•Annual Corrosion Forum (ACF)

•Aberdeen Branch - August 2021

•Sponsor: TRAC Oil and Gas

Title: Surface Inspection Techniques

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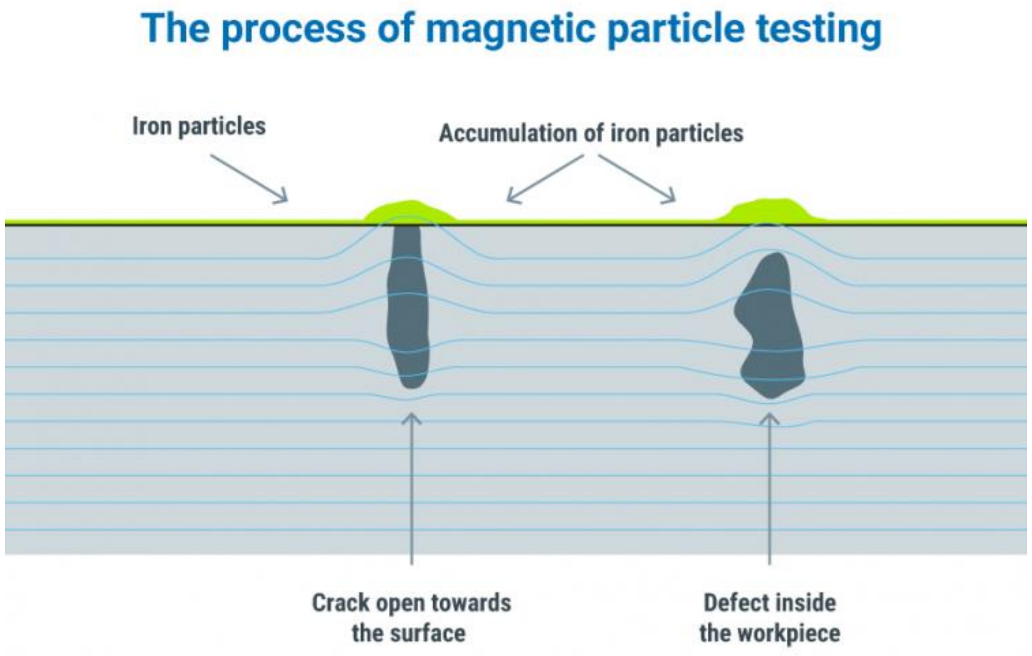
Position: NDT Technical Manager
Company: TRAC Oil & Gas

Magnetic Particle Testing

Magnetic Particle Inspection (MPI) is a non-destructive testing method that can detect surface and subsurface flaws in ferromagnetic materials. Magnetic particle inspection is often carried out to help determine an item's fitness for use or conformity.

- MPI detects surface and near-surface flaws in ferromagnetic materials and is primarily used for crack detection.
- The component is magnetised locally, and if the material is sound the magnetic flux stays predominantly inside the material.
- However, if there is a surface-breaking flaw, the magnetic field is distorted, causing local magnetic flux leakage around the flaw. This leakage flux is displayed by covering the surface with very fine iron particles applied either dry or suspended in a liquid. The particles accumulate at the regions of flux leakage, producing a build-up which can be seen visually even when the crack opening is very narrow. Thus, a crack is indicated as a line of iron powder particles on the surface.

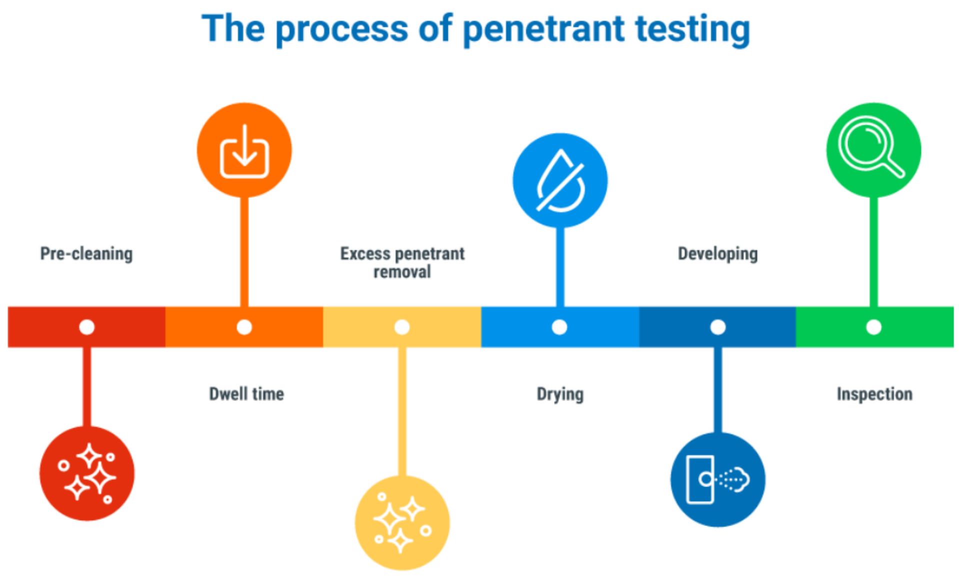


The method is applicable to all metals which can be strongly magnetised – ferritic steels and irons, but not generally austenitic steels.

Liquid Penetrant Inspection (Dye Penetrant)

This is a simple low-cost method of detecting surface-breaking flaws such as cracks, laps, porosity, etc. ***To be detected, the flaw must reach the surface to be tested*.** Penetrant testing is one step up from visual inspection and offers many advantages, such as speed, large-area coverage and cheapness.

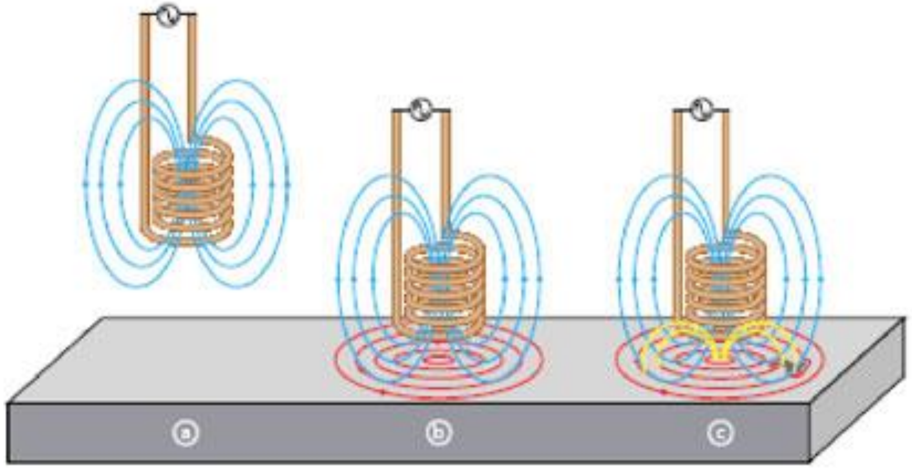
- The components which are to be tested must be cleaned superficially so that the penetrant can penetrate any existing defects. Residues on the surface of the material, such as scale, slag and rust etc. must be removed by brushing, sanding, grinding and, if necessary, by abrasive blasting. Care must be taken to ensure that the faults are not sealed by the cleaning process. The surface of the components must dry without residue.



