Pulsed Eddy Current Testing (PECT)

Presentation to SGS – 16 March 2017

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Pulsed Eddy Current Testing

How does PECT work

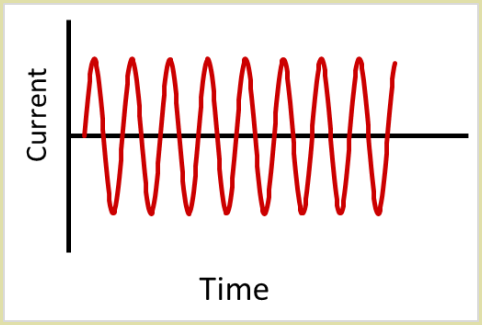
Intermezzo: short history

When to apply PECT

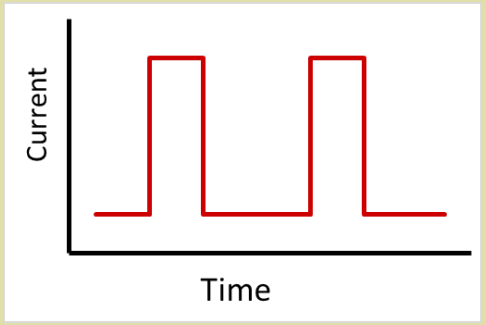
Application Examples

Conventional ECT and PECT

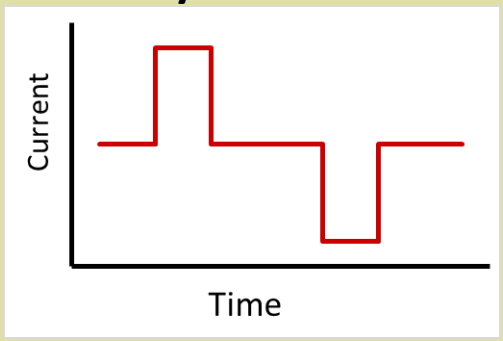
Conventional Eddy Current testing (ECT) uses a sinusoidal excitation current



PECT uses a square pulse signal to induced eddy currents



Unipolair



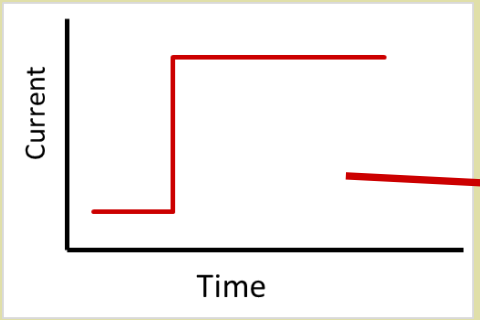
Bipolair

No fundamental difference (Fourier), but Pulsed ECT is more practical than conventional ECT for deep penetration especially in magnetic materials

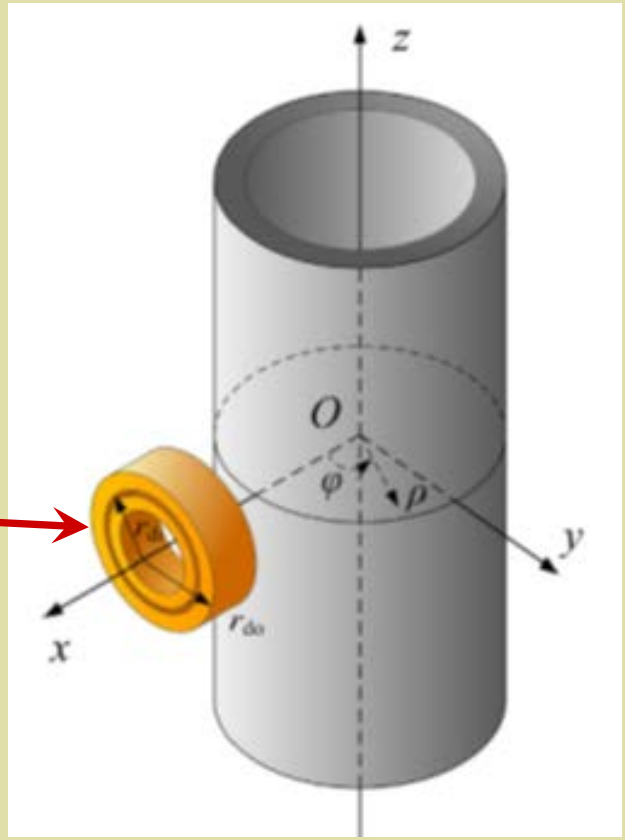
Magnetic and non-magnetic PECT

Property	Non-magnetic PECT	Magnetic PECT
Test specimen	Non-magnetic, e.g. Aluminum, Zirconium, Stainless steel	Ferro magnetic material, e.g. carbon steel, P5
Pulse duration	micro seconds	milli seconds
Data analysis	Zero crossing	Bending point
Lift-off range	<1” (contact)	>1” (non-contact)
Application	Aircraft structures	Corrosion under insulation (CUI)

