Detection of Corrosion under insulation (CUI) using the Pulsed Eddy Current Technique (PECT)

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Agenda of presentation

- What is PEC?
- Strength and limitations
- When to apply PEC
- Successful PEC applications

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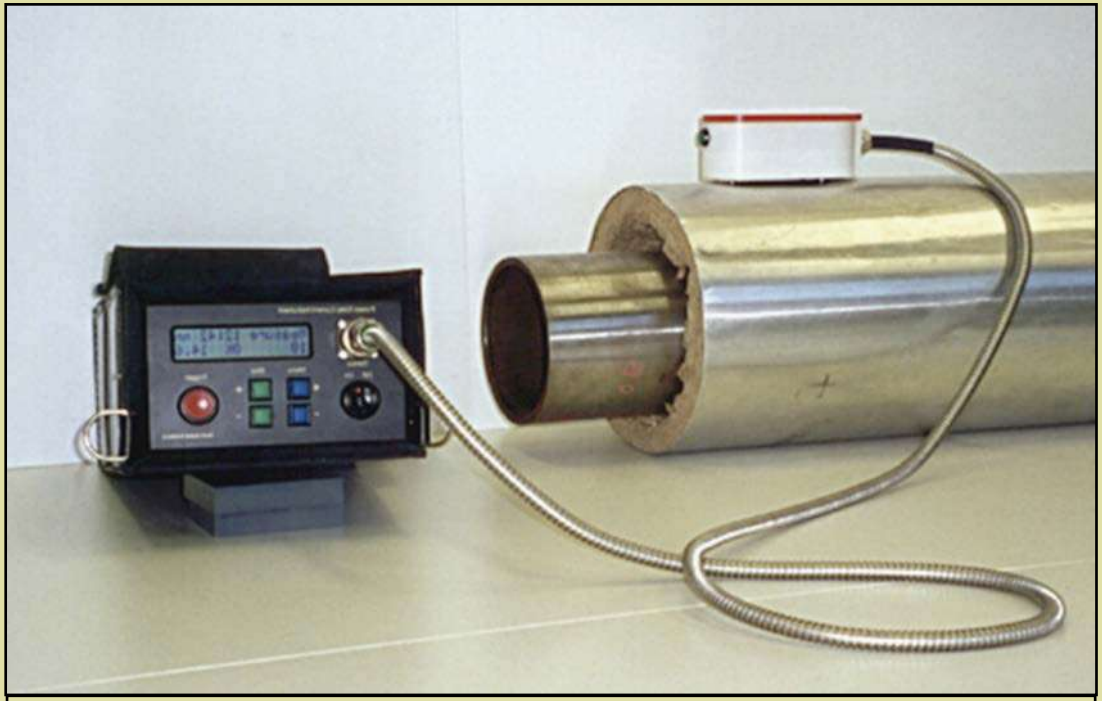
Pulsed Eddy Current Testing:
measures steel thickness through insulation

Early tools (late 1990's):