Eddy Current Inspection

Eddy current NDT can examine large areas very quickly, and it does not require use of coupling liquids. In addition to finding cracks, eddy current can also be used to check metal hardness and conductivity in applications where those properties are of interest, and to measure thin layers of nonconductive coatings like paint on metal parts.

- Eddy current testing is based on the physics phenomenon of electromagnetic induction. In an eddy current probe, an alternating current flows through a wire coil and generates an oscillating magnetic field. If the probe and its magnetic field are brought close to a conductive material like a metal test piece, a circular flow of electrons known as an eddy current will begin to move through the metal like swirling water in a stream. That eddy current flowing through the metal will in turn generate its own magnetic field, which will interact with the coil and its field through mutual inductance. Changes in metal thickness or defects like near-surface cracking will interrupt or alter the amplitude and pattern of the eddy current and the resulting magnetic field. This in turn affects the movement of electrons in the coil by varying the electrical impedance of the coil. The eddy current instrument plots changes in the impedance amplitude and phase angle, which can be used by a trained operator to identify changes in the test piece.



a—The alternating current flowing through the coil at a chosen frequency generates a magnetic field around the coil.

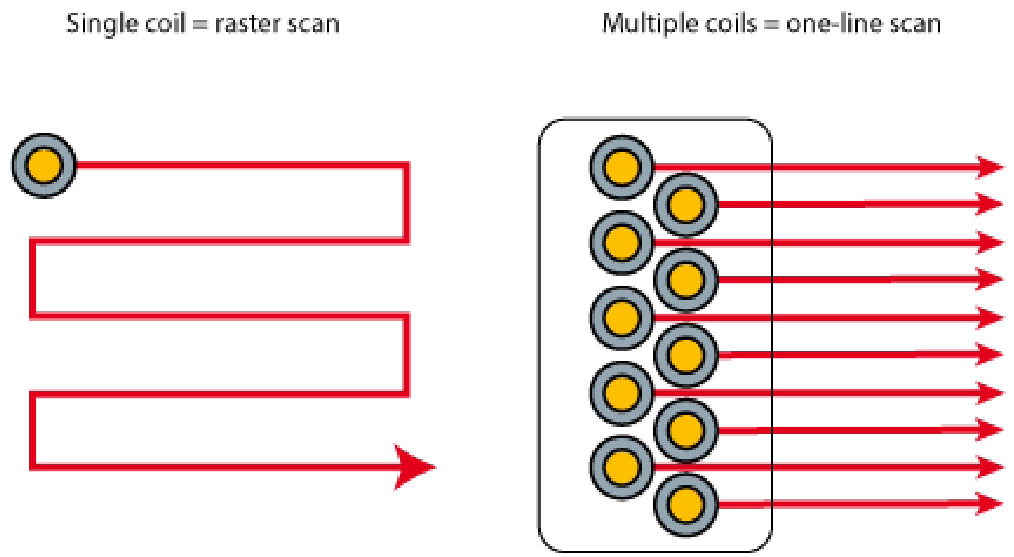
b—When the coil is placed close to an electrically conductive material, eddy current is induced in the material.

c—If a flaw in the conductive material disturbs the eddy current circulation, the magnetic coupling with the probe is changed and a defect signal can be read by measuring the coil impedance variation.

Eddy Current Array Inspection

Eddy current array and conventional eddy current technology share the same basic principle.

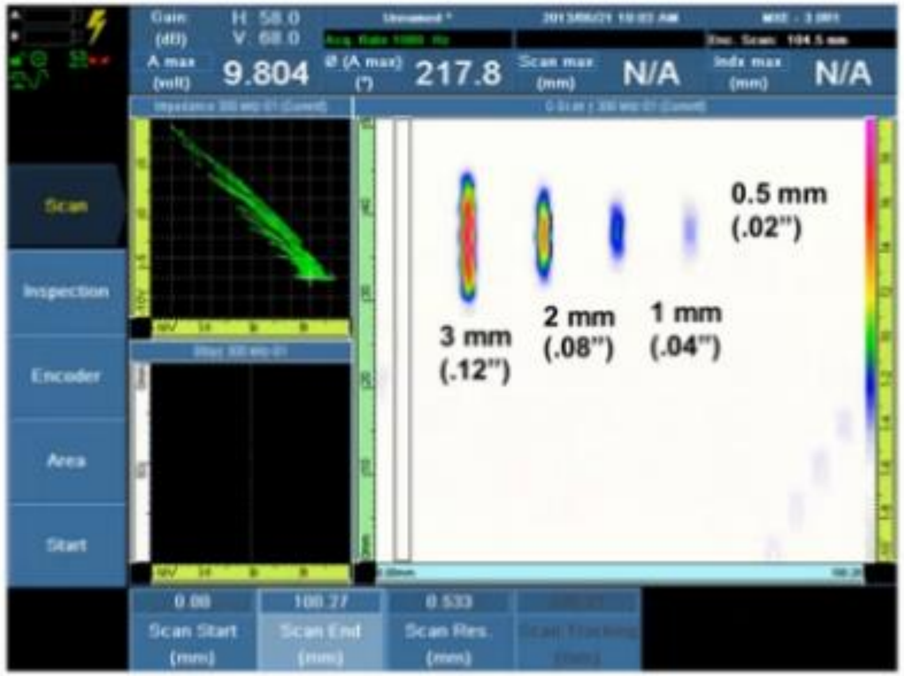
- Eddy current array (ECA) technology provides the ability to electronically drive multiple eddy current coils placed side by side in the same probe assembly. Data acquisition is performed by multiplexing the eddy current coils in a special pattern to avoid mutual inductance between the individual coils.
  Most conventional eddy current flaw detection techniques can be reproduced with an ECA inspection. With the benefits of single-pass coverage, and enhanced imaging capabilities, ECA technology provides a remarkably powerful tool and significant time savings during inspections.



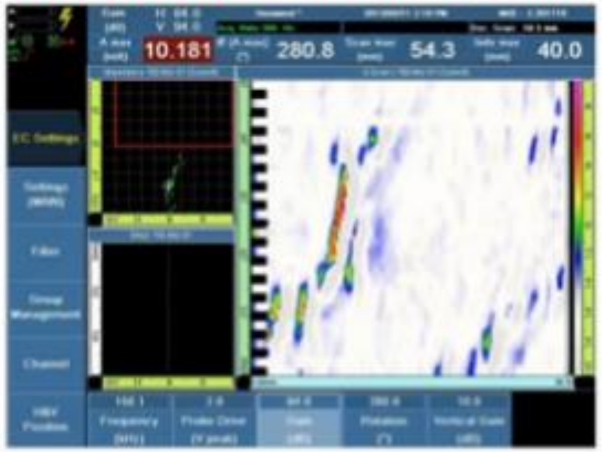
Eddy Current Array Inspection

- Many advantages compared to MPI and Dye Penetrant
- Allows inspection through paint
- Large Area Coverage (probe width)
- Fast Scanning
- Colour Imagery
- Archiving for future Analysis
- Defect Depth Evaluation
- Adaptable to pipe from 1.3" Diameter to flat