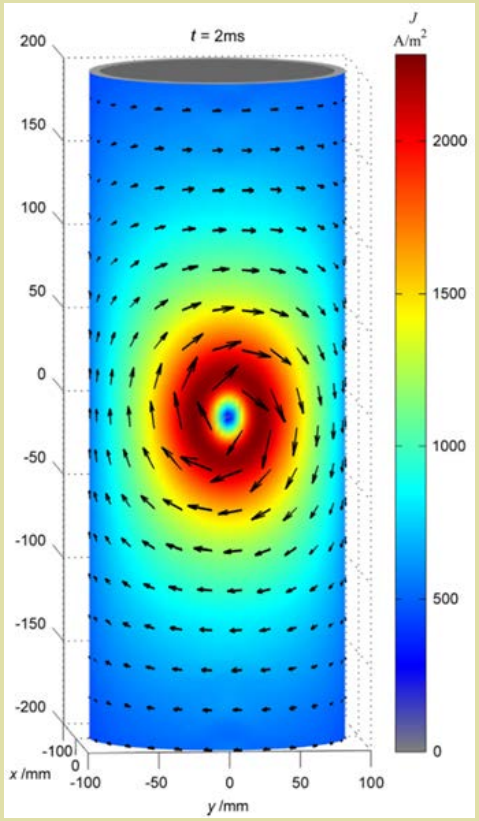
Step 1 of a PECT measurement:
induce electrical currents in steel with a with a pulsed magnetic field



