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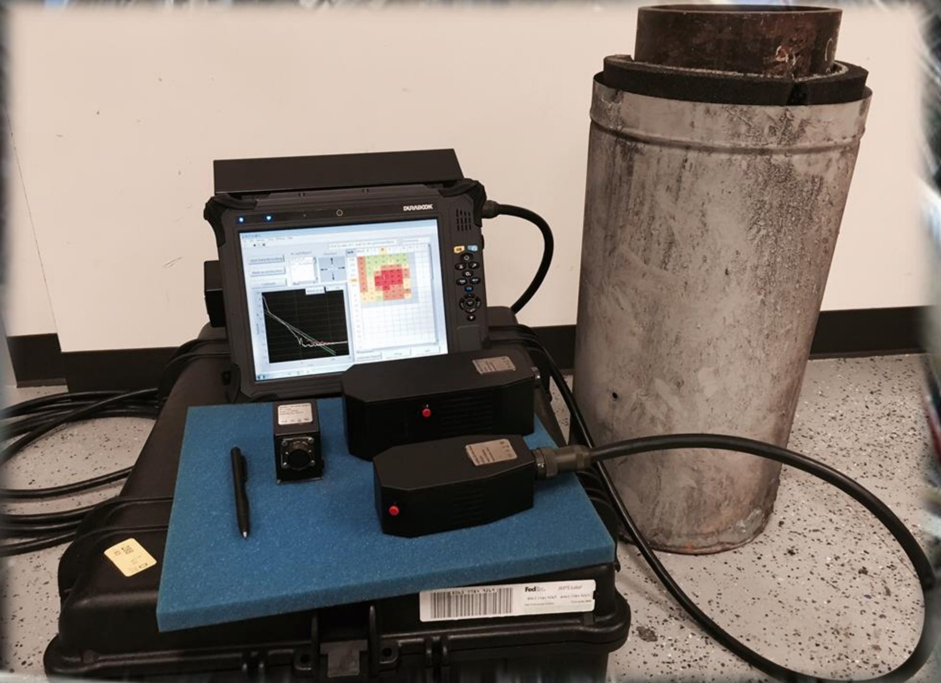
Pulsed Eddy Current Testing (PECT)

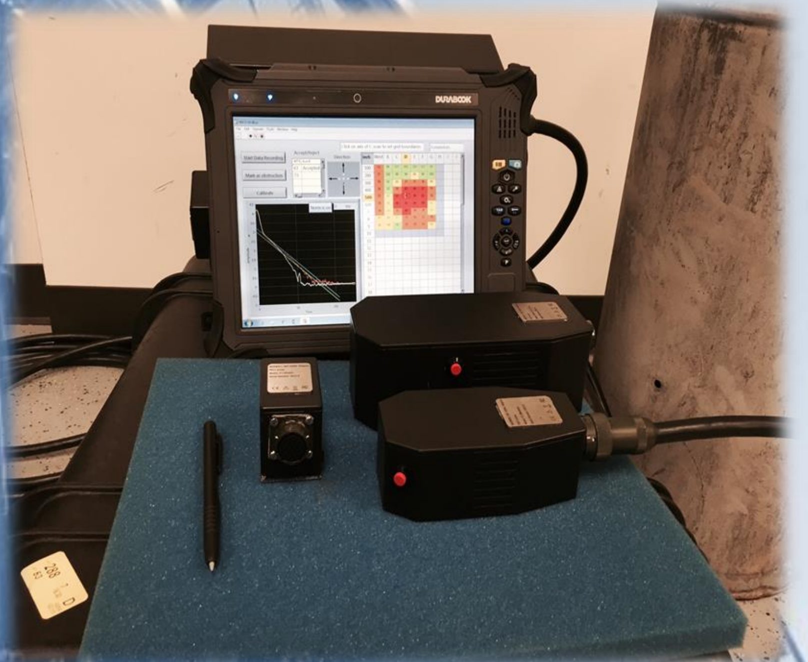


Pulsed Eddy Current Testing: measures steel thickness through insulation

Early tool (late 1990's):

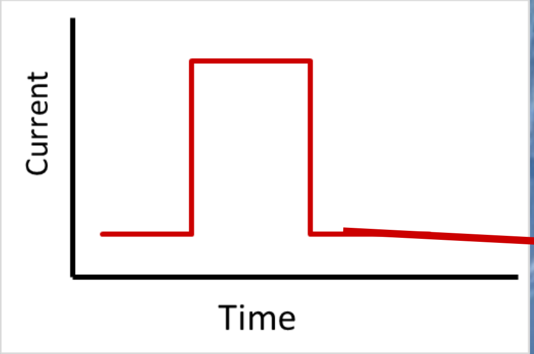
Actual tool (2015)