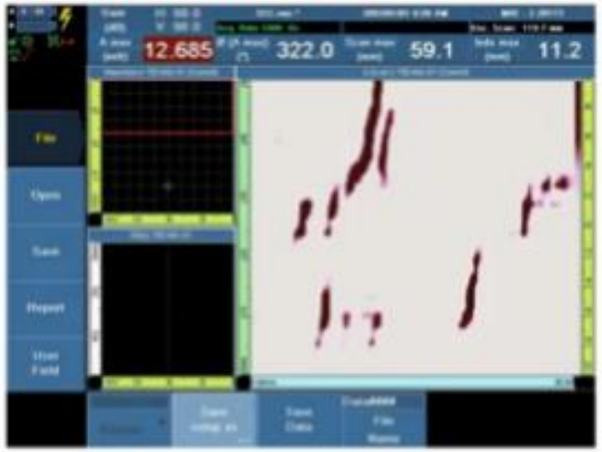
Eddy Current Array Post Process Analysis



Flaw depth evaluation (using color)



Go/No-Go based on a target flaw depth



Pulsed Eddy Current

- PEC is an electromagnetic inspection technique used for measuring the thickness of steel objects (e.g. pipes and vessels) without the need for contact with the surface
- PEC is therefore very suitable for inspections where the surface of an object is not accessible

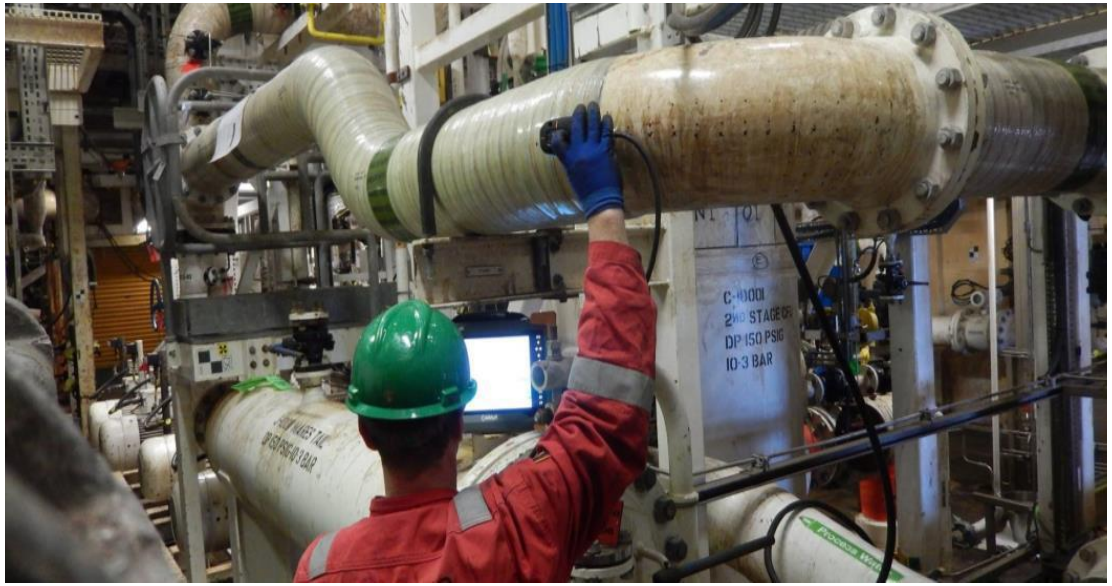
Inspections under non-conductive layers, e.g. engineered wraps and fireproof coatings

Inspections beneath corrosion scabs

Corrosion under insulation (CUI) inspections

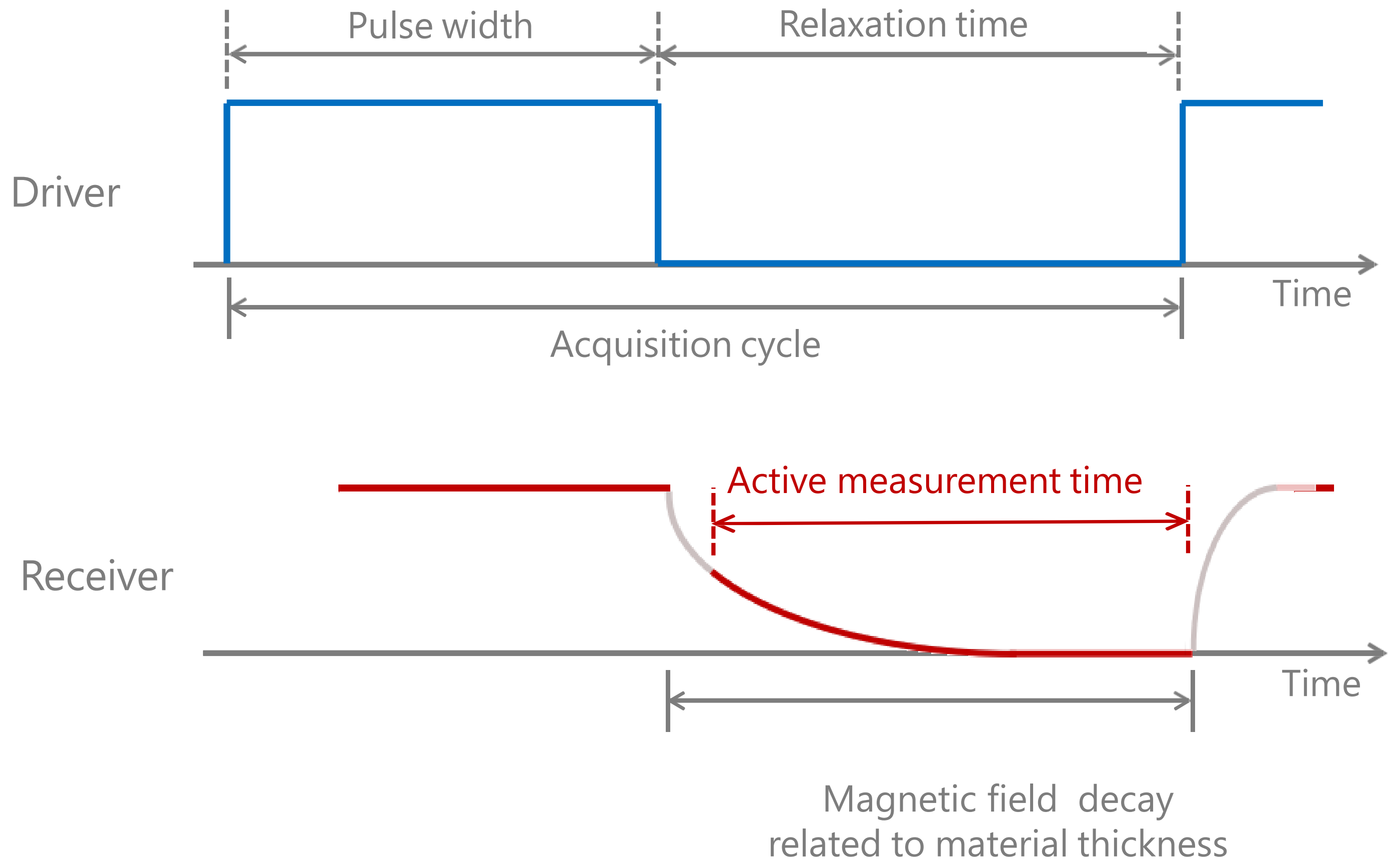
Pulsed Eddy Current

- Readings are generated when a transmitter coil within a protective housing produces a magnetic pulse which induces eddy currents within the component wall
- The eddy currents in turn induce a second magnetic pulse which is detected by a receiving coil
- The system monitors the rate of decay of the eddy current pulse within the steel wall and produces an average thickness value from the comparison of a calibrated signal