Pulsed electrical current transmission coil of probe

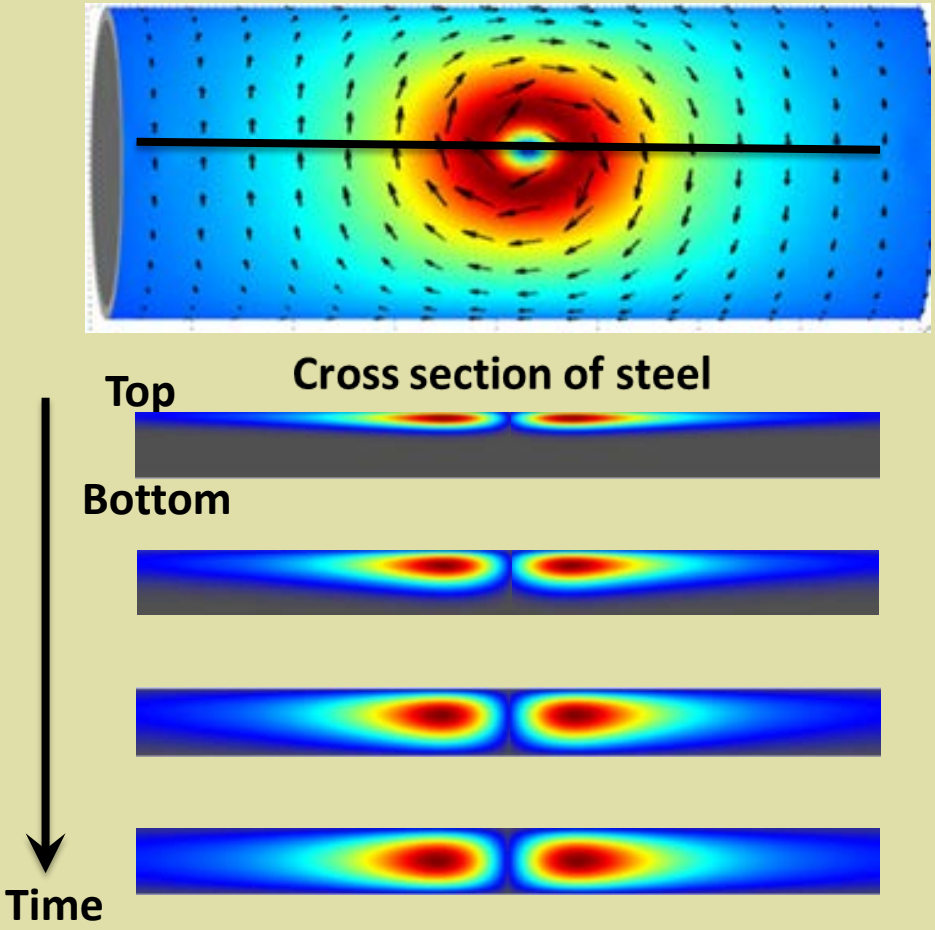


Carbon steel pipe



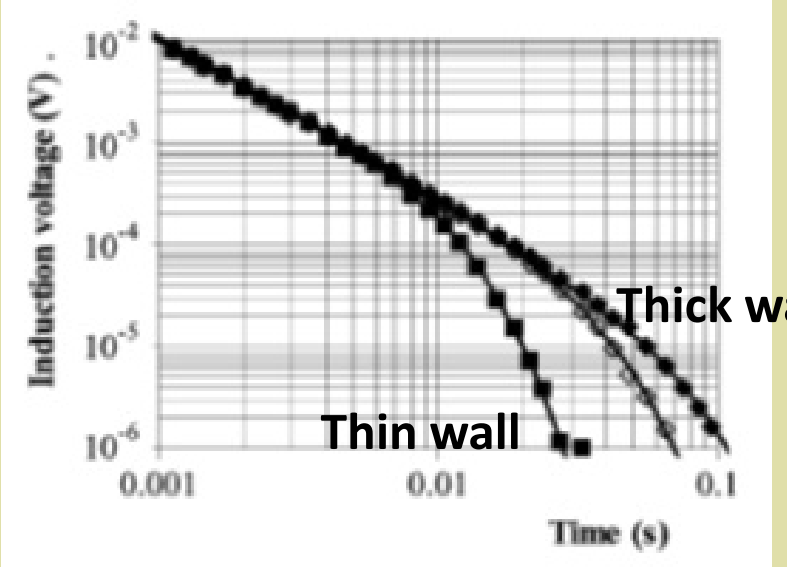
Induced electrical current in steel pipe wall

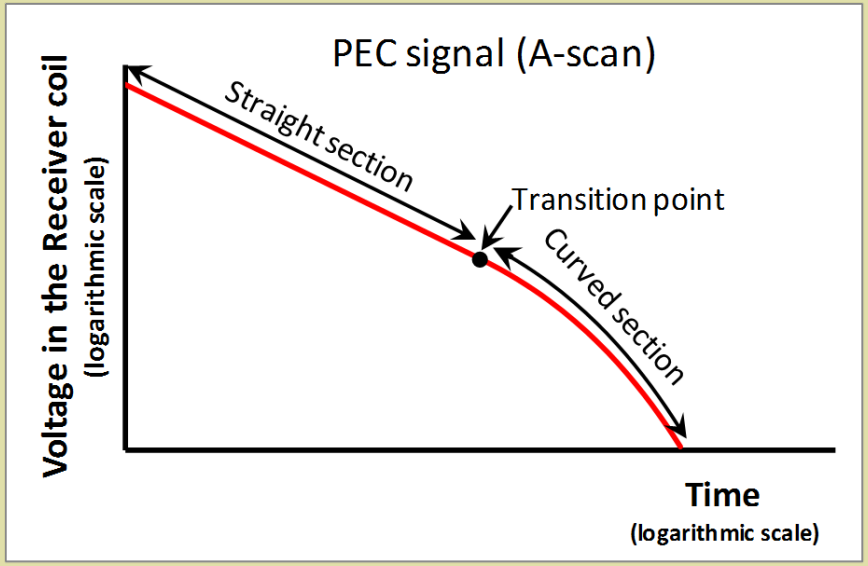
Step 2: Diffusion of the eddy currents in the steel wall



Finite element calculations Huazhong

Step 3: Measure induced signal in receiver coil of the probe





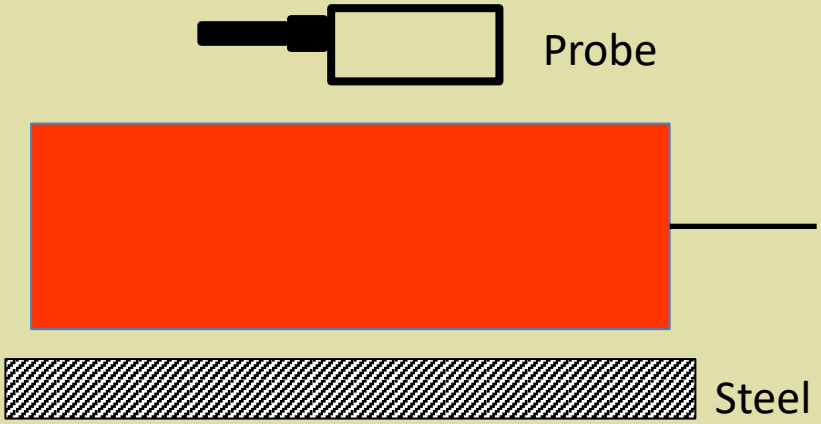
Step 4: Determine steel thickness from 'Transition point' ≈ Backwall echo. The higher the transition time, the thicker the wall

The 'speed of diffusion' depends on the magnetic properties of the steel, which are unknown.

