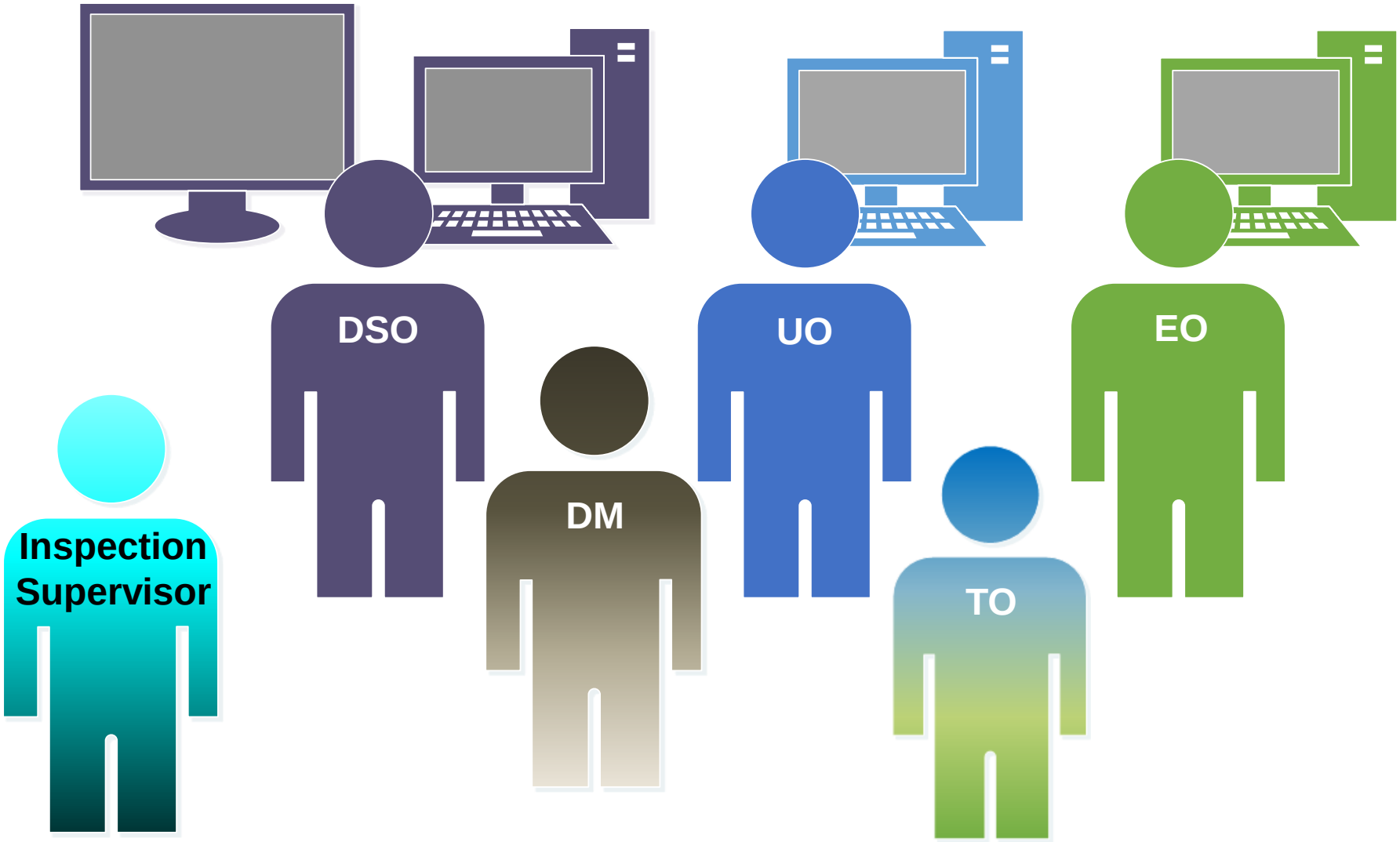
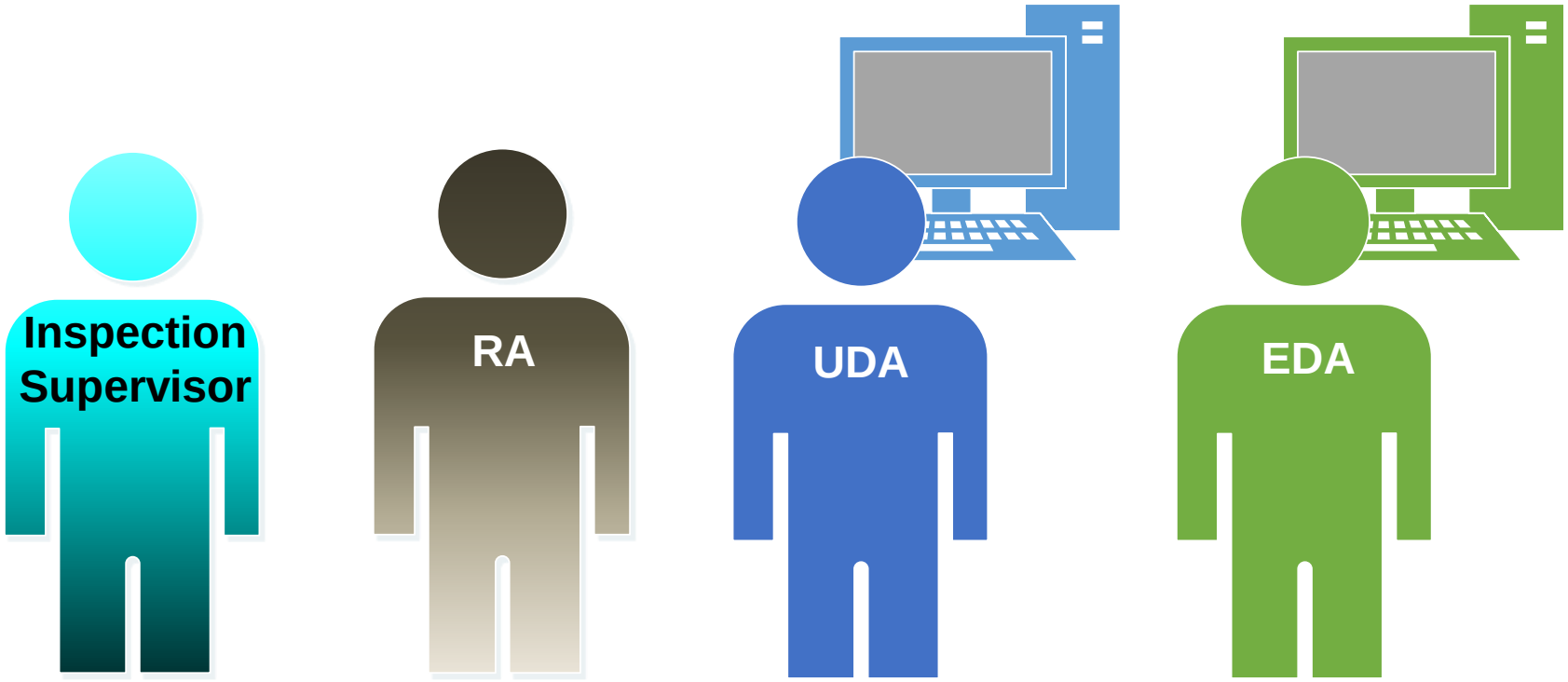
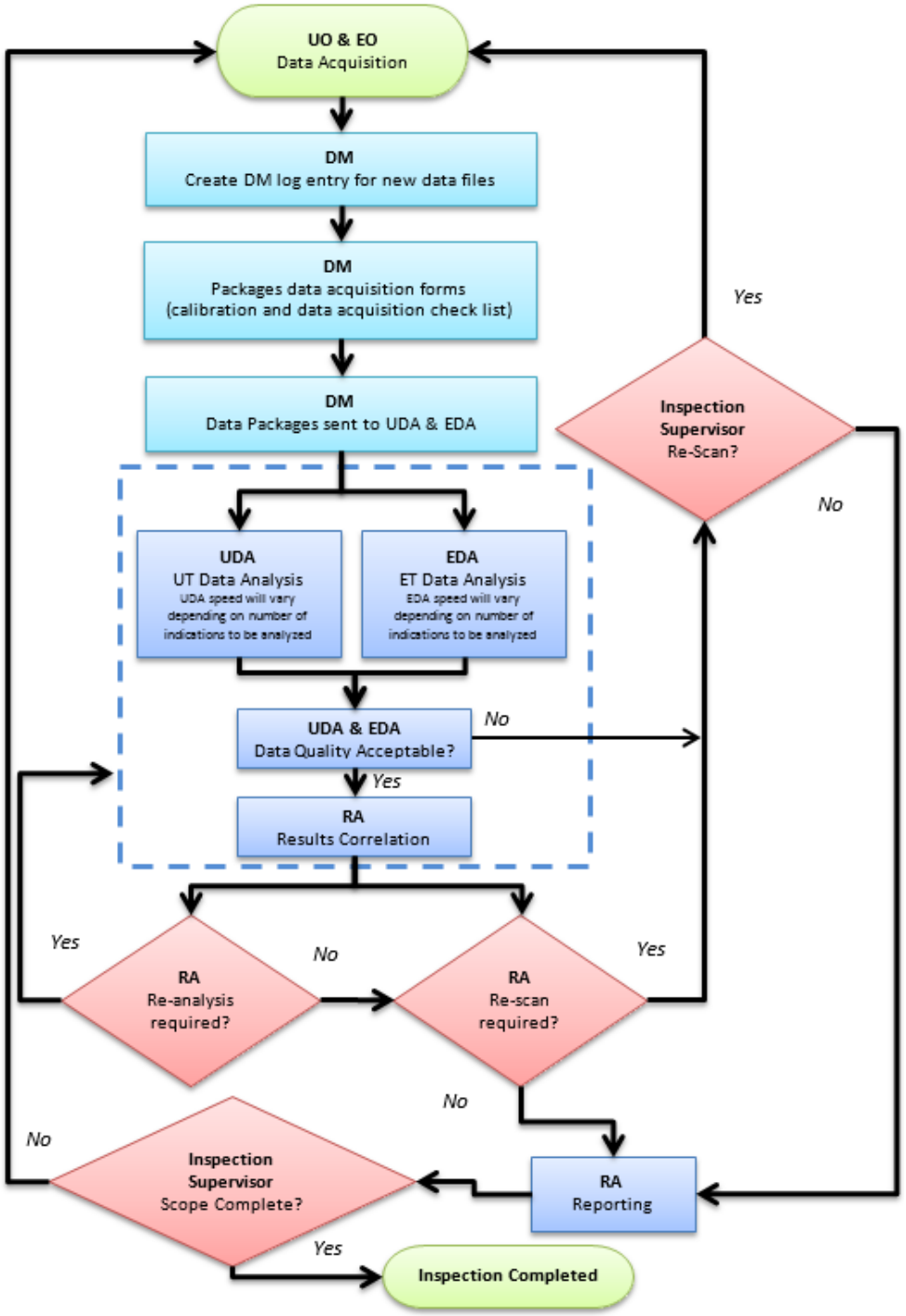
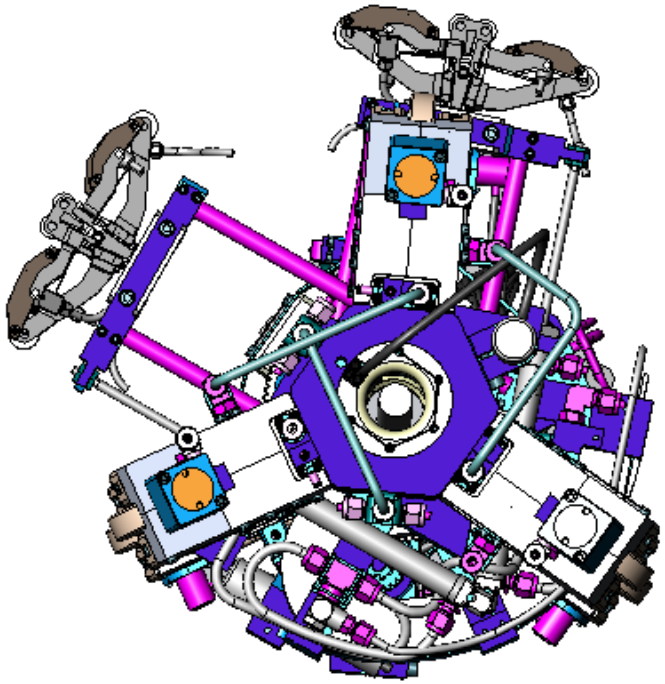


Field Deployment



Field Deployment





Conclusions

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Conclusion

- Performance meeting the required specifications
- First Deployment:
  - Identified the Challenges
  - Overall, *successful* field deployment
- Future Work:
  - Optimize NDE Tooling for Actual Duct Conditions

Question