Pulsed Eddy Current

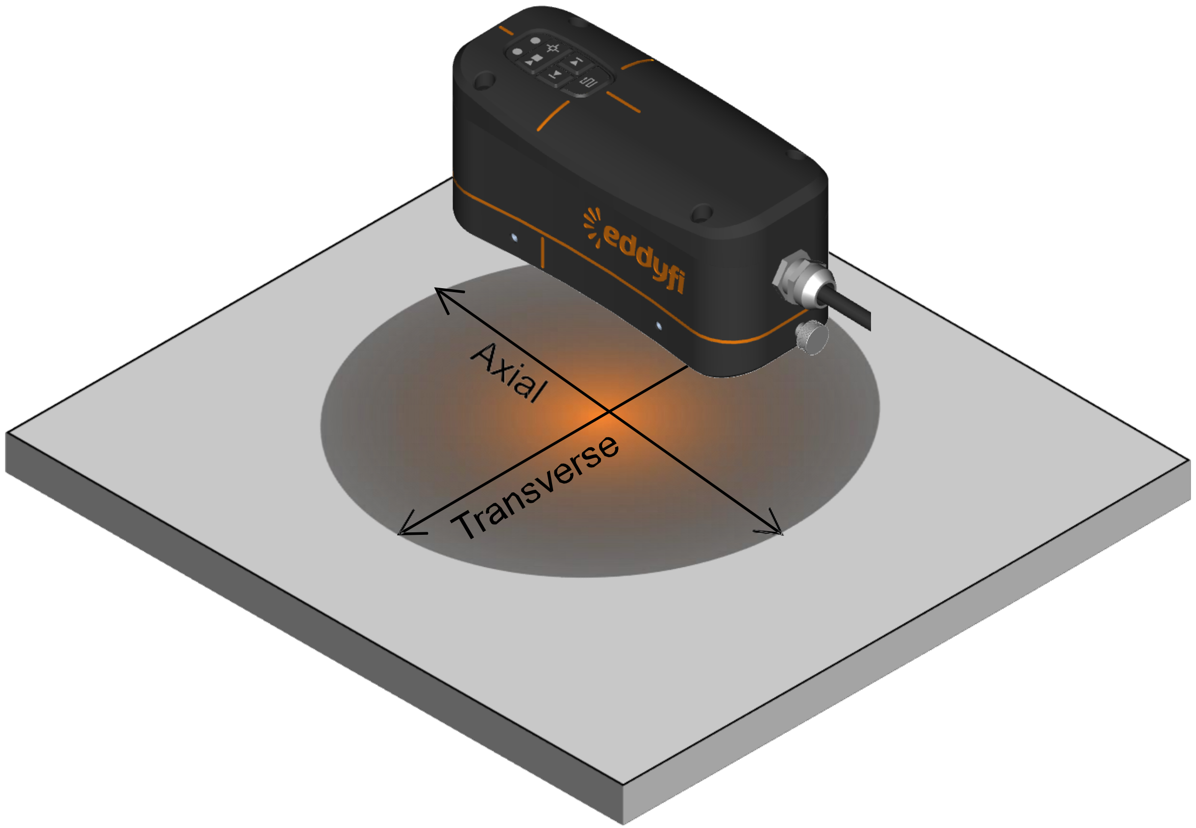
- PEC acquisition cycle



Pulsed Eddy Current

Footprint (FP) represents the surface area seen by the probe and is influenced by:

- Probe size
- Coating/insulation thickness (lift-off)
- Weather jacket material
- Component wall thickness