PEC instrument developed by Shell

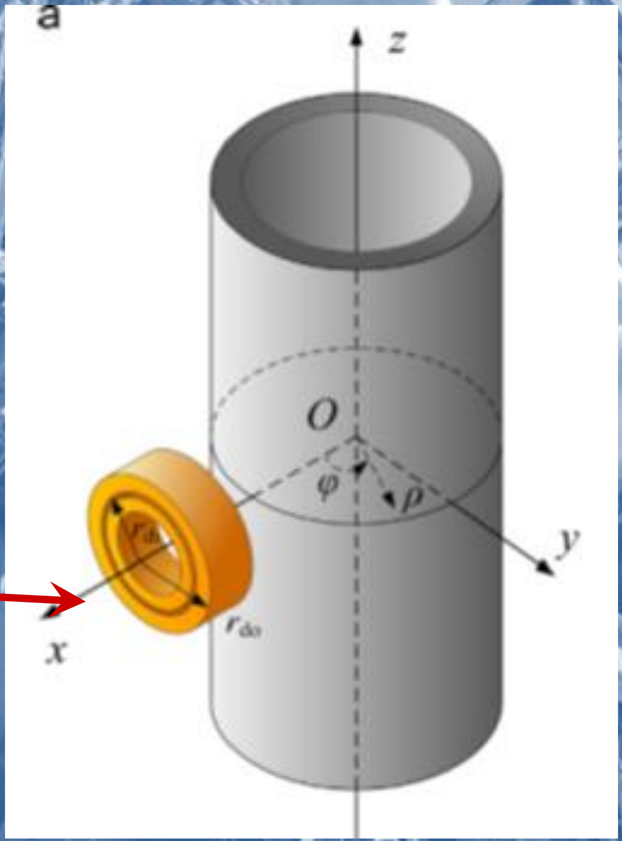


PEC instrument developed by Maxwell NDT

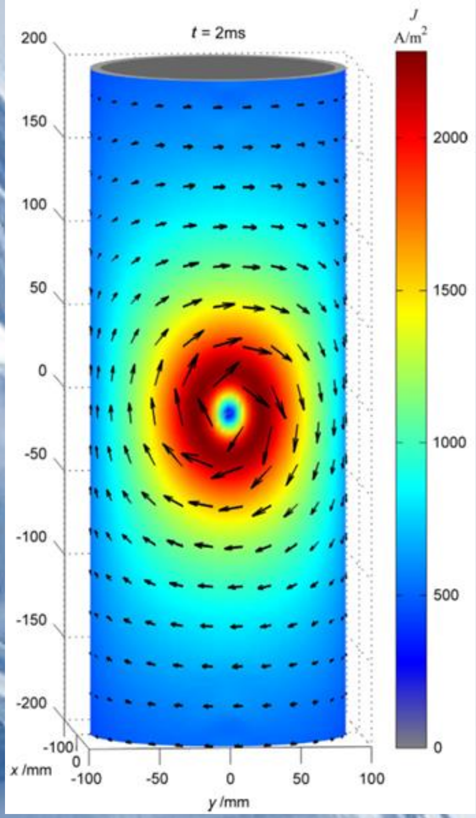
Principle of Pulsed Eddy Current Testing:
Step 1: induce eddy currents in steel with a pulsed magnetic field



Pulsed electrical current transmission coil of probe



Carbon steel pipe



Induced electrical current in steel pipe wall

Principle of Pulsed Eddy Current Testing:
Step 2: Measure time it takes for eddy currents to diffuse in steel

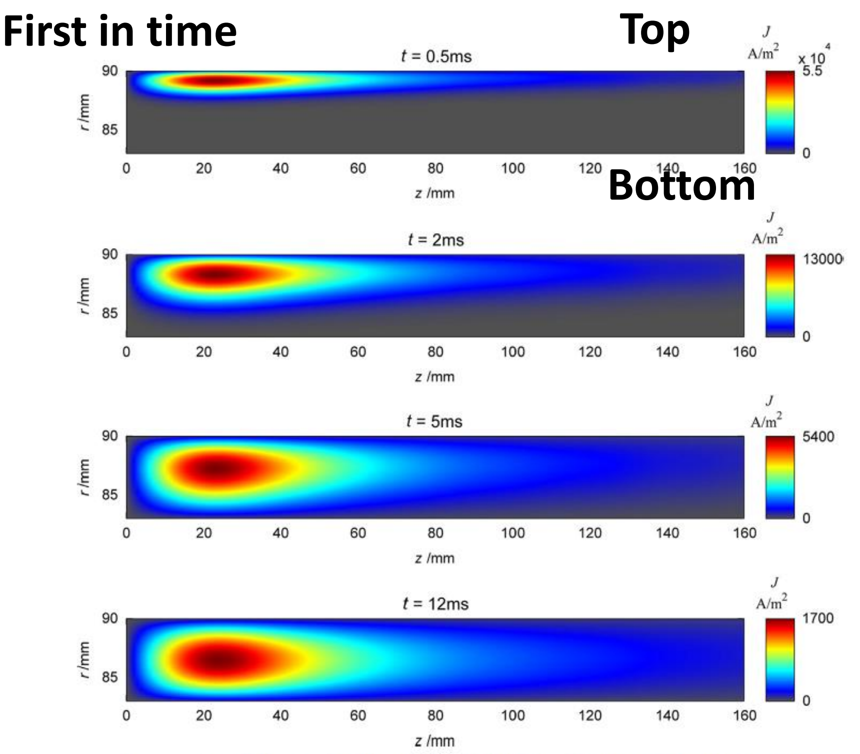
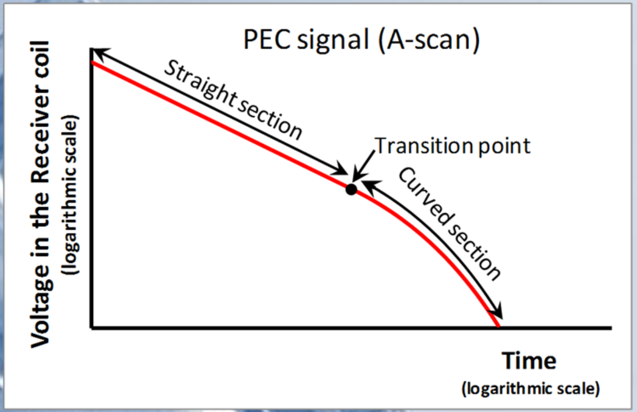
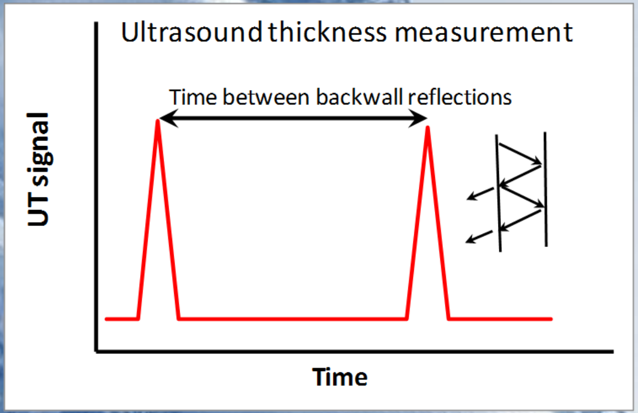


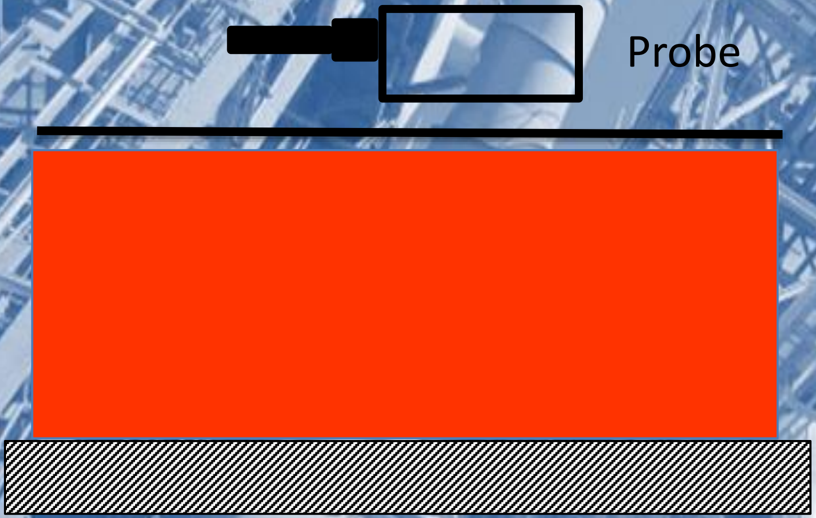
Fig. . The diffusion process of the pulsed eddy current density in the cross section of ($\varphi=0$, $z \geq 0$).