Consequence: PECT measures variations of steel thickness; report in %

need calibration on one spot to convert %-measurement to millimetres (or inch)

Main advantage PECT: can measure through (almost) any material between probe and steel surface



PEC cannot measure through:

1. **Plate that is electrically highly conductive & magnetic: e.g. galvanised sheeting**
   Reason: magnetic field diverts, footprint becomes larger. Result: loss of defect sensitivit
2. **Magnetic material that is free to move (loose chicken wire) – signal distortion**

PEC can measure through (almost) anything else:

all insulation materials, coatings, fixed chicken wire, concrete, re-bars, corrosion produc
stainless steel sheeting, aluminium sheeting, water, marine growth etc. ect.

First publication on Pulsed Eddy Current Testing

Gage Plating Thickness

SUMMARY — Echo-sounding technique making use of pulsed eddy currents determines thickness of one metal coated on a base metal. System takes advantage of electrical dissimilarities and is effective even when both metals are nonmagnetic

By DONALD L. WAIDELICH* *Argonne National Laboratory, Lemont, Illinois*

ELECTRONICS — November, 1955

…..61 years ago

Application: measure thickness of zirconium metal thickness of nuclear fuel pallets

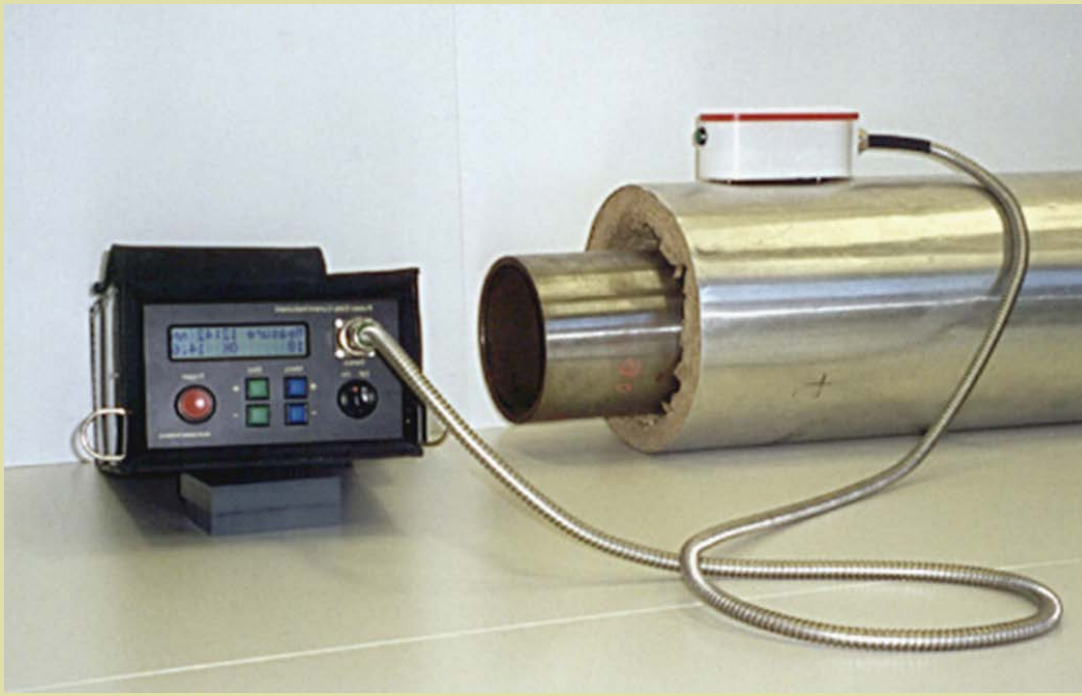
PECT for magnetic material (carbon steel): first developed by ARCO (90