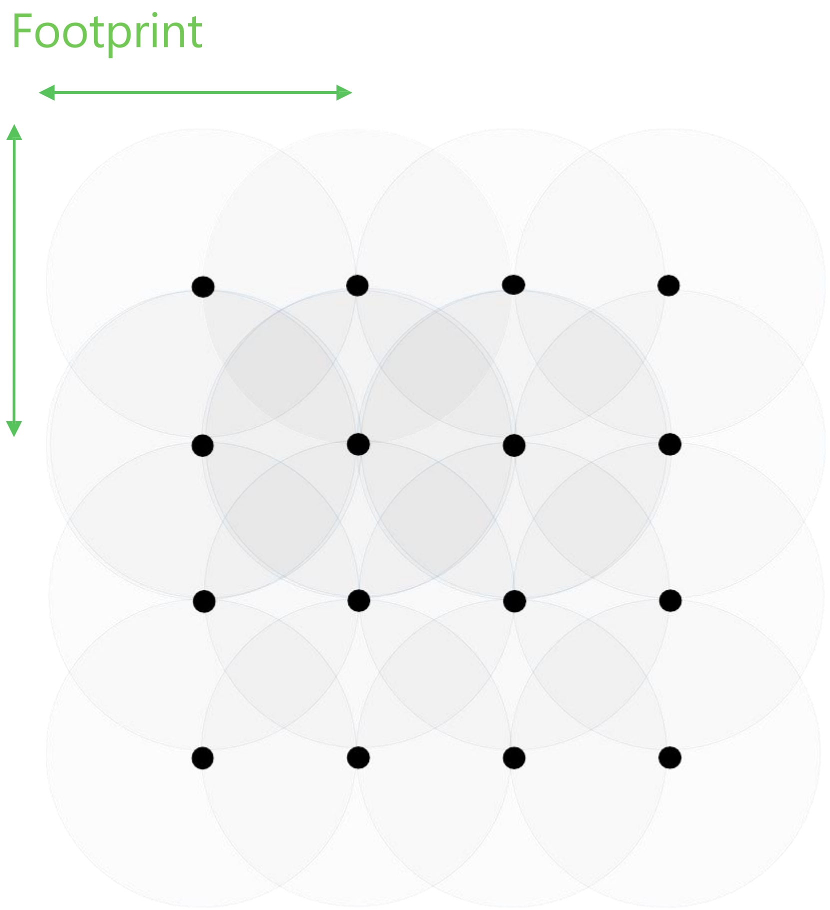


Pulsed Eddy Current

Grid mapping mode for fast screening

FP is a row-column grid resolution

Ensure 50% overlap between acquisition points



Pulsed Eddy Current

Table below provides footprint size compared to lift-off

			Insulation / Coating Thickness (Liftoff)											
			0.0 mm	6.4 mm	12.7 mm	19.1 mm	25.4 mm	38.1 mm	50.8 mm	63.5 mm	76.2 mm	88.9 mm	101.6 mm	127.0 mm	152.4 mm
			0.00 in	0.25 in	0.50 in	0.75 in	1.00 in	1.50 in	2.00 in	2.50 in	3.00 in	3.50 in	4.00 in	5.00 in	6.00 in
Footprint	PEC-025	mm	35.0	39.2	43.3	47.4	51.5	–	–	–	–	–	–	–	–
		in	1.38	1.54	1.70	1.87	2.03	–	–	–	–	–	–	–	–
	PEC-089	mm	62.0	66.2	70.3	74.4	78.5	86.8	95.0	103.3	111.5	119.8	–	–	–
		in	2.44	2.61	2.77	2.93	3.09	3.42	3.74	4.07	4.39	4.72	–	–	–
	PEC-152	mm	100.0	104.2	108.3	112.4	116.5	124.8	133.0	141.3	149.5	157.8	166.0	182.6	199.1
		in	3.94	4.10	4.26	4.43	4.59	4.91	5.24	5.56	5.89	6.21	6.54	7.19	7.84

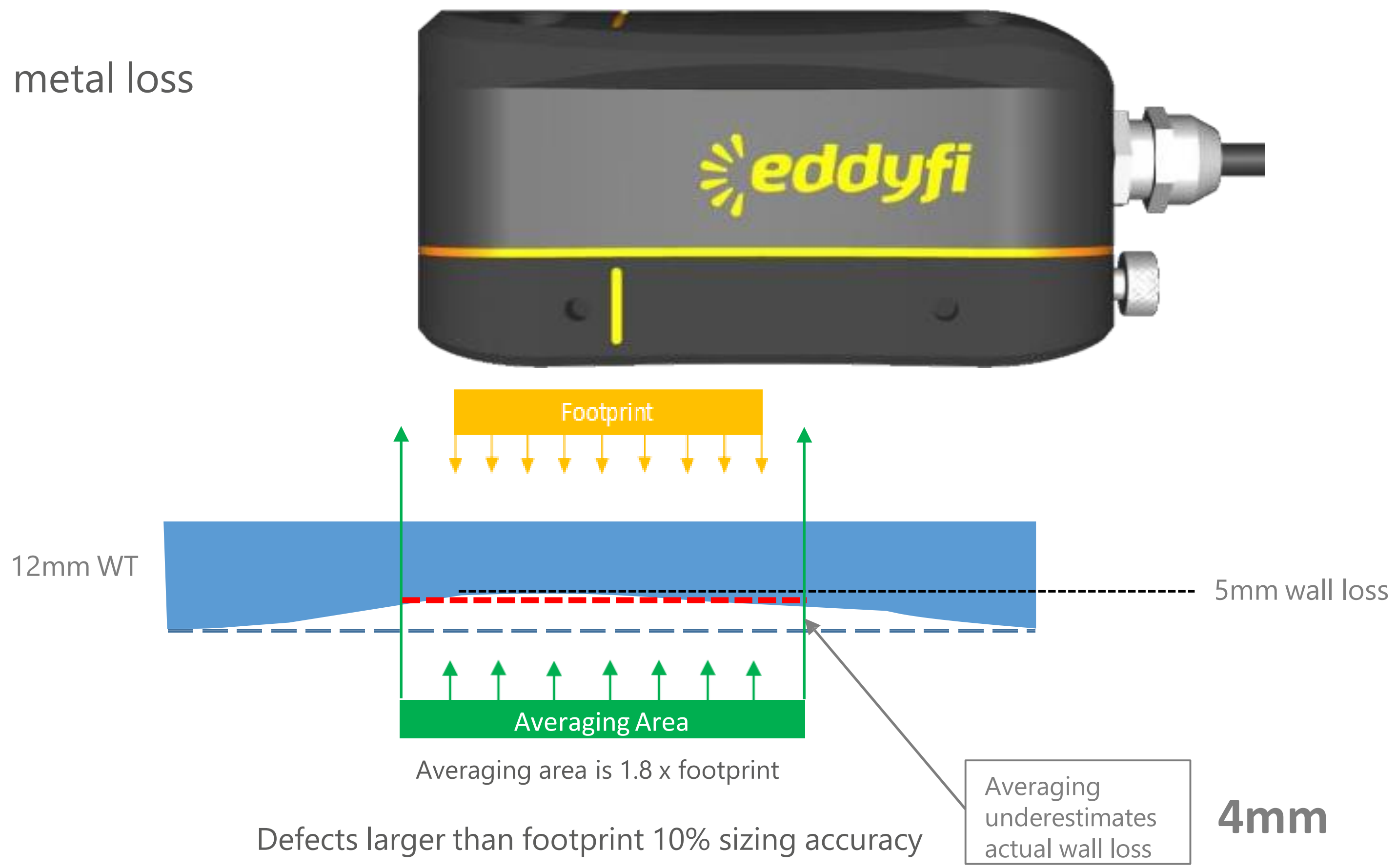
$$FP \approx 0.65 \times LO + FP_0$$

PEC-025: FP0 = 35 mm (1.38”)
PEC-089: FP0 = 62 mm (2.44”)
PEC-152: FP0 = 100 mm (3.94”)