Determine steel thickness from diffusion time

Main benefit of PECT: can measure through most materials



Probe

Metal insulation cover

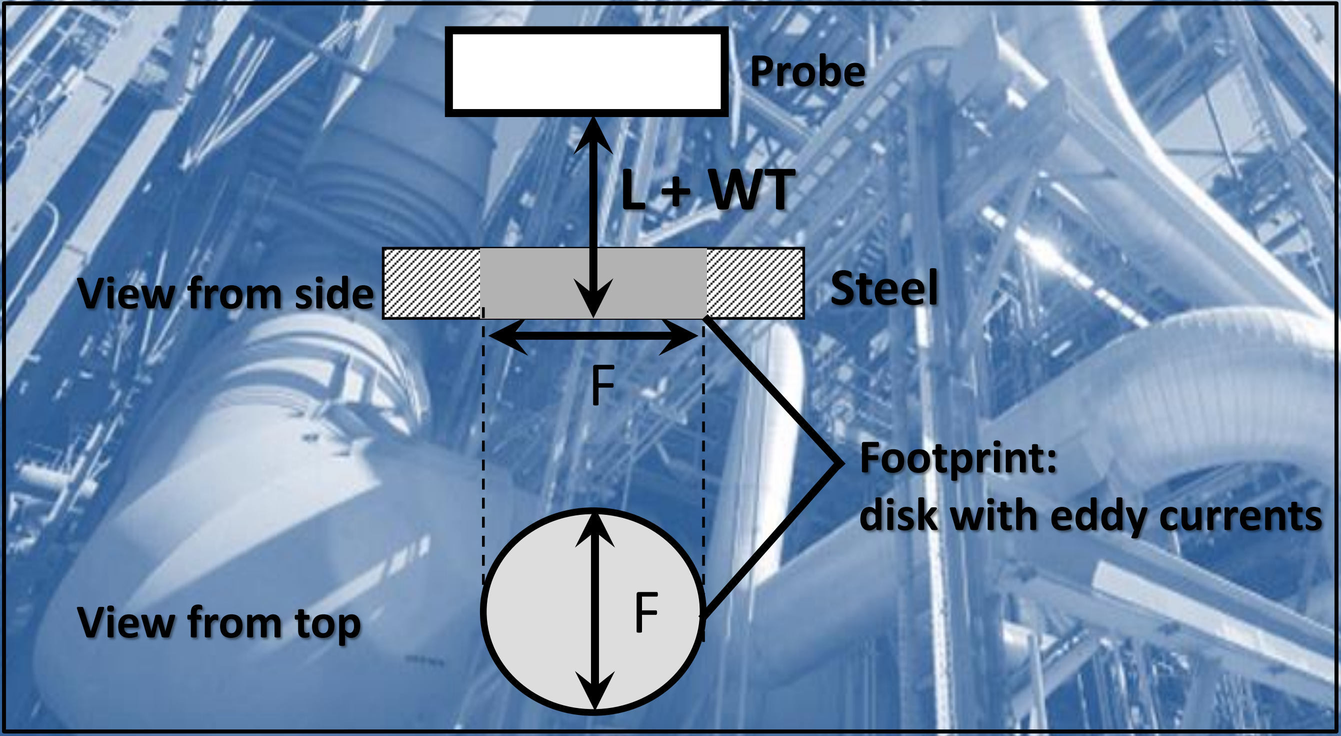
Material between probe and steel:
insulation material, chicken wire, straps, concrete
re-inforcement bars, corrosion product,
sea water, marine growth, bitumen, etc.

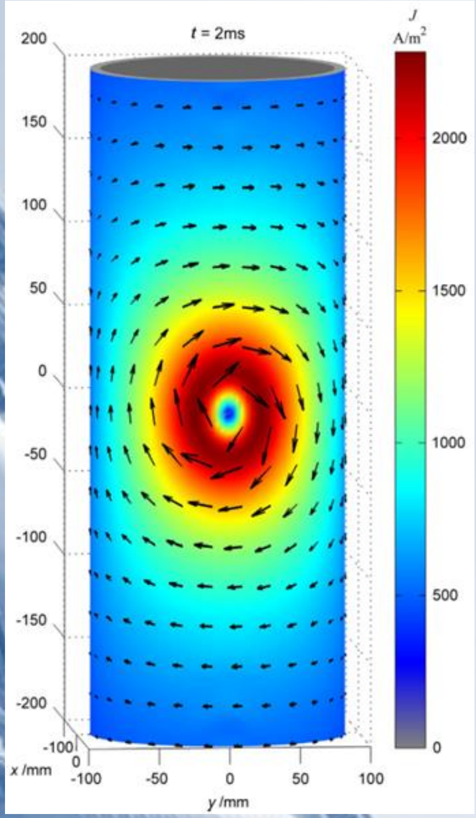
Steel

Restrictions:

1. **Loose chicken wire**
   (rarely observed in insulated equipment, when insulation seriously deteriorated)
2. **Galvanised insulation covers**
   (performance depends on properties insulation covers)
3. **Close to supports and flanges**
   (requires special precautions during the inspection)

Main limitation: PECT averages over a footprint

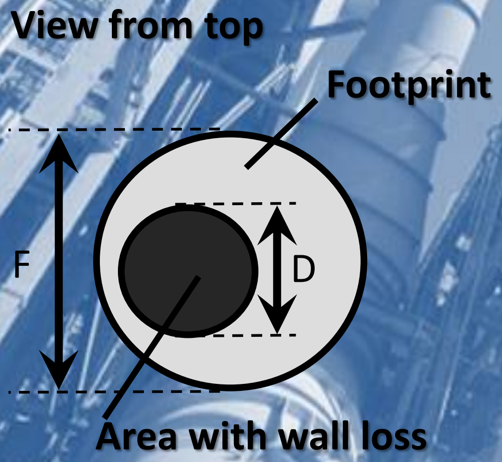




$$\text{Diameter Footprint} = F \approx 1.5 \text{ x } (L + WT)$$

$$\text{Minimum footprint} = 1'' \, (= 25\text{mm})$$

Example



$$2''\ \text{insulation and}\ 0.250''\ \text{wall thickness}$$

$$F \approx 1.5 \times (2'' + 0.250'') = 3.375''$$

$$1.5''\ \text{diameter defect with 50\% wall loss in}\ 3.375''\ \text{footprint}$$

$$\text{PEC reading} \approx 50\% \left(\frac{1.5}{3.375} \right)^2 = 10\%$$

$$2.5''\ \text{diameter defect with 50\% wall loss in}\ 3.375''\ \text{footprint}$$

$$\text{PEC reading} \approx 50\% \left(\frac{2.5}{3.375} \right)^2 = 27\%$$

$$3.375''\ \text{diameter defect with 50\% wall loss in}\ 3.375''\ \text{footprint}$$

$$\text{PEC reading} \approx 50\% \left(\frac{3.375}{3.375} \right)^2 = 50\%$$

Rule of thumb: if the diameter of the area with wall loss is….	
Smaller than ½ Footprint	PEC will not detect wall loss
Between ½ and 1 Footprint	PEC will detect, but underestimate wall loss
Larger than Footprint	PEC will detect and correctly size the average WT