ARCO TEMP equipment, intended for Corrosion under Insulation

Adopted and improved independently by RTD and Shell since 1997

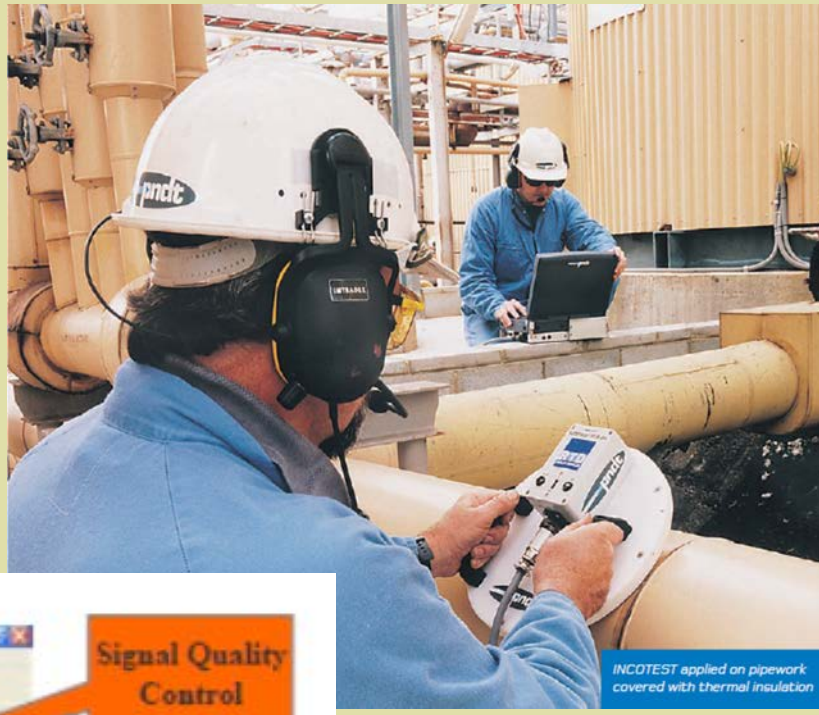
Who is applying Pulsed Eddy Current Testing?