Pulsed Eddy Current

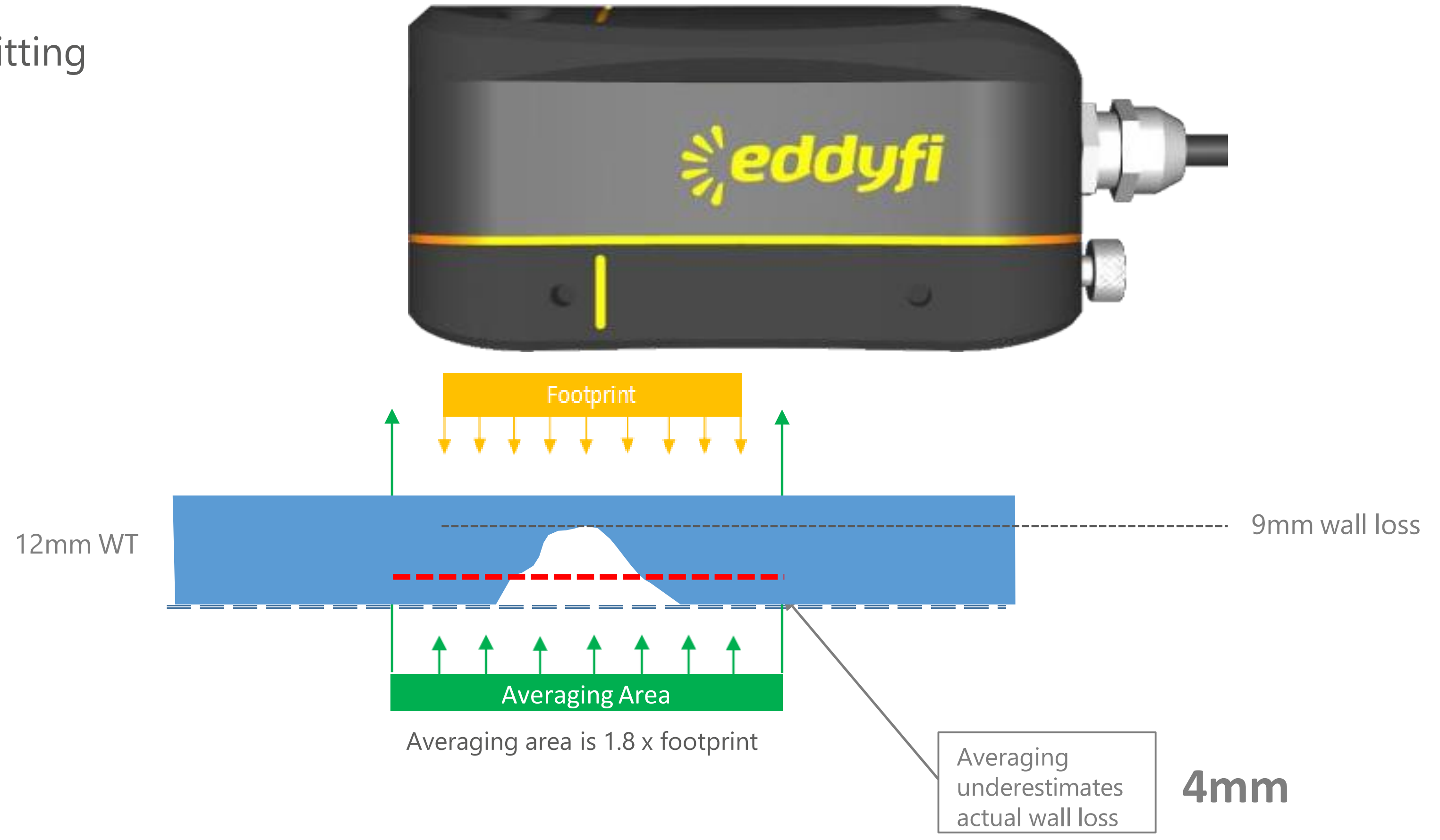
Pulsed Eddy Current

Example: General metal loss



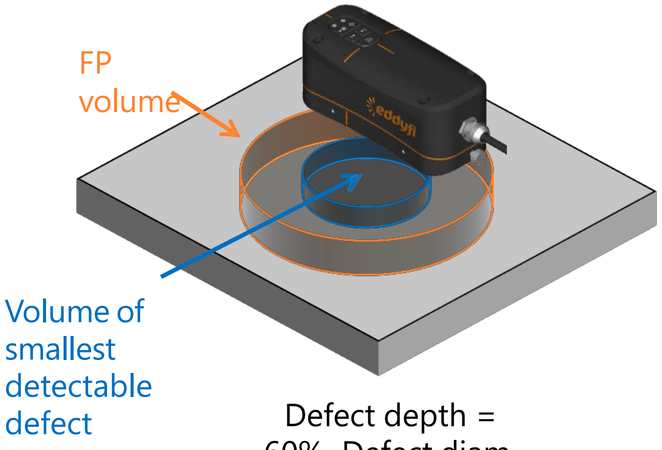
Pulsed Eddy Current

Example: Isolated pitting

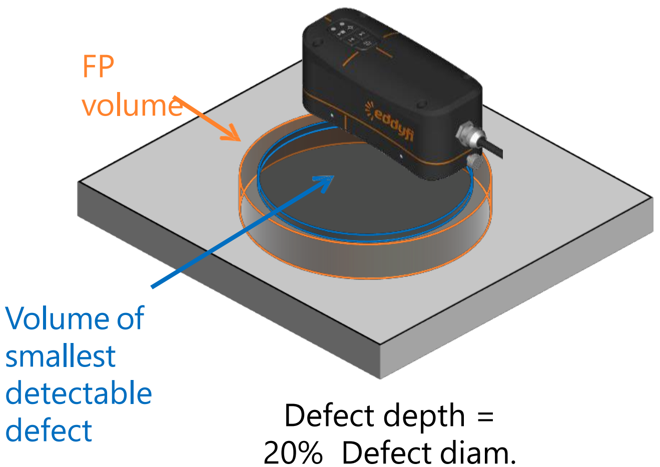


Determining the smallest detectable defect:

- The smallest detectable defect volume is 15% of footprint volume
- Example: PEC-089 probe + 50.8 mm (2”) insulation, FP approx. 95 mm (3.75”)



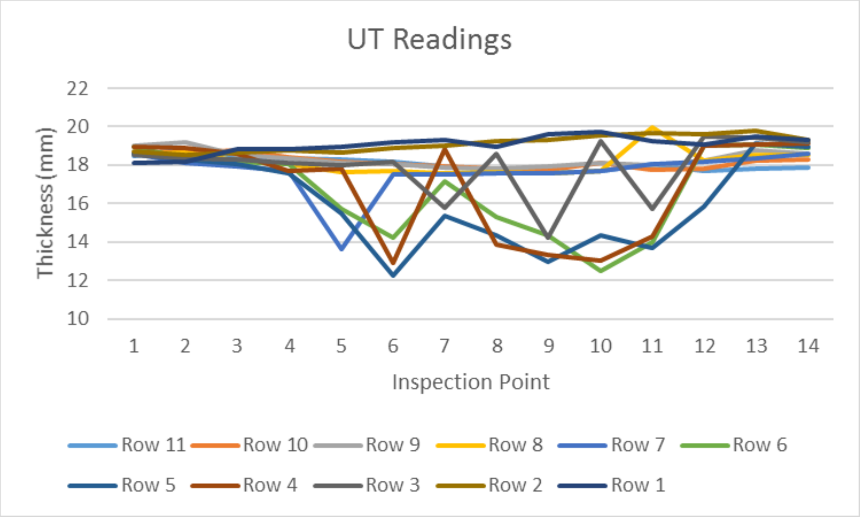
Defect depth =
60% Defect diam.
= 47.5 mm (1.87 in)

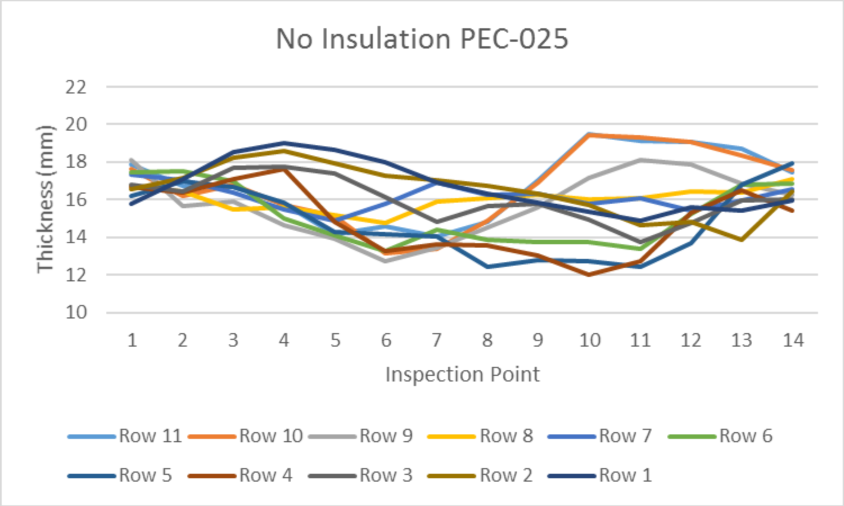


Defect depth =
20% Defect diam.
= 82.0 mm (3.25 in)