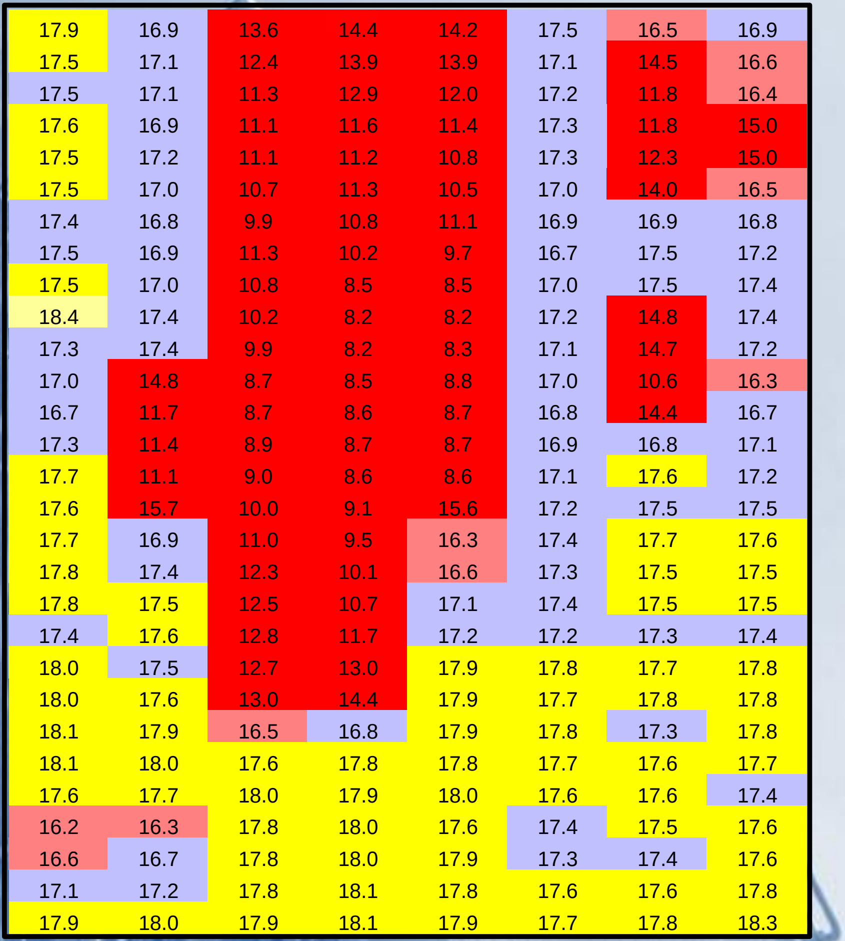
Other Limitation : PECT measures percentage variations in steel thickness. So: not in inches, but in % . You need 1 calibration spot to covert % to inch

When to apply PECT?
Condition 1: General corrosion, not isolated pitting
Condition 2: Conventional techniques (UT, Radiography) not possible

Examples:

- Corrosion under insulation
- Corrosion under fire proofing
- Remaining wall thickness under heavy corrosion
- Repair wraps
- Monitoring; repeat surveys
- Offshore structures (splash zone)
- Underwater inspections
- Flow accelerated corrosion

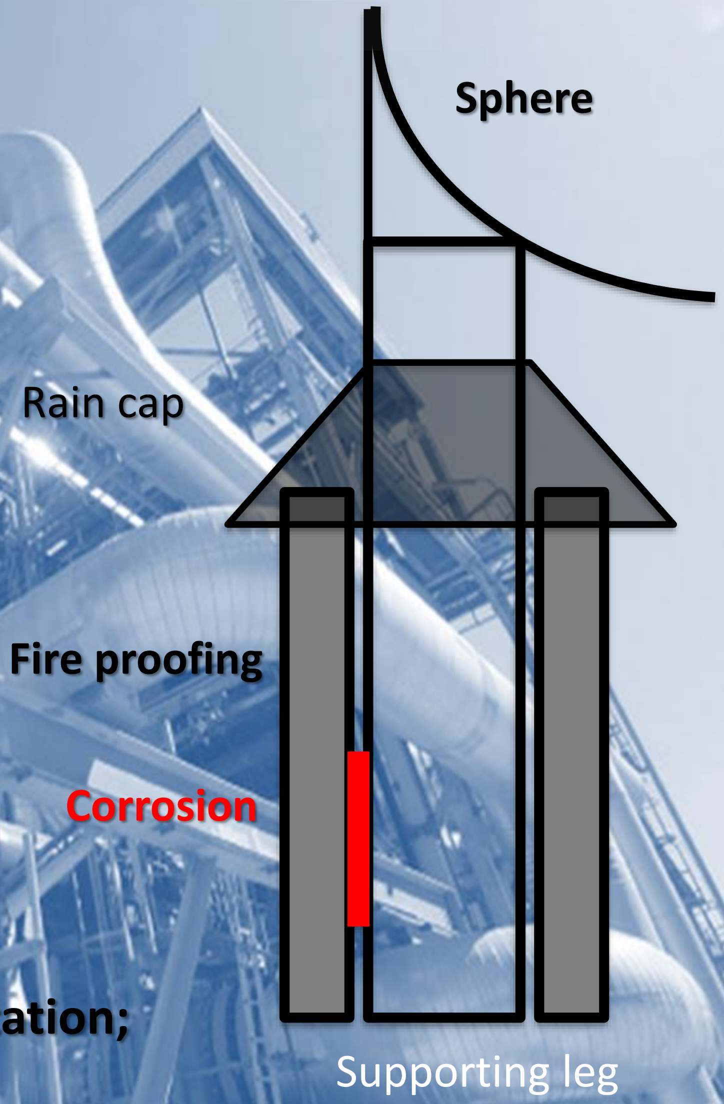
Corrosion Under Insulation:
PEC can inspect in-service without removing insulation