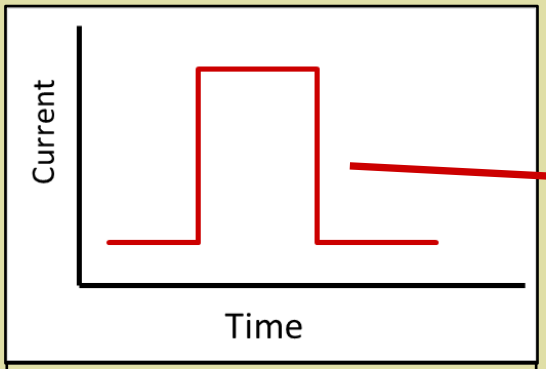
INCOTEST system of Applus-RTD



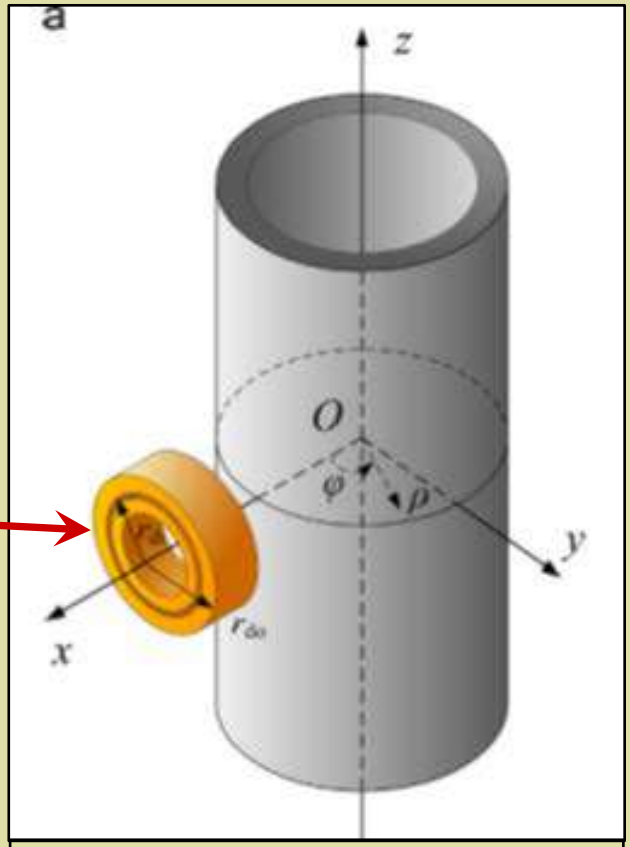
PEC instrument developed by Shell

Principle of Pulsed Eddy Current Testing:

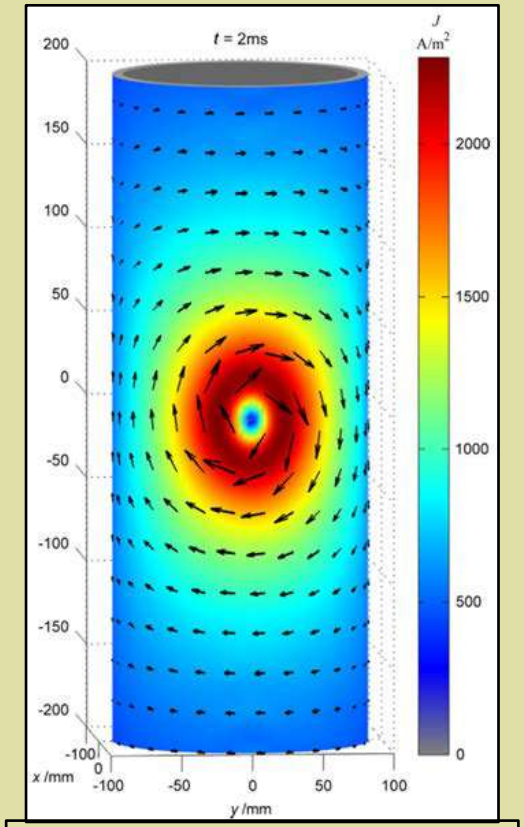
Step 1: induce eddy currents in steel with a pulsed magnetic field