Smaller diameter defects can be detected if depth is increased to maintain a minimum volume ratio of 15% with the footprint

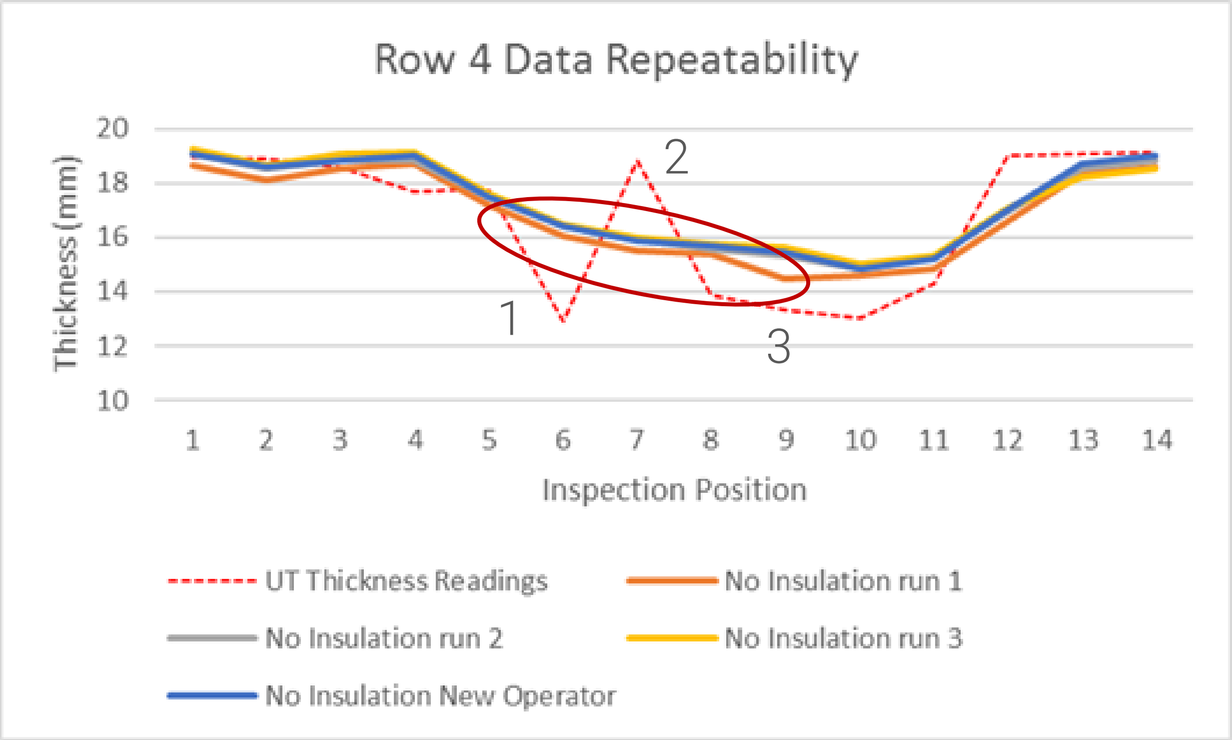
Pulsed Eddy Current v Ultrasonics





Pulsed Eddy Current v Ultrasonics

- Averaging Effect
- Point 1 a Dip
- Point 2 A Peak
- Point 3 PEC Averaging



Pulsed Eddy Current Example

	A	B	C	D	E	F	G	H	I	J	K
1	96	96	98	100	100	97	90	92	92	90	90
2	97	95	99	100	102	96	87	92	92	90	93
3	97	97	98	100	101	94	84	91	91	91	92
4	95	96	98	99	99	91	79	90	91	93	92
5	94	97	98	97	96	91	76	89	90	92	92
6	94	95	94	94	93	84	74	91	92	93	90
7	94	92	90	91	84	74	75	91	91	89	90
8	94	92	92	90	82	74	76	88	89	90	90
9	92	94	93	89	83	76	77	92	93	92	89
10	95	93	91	91	86	81	84	95	95	94	91
11	96	94	92	92	92	90	90	95	95	93	92
12	94	95	95	95	95	95	90	93	95	96	95
13	96	96	97	95	94	93	92	90	96	96	95
14	97	95	94	92	92	96	97	91	96	94	88
15	98	93	92	92	91	91	96	95	96	95	88
16	98	95	95	94	91	92	97	96	97	94	93

Pallete 1

Level

110.0

75.0

55.0

50.0

	A	B	C	D	E	F	G	H	I	J	K
1	96	96	98	100	100	97	90	92	92	90	90
2	97	95	99	100	102	96	87	92	92	90	93
3	97	97	98	100	101	94	84	91	91	91	92
4	95	96	98	99	99	91	79	90	91	93	92
5	94	97	98	97	96	91	76	89	90	92	92
6	94	95	94	94	93	84	74	91	92	93	90
7	94	92	90	91	84	74	75	91	91	89	90
8	94	92	92	90	82	74	76	88	89	90	90
9	92	94	93	89	83	76	77	92	93	92	89
10	95	93	91	91	86	81	84	95	95	94	91
11	96	94	92	92	92	90	90	95	95	93	92
12	94	95	95	95	95	95	90	93	95	96	95
13	96	96	97	95	94	93	92	90	96	96	95
14	97	95	94	92	92	96	97	91	96	94	88
15	98	93	92	92	91	91	96	95	96	95	88
16	98	95	95	94	91	92	97	96	97	94	93