17.9	16.9	13.6	14.4	14.2	17.5	16.5	16.9
17.5	17.1	12.4	13.9	13.9	17.1	14.5	16.6
17.5	17.1	11.3	12.9	12.0	17.2	11.8	16.4
17.6	16.9	11.1	11.6	11.4	17.3	11.8	15.0
17.5	17.2	11.1	11.2	10.8	17.3	12.3	15.0
17.5	17.0	10.7	11.3	10.5	17.0	14.0	16.5
17.4	16.8	9.9	10.8	11.1	16.9	16.9	16.8
17.5	16.9	11.3	10.2	9.7	16.7	17.5	17.2
17.5	17.0	10.8	8.5	8.5	17.0	17.5	17.4
18.4	17.4	10.2	8.2	8.2	17.2	14.8	17.4
17.3	17.4	9.9	8.2	8.3	17.1	14.7	17.2
17.0	14.8	8.7	8.5	8.8	17.0	10.6	16.3
16.7	11.7	8.7	8.6	8.7	16.8	14.4	16.7
17.3	11.4	8.9	8.7	8.7	16.9	16.8	17.1
17.7	11.1	9.0	8.6	8.6	17.1	17.6	17.2
17.6	15.7	10.0	9.1	15.6	17.2	17.5	17.5
17.7	16.9	11.0	9.5	16.3	17.4	17.7	17.6
17.8	17.4	12.3	10.1	16.6	17.3	17.5	17.5
17.8	17.5	12.5	10.7	17.1	17.4	17.5	17.5
17.4	17.6	12.8	11.7	17.2	17.2	17.3	17.4
18.0	17.5	12.7	13.0	17.9	17.8	17.7	17.8
18.0	17.6	13.0	14.4	17.9	17.7	17.8	17.8
18.1	17.9	16.5	16.8	17.9	17.8	17.3	17.8
18.1	18.0	17.6	17.8	17.8	17.7	17.6	17.7
17.6	17.7	18.0	17.9	18.0	17.6	17.6	17.4
16.2	16.3	17.8	18.0	17.6	17.4	17.5	17.6
16.6	16.7	17.8	18.0	17.9	17.3	17.4	17.6
17.1	17.2	17.8	18.1	17.8	17.6	17.6	17.8
17.9	18.0	17.9	18.1	17.9	17.7	17.8	18.3

Color-coded wall thickness graph

Corrosion under fireproofing



Root cause: water ingress
at rain caps and cracks in fireproofing

Note: footprint averaging no longer a limitation;
load-bearing structure

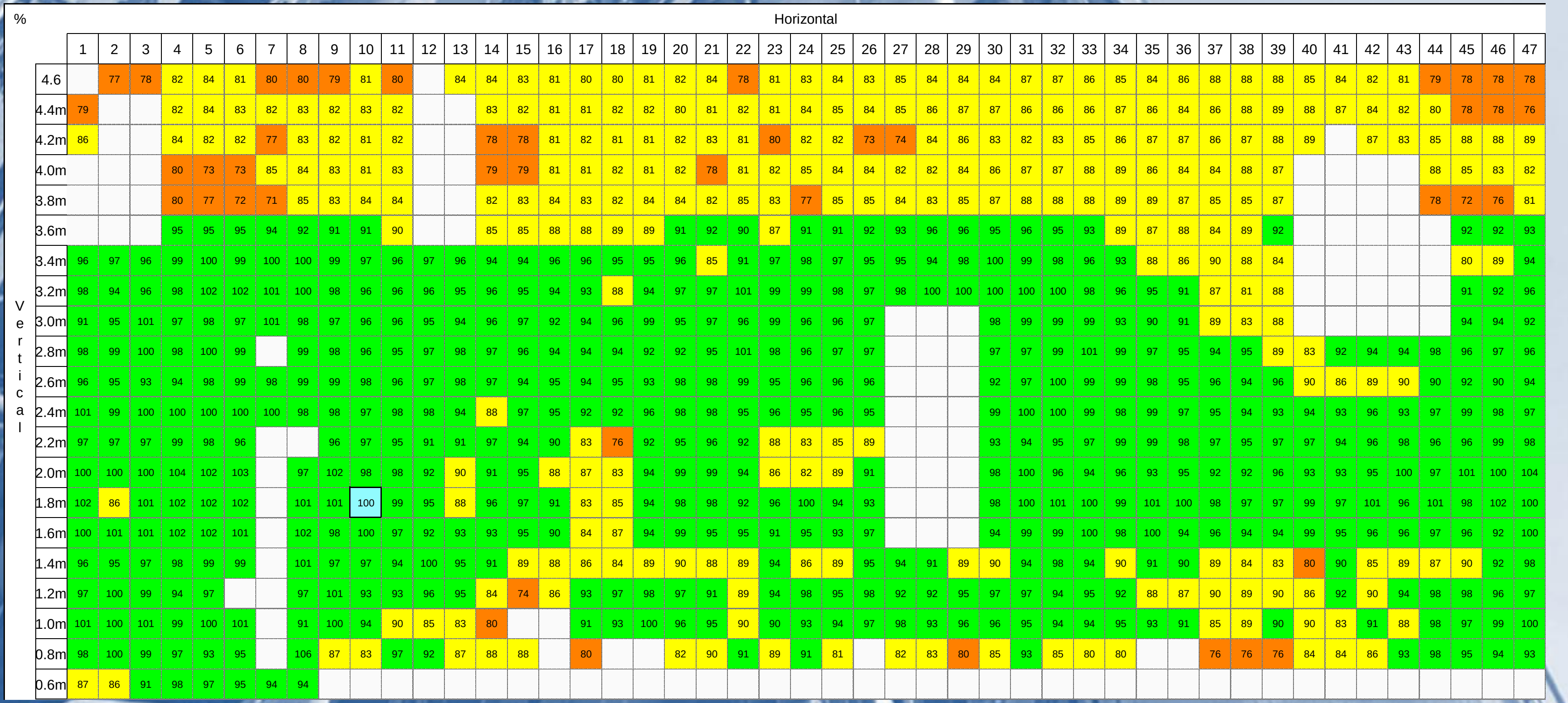
Water ingress: deflector not large enough and cracks