Pulsed electrical current transmission coil of probe



Carbon steel pipe



Induced electrical current in steel pipe wall

Step 2: Measure time it takes for eddy currents to diffuse in steel

Top of steel

First in time

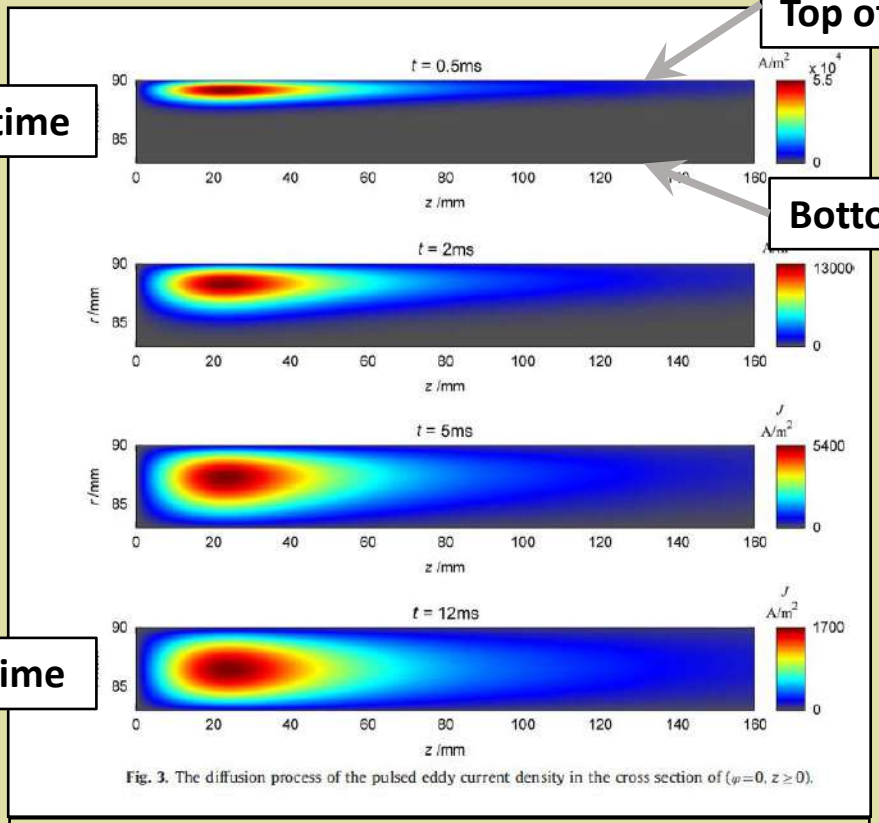
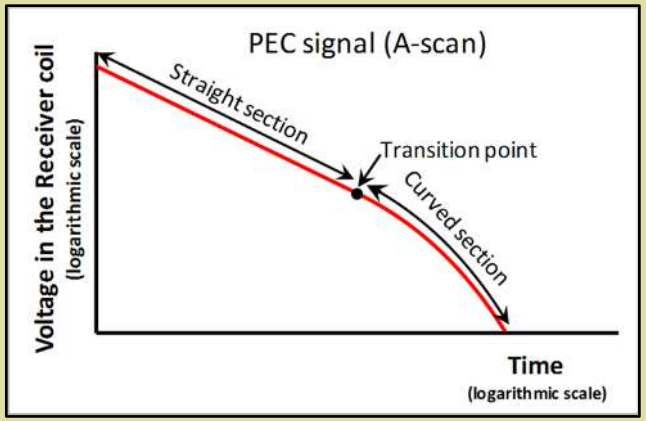


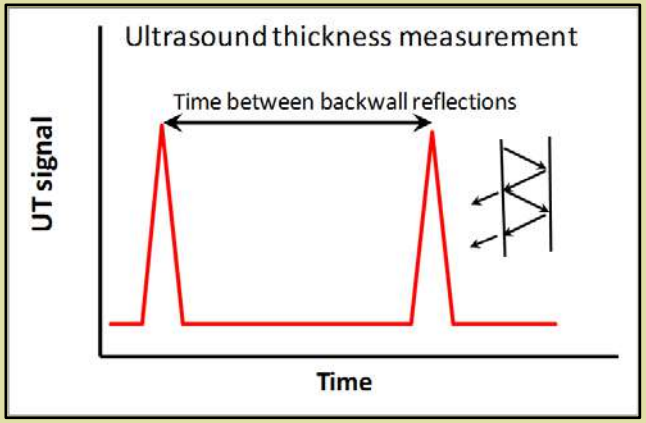
Fig. 3. The diffusion process of the pulsed eddy current density in the cross section of (φ=0, $z \geq 0$).