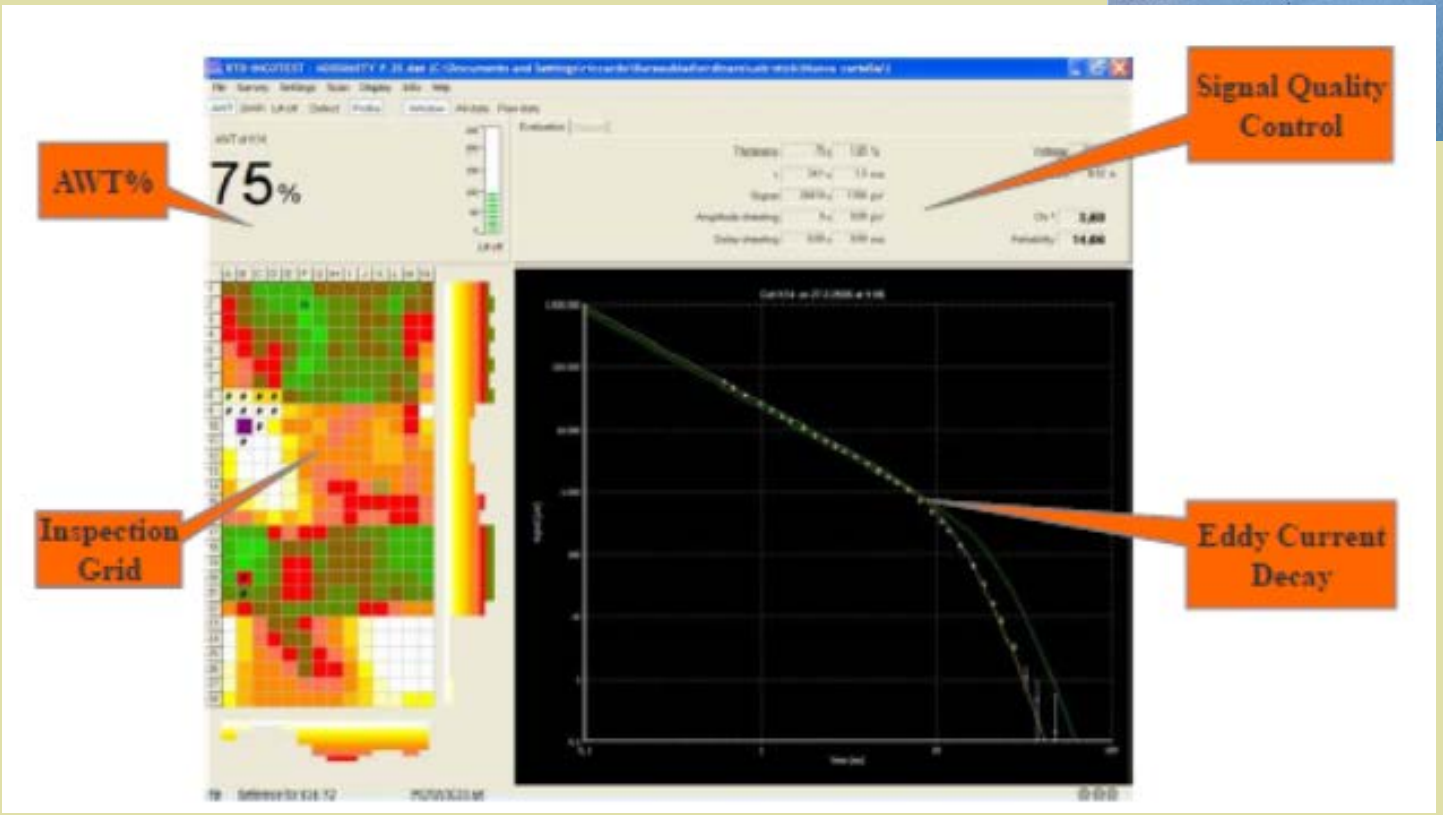
INCOTEST system of Applus-RTD

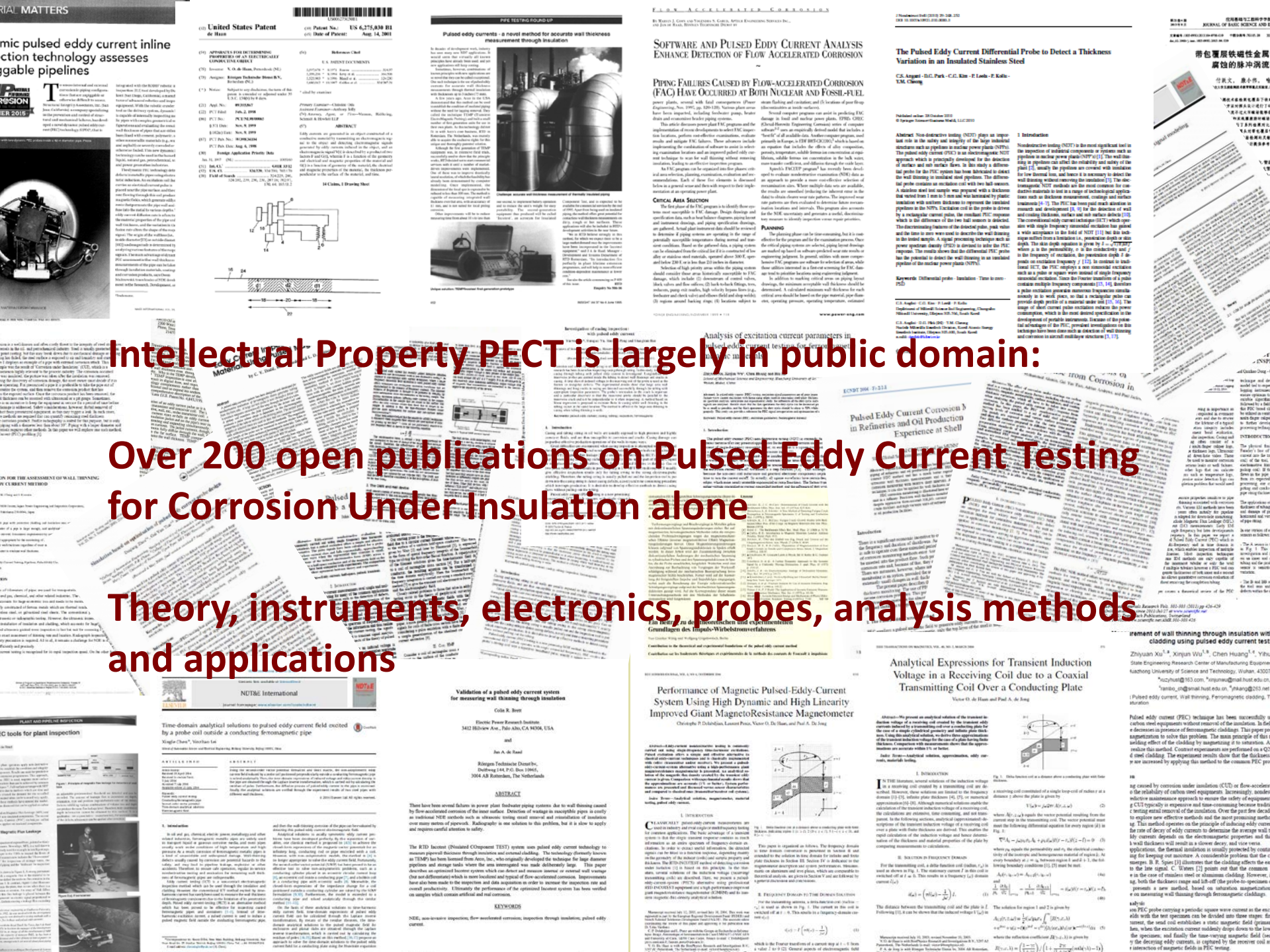


PEC instrument developed by Shell

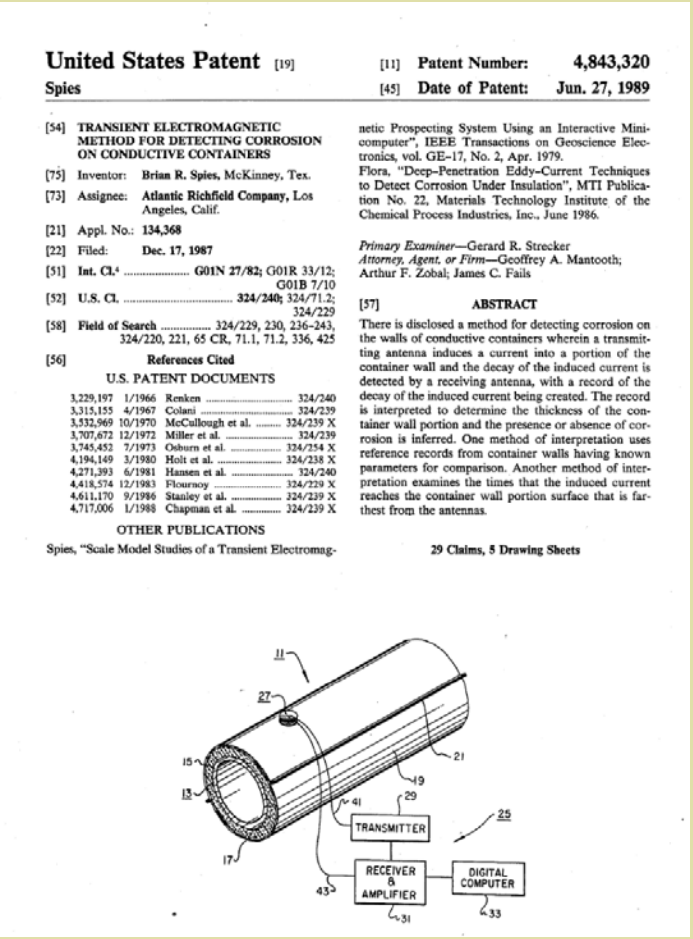
INCOTEST system of Applus RTD (2)






Intellectual Property PECT is largely in public domain:
Over 200 open publications on Pulsed Eddy Current Testing for Corrosion Under Insulation alone
Theory, instruments, electronics, probes, analysis methods and applications

Patent protection Pulsed Eddy Current Testing



United States Patent [19]
Spies

[11] **Patent Number: 4,843,320**
[45] **Date of Patent: Jun. 27, 1989**

[54] **TRANSIENT ELECTROMAGNETIC METHOD FOR DETECTING CORROSION ON CONDUCTIVE CONTAINERS**

[75] Inventor: **Brian R. Spies**, McKinney, Tex.

[73] Assignee: **Atlantic Richfield Company**, Los Angeles, Calif.

[21] Appl. No.: **134,368**

[22] Filed: **Dec. 17, 1987**

[51] **Int. Cl.**[4] **G01N 27/82**; G01R 33/12; G01B 7/10

[52] **U.S. Cl.** **324/240**; 324/71.2; 324/229

[58] **Field of Search** ..... 324/229, 230, 236-243, 324/220, 221, 65 CR, 71.1, 71.2, 336, 425

[56] **References Cited**

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OTHER PUBLICATIONS

Spies, "Scale Model Studies of a Transient Electromagnetic Prospecting System Using an Interactive Minicomputer", IEEE Transactions on Geoscience Electronics, vol. GE-17, No. 2, Apr. 1979.

Flora, "Deep-Penetration Eddy-Current Techniques to Detect Corrosion Under Insulation", MTI Publication No. 22, Materials Technology Institute of the Chemical Process Industries, Inc., June 1986.

Primary Examiner—Gerard R. Strecker
Attorney, Agent, or Firm—Geoffrey A. Mantooth; Arthur F. Zobal; James C. Fails

[57] **ABSTRACT**

There is disclosed a method for detecting corrosion on the walls of conductive containers wherein a transmitting antenna induces a current into a portion of the container wall and the decay of the induced current is detected by a receiving antenna, with a record of the decay of the induced current being created. The record is interpreted to determine the thickness of the container wall portion and the presence or absence of corrosion is inferred. One method of interpretation uses reference records from container walls having known parameters for comparison. Another method of interpretation examines the times that the induced current reaches the container wall portion surface that is farthest from the antennas.