PEC inspections of sphere legs: scaffolding, poles & cherry pickers

PEC inspection column skirts
Data collection on outside and/or inside

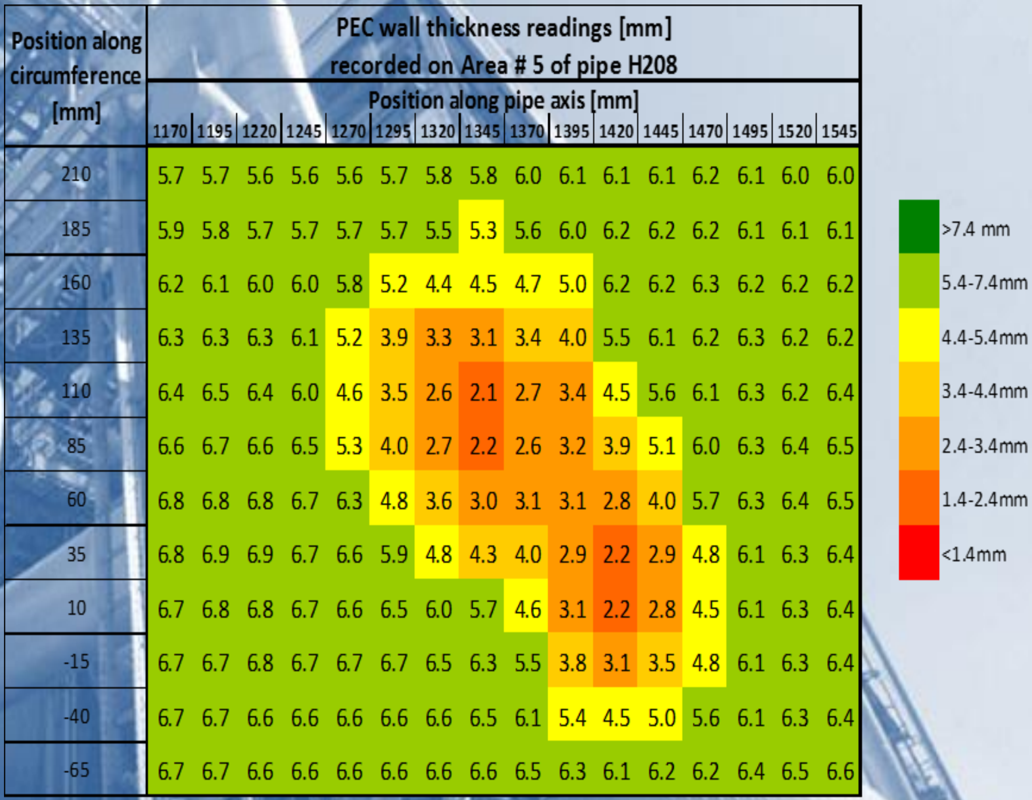
Operating temperature vessel determines where maximum corrosion takes place

Percentage wall thickness reading on a column skirt



%	Horizontal																																													
Vertical	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47
4.6		77	78	82	84	81	80	80	79	81	80		84	84	83	81	80	80	81	82	84	78	81	83	84	83	85	84	84	84	87	87	86	85	84	86	88	88	88	85	84	82	81	79	78	78	78
4.4m	79			82	84	83	82	83	82	83	82			83	82	81	81	82	82	80	81	82	81	84	85	84	85	86	87	87	86	86	86	87	86	84	86	88	89	88	87	84	82	80	78	78	76
4.2m	86			84	82	82	77	83	82	81	82			78	78	81	82	81	81	82	83	81	80	82	82	73	74	84	86	83	82	83	85	86	87	87	86	87	88	89		87	83	85	88	88	89
4.0m				80	73	73	85	84	83	81	83			79	79	81	81	82	81	82	78	81	82	85	84	84	82	82	84	86	87	87	88	89	86	84	84	88	87					88	85	83	82
3.8m				80	77	72	71	85	83	84	84			82	83	84	83	82	84	84	82	85	83	77	85	85	84	83	85	87	88	88	88	89	89	87	85	85	87					78	72	76	81
3.6m				95	95	95	94	92	91	91	90			85	85	88	88	89	89	91	92	90	87	91	91	92	93	96	96	95	96	95	93	89	87	88	84	89	92						92	92	93
3.4m	96	97	96	99	100	99	100	100	99	97	96	97	96	94	94	96	96	95	95	96	85	91	97	98	97	95	95	94	98	100	99	98	96	93	88	86	90	88	84						80	89	94
3.2m	98	94	96	98	102	102	101	100	98	96	96	96	95	96	95	94	93	88	94	97	97	101	99	99	98	97	98	100	100	100	100	100	98	96	95	91	87	81	88						91	92	96
3.0m	91	95	101	97	98	97	101	98	97	96	96	95	94	96	97	92	94	96	99	95	97	96	99	96	96	97				98	99	99	99	93	90	91	89	83	88						94	94	92
2.8m	98	99	100	98	100	99		99	98	96	95	97	98	97	96	94	94	94	92	92	95	101	98	96	97	97				97	97	99	101	99	97	95	94	95	89	83	92	94	94	98	96	97	96
2.6m	96	95	93	94	98	99	98	99	99	98	96	97	98	97	94	95	94	95	93	98	98	99	95	96	96	96				92	97	100	99	99	98	95	96	94	96	90	86	89	90	90	92	90	94
2.4m	101	99	100	100	100	100	100	98	98	97	98	98	94	88	97	95	92	92	96	98	98	95	96	95	96	95				99	100	100	99	98	99	97	95	94	93	94	93	96	93	97	99	98	97
2.2m	97	97	97	99	98	96			96	97	95	91	91	97	94	90	83	76	92	95	96	92	88	83	85	89				93	94	95	97	99	99	98	97	95	97	97	94	96	98	96	96	99	98
2.0m	100	100	100	104	102	103		97	102	98	98	92	90	91	95	88	87	83	94	99	99	94	86	82	89	91				98	100	96	94	96	93	95	92	92	96	93	93	95	100	97	101	100	104
1.8m	102	86	101	102	102	102		101	101	100	99	95	88	96	97	91	83	85	94	98	98	92	96	100	94	93				98	100	101	100	99	101	100	98	97	97	99	97	101	96	101	98	102	100
1.6m	100	101	101	102	102	101		102	98	100	97	92	93	93	95	90	84	87	94	99	95	95	91	95	93	97				94	99	99	100	98	100	94	96	94	94	99	95	96	96	97	96	92	100
1.4m	96	95	97	98	99	99		101	97	97	94	100	95	91	89	88	86	84	89	90	88	89	94	86	89	95	94	91	89	90	94	98	94	90	91	90	89	84	83	80	90	85	89	87	90	92	98
1.2m	97	100	99	94	97			97	101	93	93	96	95	84	74	86	93	97	98	97	91	89	94	98	95	98	92	92	95	97	97	94	95	92	88	87	90	89	90	86	92	90	94	98	98	96	97
1.0m	101	100	101	99	100	101		91	100	94	90	85	83	80			91	93	100	96	95	90	90	93	94	97	98	93	96	96	95	94	94	95	93	91	85	89	90	90	83	91	88	98	97	99	100
0.8m	98	100	99	97	93	95		106	87	83	97	92	87	88	88		80			82	90	91	89	91	81		82	83	80	85	93	85	80	80			76	76	76	84	84	86	93	98	95	94	93
0.6m	87	86	91	98	97	95	94	94																																							