Pallete 5

Level

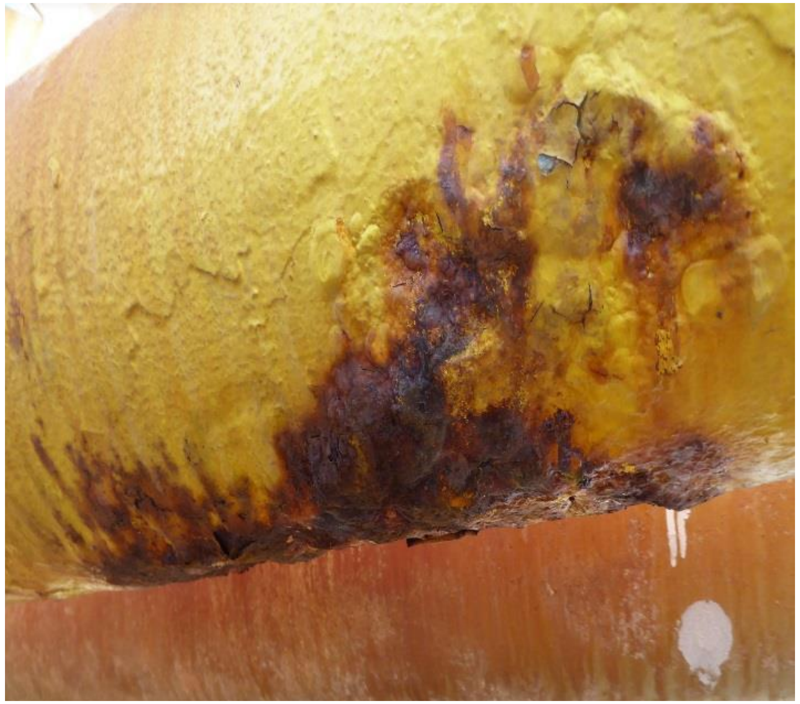
120.0

90.0

80.0

70.0

Pulsed Eddy Current Example



	A	B	C	D	E	F	G	H	I	J	K	L
1	100	97	96	91	92	91	92	97	94	91	94	94
2	100	97	97	95	93	89	87	94	95	94	94	93
3	94	94	92	94	90	88	88	85	92	91	91	92
4	95	89	89	89	89	88	85	75	76	83	90	91
5	97	88	87	85	83	86	86	74	71	76	88	89
6	94	93	91	84	80	83	84	76	70	72	84	86
7	96	97	95	85	81	81	81	77	69	72	83	85
8	100	97	95	86	85	82	77	77	75	81	94	90
9	101	89	85	82	84	76	75	77	84	87	92	91
10	96	84	80	79	73	71	73	84	94	95	94	93
11	93	86	85	71	68	70	73	89	97	95	95	92
12	93	84	81	70	67	71	75	90	98	95	97	93
13	93	86	82	74	75	76	79	91	95	98	96	93
14	97	90	87	82	79	79	80	95	98	97	95	93
15	96	93	92	91	84	81	81	93	100	96	98	95

Pallete 1

Level
110.0
75.0
55.0
50.0

	A	B	C	D	E	F	G	H	I	J	K	L
1	100	97	96	91	92	91	92	97	94	91	94	94
2	100	97	97	95	93	89	87	94	95	94	94	93
3	94	94	92	94	90	88	88	85	92	91	91	92
4	95	89	89	89	89	88	85	75	76	83	90	91
5	97	88	87	85	83	86	86	74	71	76	88	89
6	94	93	91	84	80	83	84	76	70	72	84	86
7	96	97	95	85	81	81	81	77	69	72	83	85
8	100	97	95	86	85	82	77	77	75	81	94	90
9	101	89	85	82	84	76	75	77	84	87	92	91
10	96	84	80	79	73	71	73	84	94	95	94	93
11	93	86	85	71	68	70	73	89	97	95	95	92
12	93	84	81	70	67	71	75	90	98	95	97	93
13	93	86	82	74	75	76	79	91	95	98	96	93
14	97	90	87	82	79	79	80	95	98	97	95	93
15	96	93	92	91	84	81	81	93	100	96	98	95

Pallete 5

Level
120.0
90.0
80.0
70.0

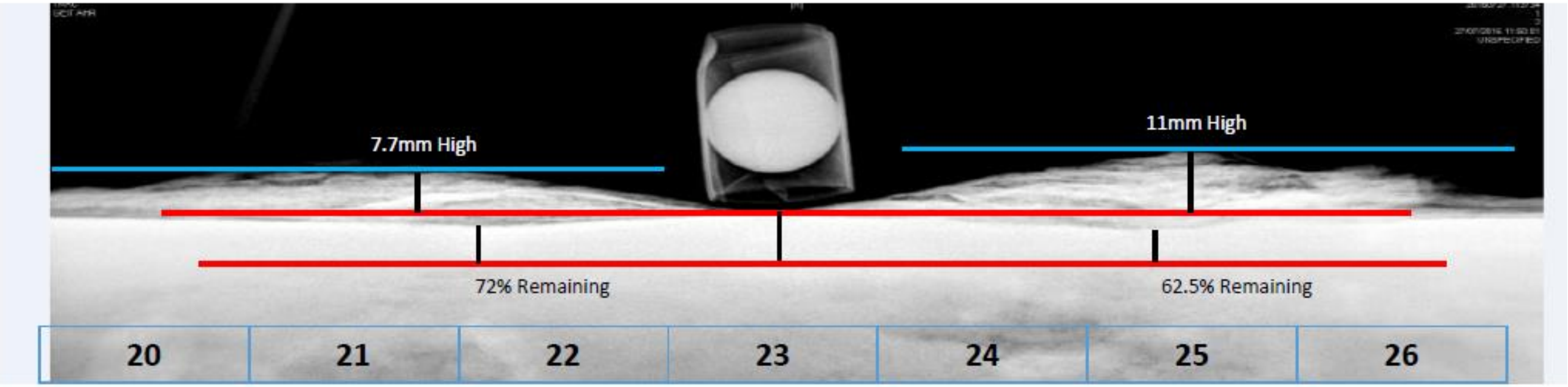
Pulsed Eddy Current Example

	A	B	C	D	E	F	G	H	I	J	K	L
1	81	78	76	77	84	79	76	90	91	91	92	92
2	95	89	90	79	83	89	91	91	91	92	92	92
3	96	90	88	77	81	85	87	90	90	91	91	92
4	97	91	86	75	77	80	82	87	89	89	90	90
5	97	92	87	73	73	70	76	84	86	89	90	88
6	97	94	87	68	58	51	63	77	81	83	85	80
7	99	92	84	64	54	50	61	78	81	82	83	81
8	100	92	80	60	53	50	64	80	82	82	82	84
9	98	90	71	60	51	50	65	81	82	83	83	83
10	95	87	74	59	53	54	72	81	83	84	84	85
11	94	86	77	64	60	64	77	82	84	85	85	86
12	93	90	86	72	70	73	79	83	84	86	85	85
13	95	95	92	80	75	79	83	84	84	86	86	84
14	95	95	94	81	75	83	84	86	86	88	87	84
15	94	92	87	78	75	80	83	87	87	88	87	85
16												

Pulsed Eddy Current Example

- Nominal 7.92mm
- PEC (48% Remaining) 3,8mm
- Measured remaining before wrap applied 3mm

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	1
B	61	61	61	60	60	60	61	61	63	64	64	64	63	63	
C	63	62	61	59	58	58	59	60	61	62	64	65	65	65	
D	66	64	61	58	56	52	48	50	60	64	65	66	66	67	
E	86	83	81	80	74	60	50	65	73	81	83	88	90	94	
F	93	90	88	88	88	86	93	97	95	96	95	93	92	93	
G	96	93	91	92	93	94	99	99	103	104	103	101	99	98	
H	98	95	93	94	97	101	102	104	105	106	107	105	101	101	
I	100	99	96	94	94	98	101	103	103	105	107	108	106	101	
J															



10.8	9.9	9.6	9.9	8.0	9.4	10.3
10.6	9.7	8.7	9.3	8.3	8.0	9.6
9.7	8.5	8.4	8.3	7.4	6.1	7.4
20	21	22	23	24	25	26

End of Presentation – Your Questions Please