Bottom of steel

Last in time

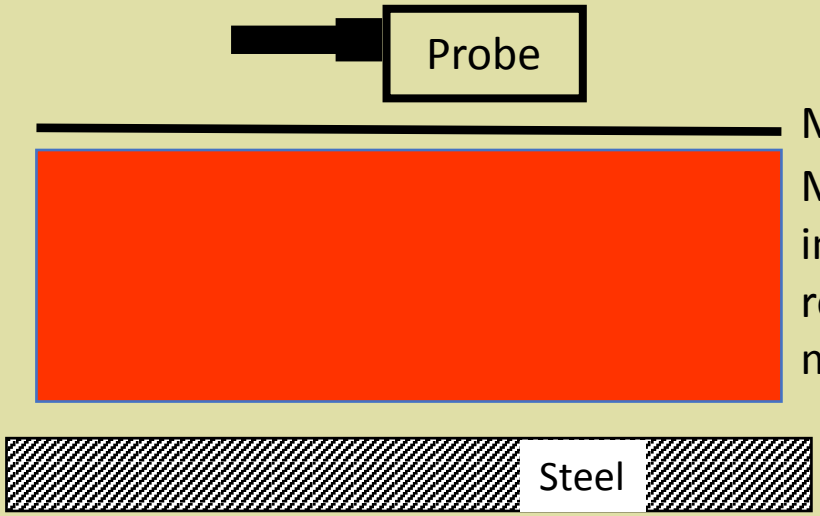
Cross-section of steel





Determine steel thickness from diffusion time

Main benefit of PECT: can measure through most materials



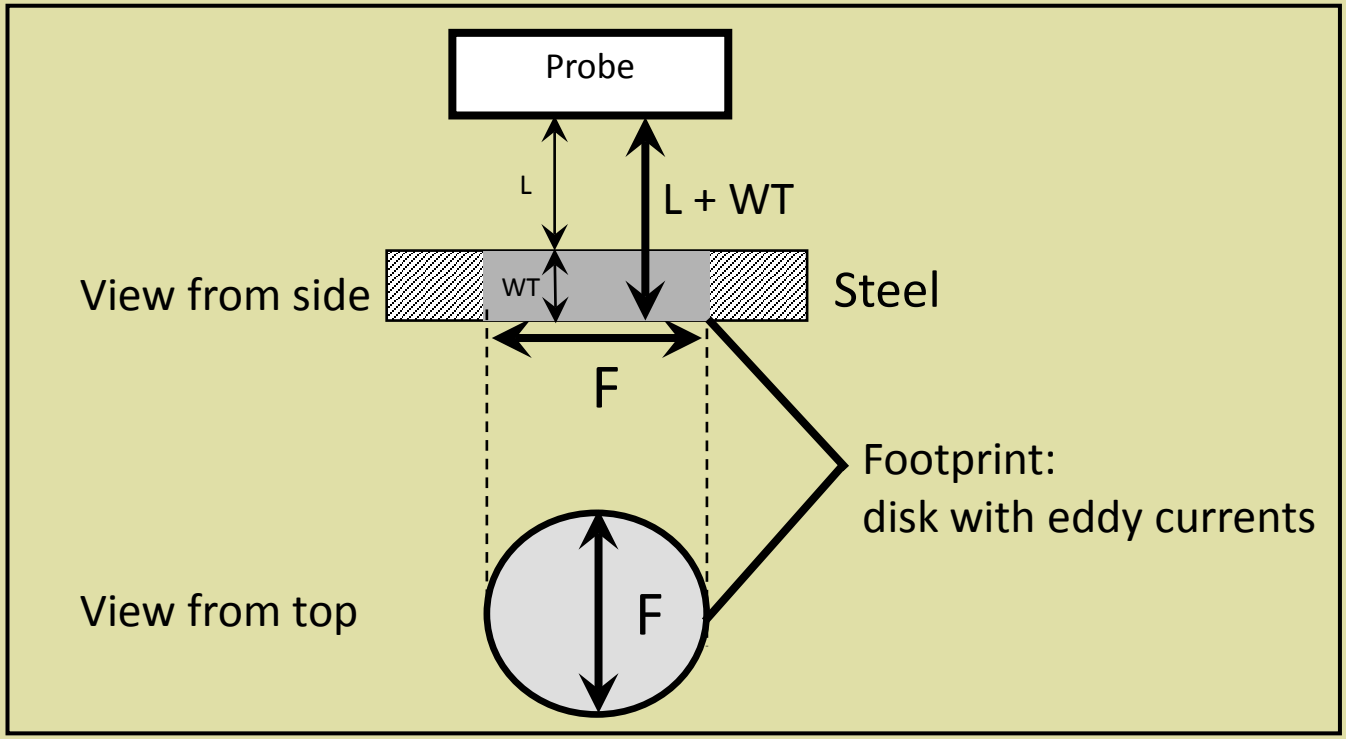
Metal insulation cover

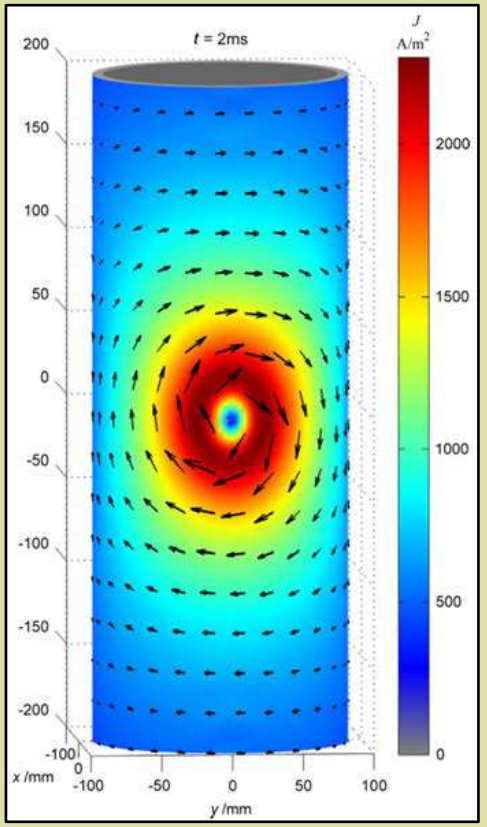
Material between probe and steel:
insulation material, chicken wire, straps, concrete, reinforcement bars, corrosion product, sea water, marine growth, bitumen, etc.

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

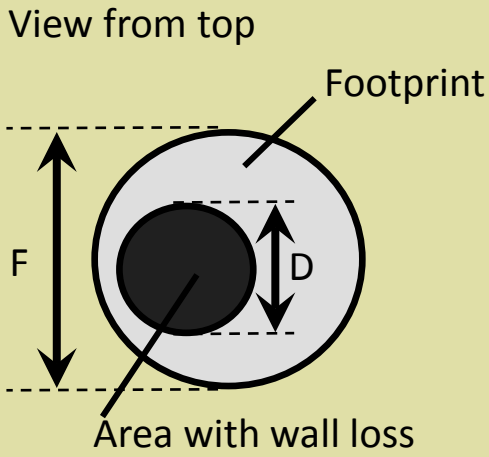




$$\text{Diameter Footprint} = F \approx 1.5 \text{ x } (L + WT)$$

$$\text{Minimum footprint} = 25\text{mm}$$

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 convert % 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**

CUI on piping

CUI of piping is large market but
also most difficult PECT application:

- PECT will not find defects with diameter < 1.5 x insulation thickness (general wall loss only)
- Sometimes loose chicken wire: very old systems and at repairs
- Aluminum sheeting increases minimum thickness to 5mm
- Galvanized sheeting: performance unpredictable; footprint increases by factor 2.
  Needs to validate with same sheeting type.
- Dead zones near supports, obstructions, re-enforcement pad
- Lots of obstructions
- Economics: is delagging more cost effective (and better) ?
  (depends on criticality, required coverage, piping vs vessels and storage tanks)

Still PECT used for CUI of piping:

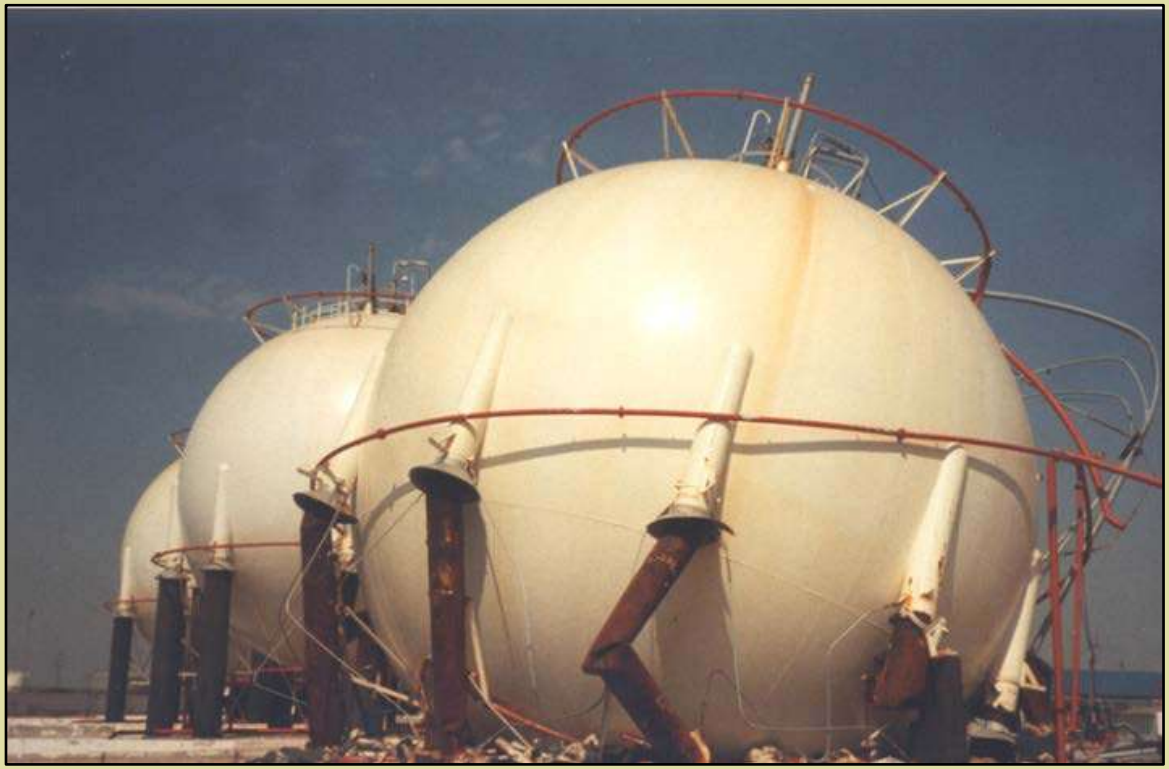
- PECT as follow-up with Long range UT; e.g. at elbows
- Modern PEC tools are much quicker than old instruments, scan mode

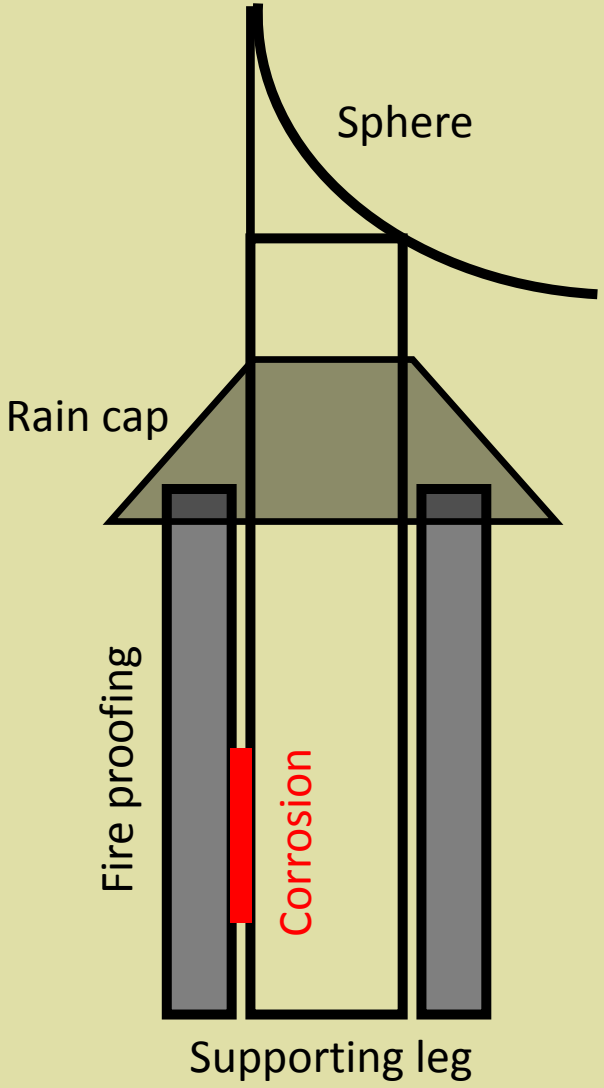
CUI on vessels, reactors and tanks

More favorable than piping if access can be done without scaffolding: rope access, poles