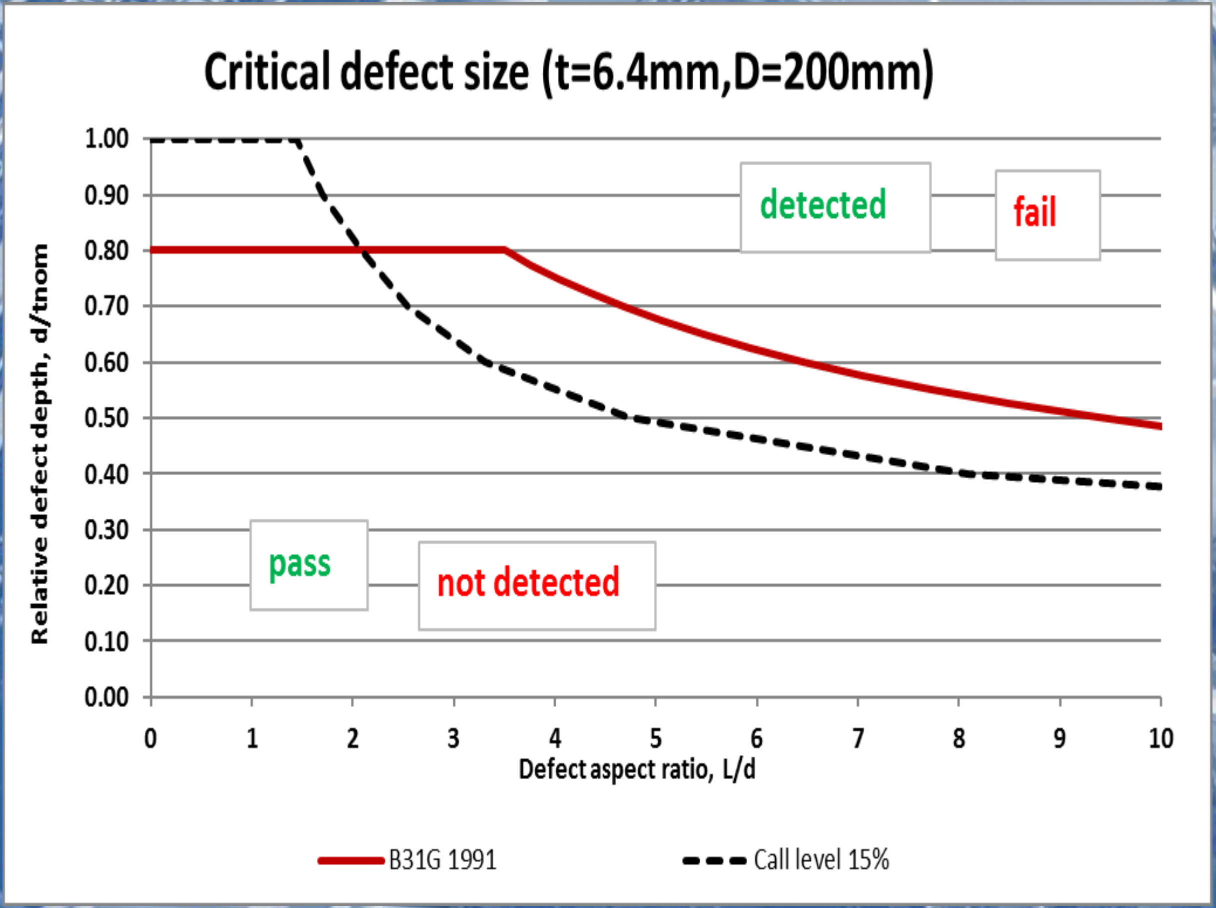
Remaining wall thickness through corrosion product

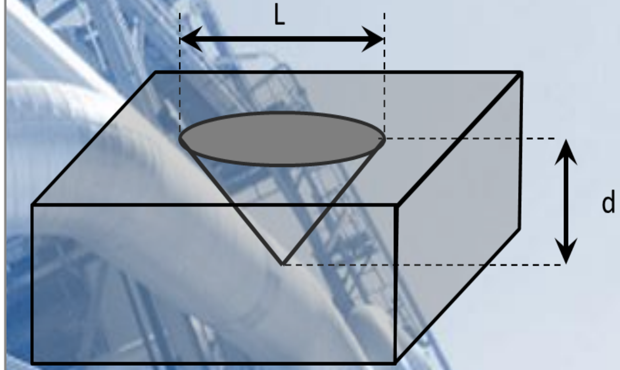


Position along circumference [mm]	PEC wall thickness readings [mm] recorded on Area # 5 of pipe H208															
	Position along pipe axis [mm]															
	1170	1195	1220	1245	1270	1295	1320	1345	1370	1395	1420	1445	1470	1495	1520	1545
210	5.7	5.7	5.6	5.6	5.6	5.7	5.8	5.8	6.0	6.1	6.1	6.1	6.2	6.1	6.0	6.0
185	5.9	5.8	5.7	5.7	5.7	5.7	5.5	5.3	5.6	6.0	6.2	6.2	6.2	6.1	6.1	6.1
160	6.2	6.1	6.0	6.0	5.8	5.2	4.4	4.5	4.7	5.0	6.2	6.2	6.3	6.2	6.2	6.2
135	6.3	6.3	6.3	6.1	5.2	3.9	3.3	3.1	3.4	4.0	5.5	6.1	6.2	6.3	6.2	6.2
110	6.4	6.5	6.4	6.0	4.6	3.5	2.6	2.1	2.7	3.4	4.5	5.6	6.1	6.3	6.2	6.4
85	6.6	6.7	6.6	6.5	5.3	4.0	2.7	2.2	2.6	3.2	3.9	5.1	6.0	6.3	6.4	6.5
60	6.8	6.8	6.8	6.7	6.3	4.8	3.6	3.0	3.1	3.1	2.8	4.0	5.7	6.3	6.4	6.5
35	6.8	6.9	6.9	6.7	6.6	5.9	4.8	4.3	4.0	2.9	2.2	2.9	4.8	6.1	6.3	6.4
10	6.7	6.8	6.8	6.7	6.6	6.5	6.0	5.7	4.6	3.1	2.2	2.8	4.5	6.1	6.3	6.4
-15	6.7	6.7	6.8	6.7	6.7	6.7	6.5	6.3	5.5	3.8	3.1	3.5	4.8	6.1	6.3	6.4
-40	6.7	6.7	6.6	6.6	6.6	6.6	6.6	6.5	6.1	5.4	4.5	5.0	5.6	6.1	6.3	6.4
-65	6.7	6.7	6.6	6.6	6.6	6.6	6.6	6.6	6.5	6.3	6.1	6.2	6.2	6.4	6.5	6.6

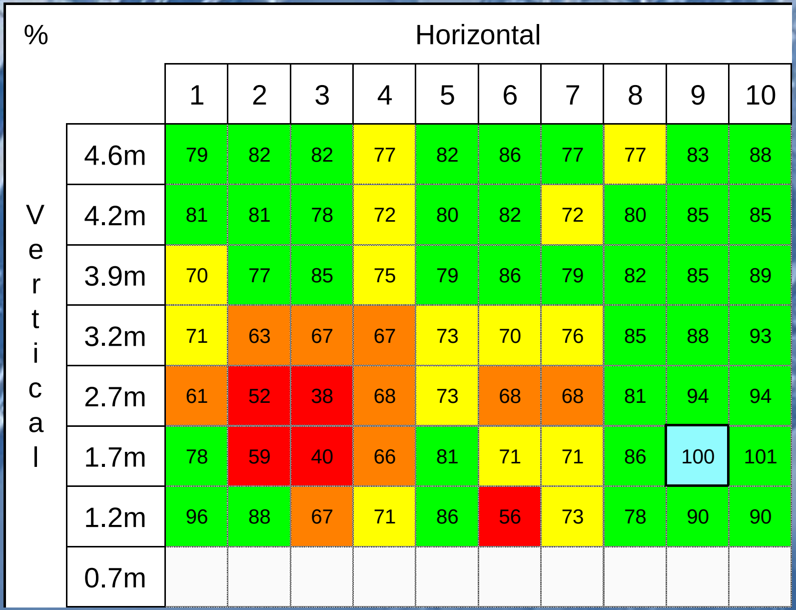
🟩 >7.4 mm
🟩 5.4-7.4mm
🟨 4.4-5.4mm
🟧 3.4-4.4mm
🟧 2.4-3.4mm
🟧 1.4-2.4mm
🟥 <1.4mm

Fitness for services vs detectability





Repair wrap: demonstrate that the corrosion does not progress



%		Horizontal									
		1	2	3	4	5	6	7	8	9	10
Vertical	4.6m	79	82	82	77	82	86	77	77	83	88
	4.2m	81	81	78	72	80	82	72	80	85	85
	3.9m	70	77	85	75	79	86	79	82	85	89
	3.2m	71	63	67	67	73	70	76	85	88	93
	2.7m	61	52	38	68	73	68	68	81	94	94
	1.7m	78	59	40	66	81	71	71	86	100	101
	1.2m	96	88	67	71	86	56	73	78	90	90
	0.7m										

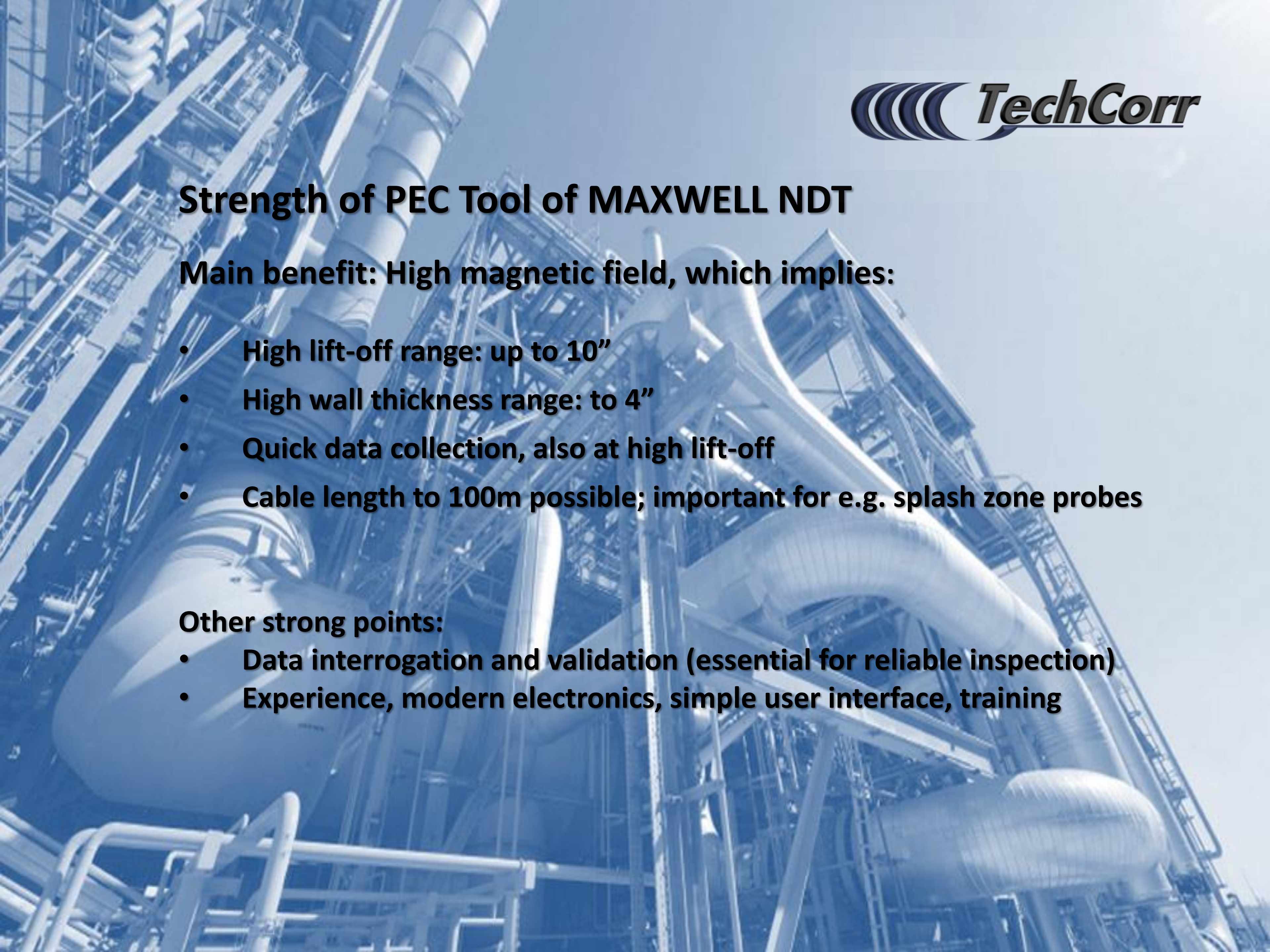
PEC is well suited for splash zone inspections: offshore risers and caissons

Jig with PEC probe

Inspect through coating, rope access

Comparison PEC to ultrasound thickness measurements

Pulsed Eddy Current	Ultrasound thickness measurements
Based on electromagnetism	Based on high-frequency sound
± **Averages over a footprint area**	**+Point measurement**
- **Measures percentage variation** in wall thickness on the same object (relative) – needs calibration	**+Measures thickness in millimetres** (absolute)
+ **No contact or surface preparation required**- (measures through thick layers insulation material, concrete, corrosion product, aluminium insulation covers etc.)	- **Contact required** and often surface preparation required
+ **Probe alignment is not critical** (key advantage in e.g. offshore applications)	- Correct placement of sensor is critical
+ **Highly repeatable** (well suited for wall thickness monitoring)	- Difficult to use ultrasound for accurate wall thickness monitoring
+ **Easy to apply at very high temperatures** (tested to 550°C (1030 °F)	- Difficult to apply at high temperatures



Strength of PEC Tool of MAXWELL NDT

Main benefit: High magnetic field, which implies:

- High lift-off range: up to 10”
- High wall thickness range: to 4”
- Quick data collection, also at high lift-off
- Cable length to 100m possible; important for e.g. splash zone probes

Other strong points:

- Data interrogation and validation (essential for reliable inspection)
- Experience, modern electronics, simple user interface, training