- Wall thickness thicker, which is favorable when there is aluminum sheeting
- PECT instrument must be powerful enough (higher lift-off and higher wall thickness
- Inspection around insulation support rings

Corrosion under fireproofing





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

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

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

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Corrosion under fire proofing

- Footprint averaging no longer a drawback; high tolerance against localized wall loss
- Sphere legs: Reinforcement bars in the concrete has similar effect as aluminum sheeting
- Skirts: temperature of column determines location of corrosion on skirt
- Skirts: inspection of bottom from the inside
- Economics for PECT are more favorable compared to CUI → PECT is used a lot for CUF

Percentage wall thickness reading on a column skirt

% Vertical \ Horizontal	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																																							

Repair wrap: demonstrate that the corrosion does not progress

%	Horizontal									
Vertical	1	2	3	4	5	6	7	8	9	10
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										

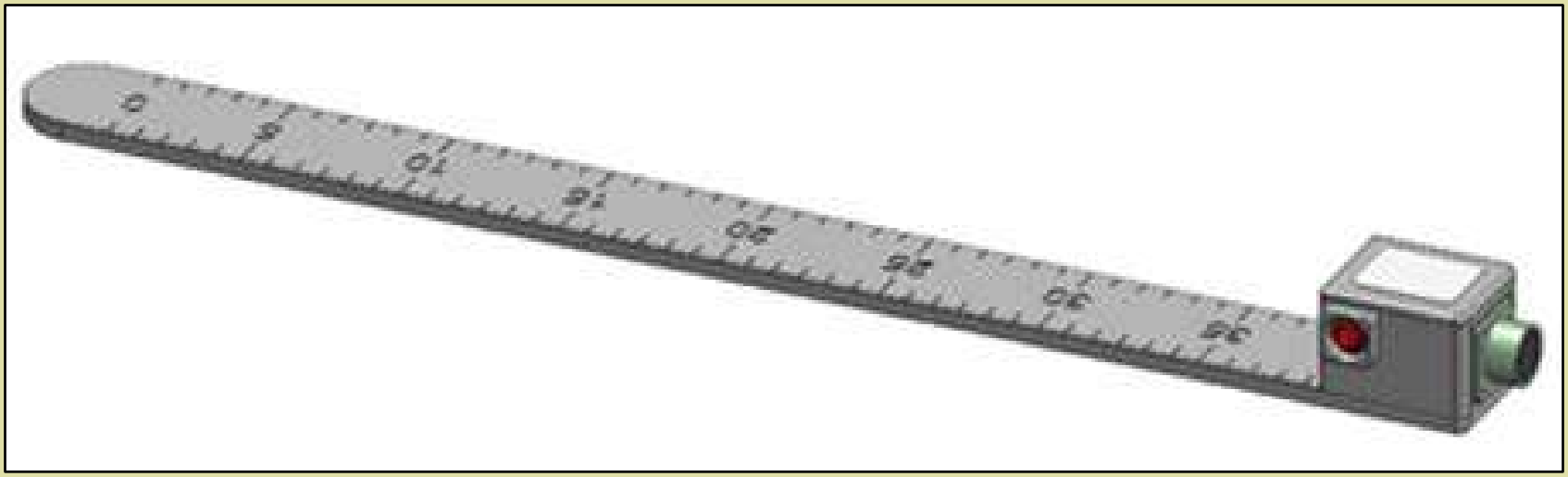
Remaining wall thickness through corrosion product

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

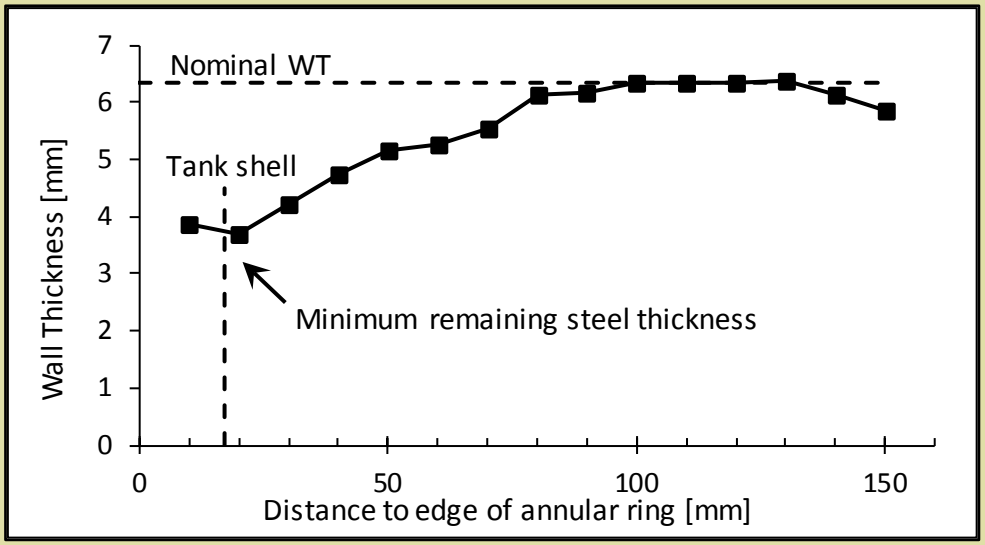
>7.4 mm
5.4-7.4mm
4.4-5.4mm
3.4-4.4mm
2.4-3.4mm
1.4-2.4mm
<1.4mm

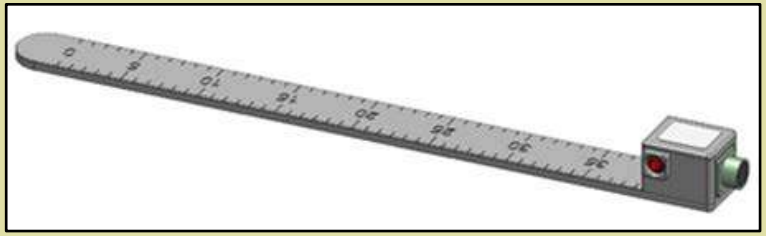
Probe for inspecting annular ring of atmospheric storage tanks

Effective length probe	370mm (14.5”)
Width	45mm (1.8”)
Height	7.5mm (0.3”)
Wall thickness range	20mm (0.8”)
Maximum lift-off	40mm (1.6”)



Annular ring of atmospheric storage tanks





Annular ring of atmospheric storage tanks

Challenges:

- Where to inspect
- Combination with UT tank edge tools – not very successful so far
- Creating access: careful digging
- Not to remove corrosion products

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

Jig with PEC probe

Inspect through coating, rope access

Jetty piles

- Splash zone inspection – inspection through splash zone coating
- Deeper (typically to ~ 20 m): measurement through marine growth
- No removal of marine growth and coating
- Similar application: risers, caissons, conductors

Splash zone of offshore structures and risers

PECT very suited for splash zone inspections

- PECT measures through coatings and marine growth.
- Inspection from inside often very expensive
- PECT is tolerant for probe mis-alignment (up to ~30°)
- Access with jigs and rope access methods

PEC Tool of MAXWELL ndt

On Display at NDTS Exhibition counter

Main difference with other PECT instruments: high magnetic power which implies

- Compact magnetic field: defect sensitivity
- High range in WT (2”) and insulation thickness: so also suited for vessel, not just piping
- Fast: single pulse, also at high insulation thickness. Scanning possible also at high lift-off
- Heavy equipment (due to powerful batteries) – unit weighs 7 kg.

Other characteristics: very robust, designed for use outdoors; very easy to use in field

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Thank - You