29 Claims, 5 Drawing Sheets

Series of basic patents on PECT by ARCO Filed in 1989

All expired - since 2009 Now free to use

Later patents: on some special applications

More recent developers of PECT

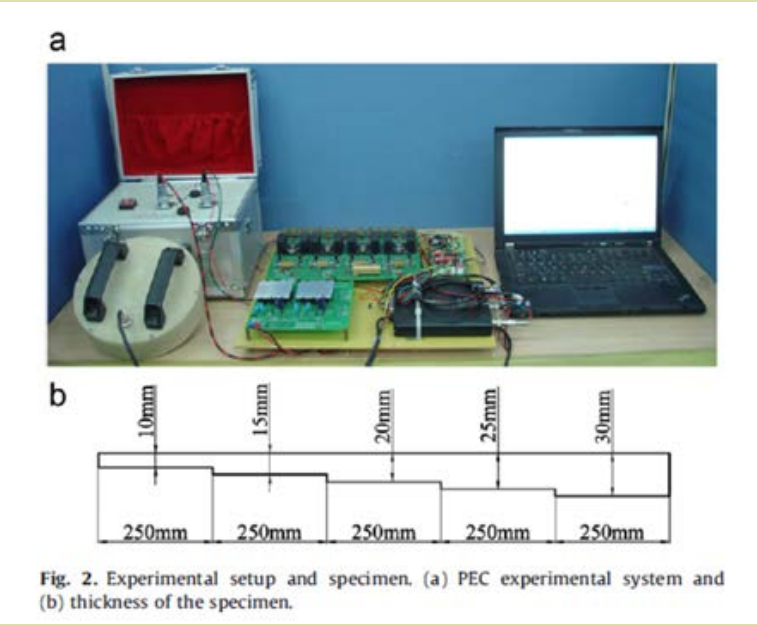


Fig. 2. Experimental setup and specimen. (a) PEC experimental system and (b) thickness of the specimen.

Huazhong University, China

Others: Japan Power Engineering and Inspection Company, Raynor Co. LTD, ABB, GOWell, Halliburton, Eddyfi

ISO standard issued

INTERNATIONAL STANDARD

ISO 20669

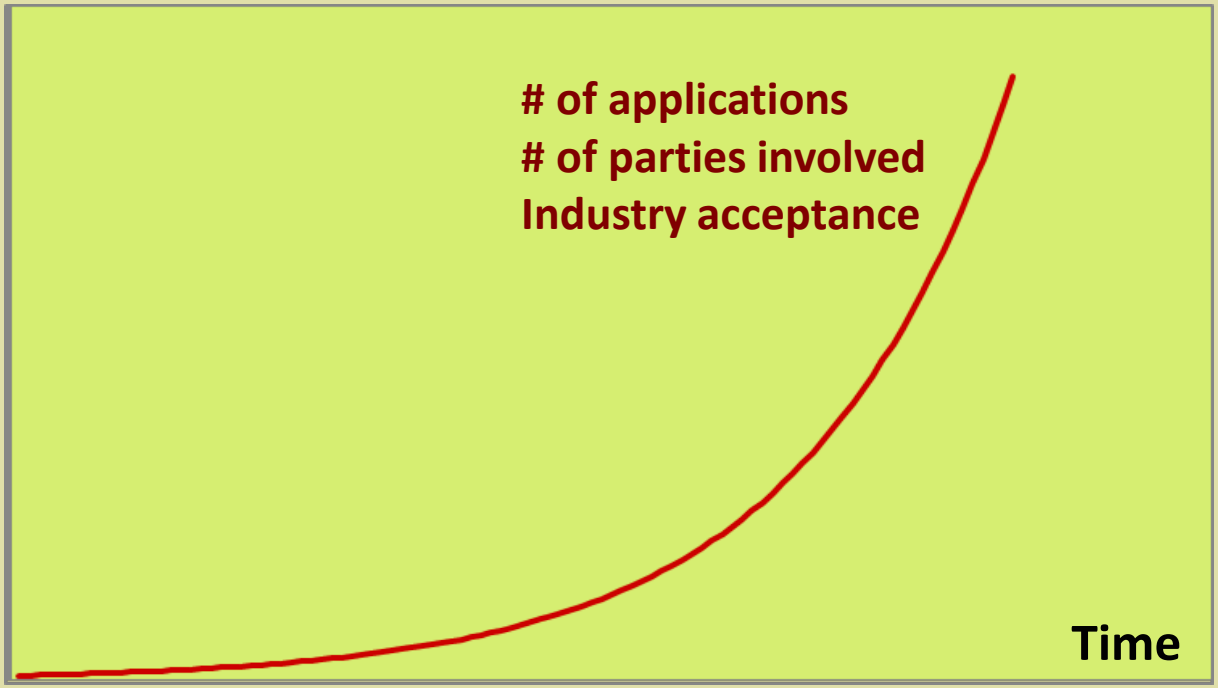
First edition
2017-03

Non-destructive testing — Pulsed eddy current testing of ferromagnetic metallic components

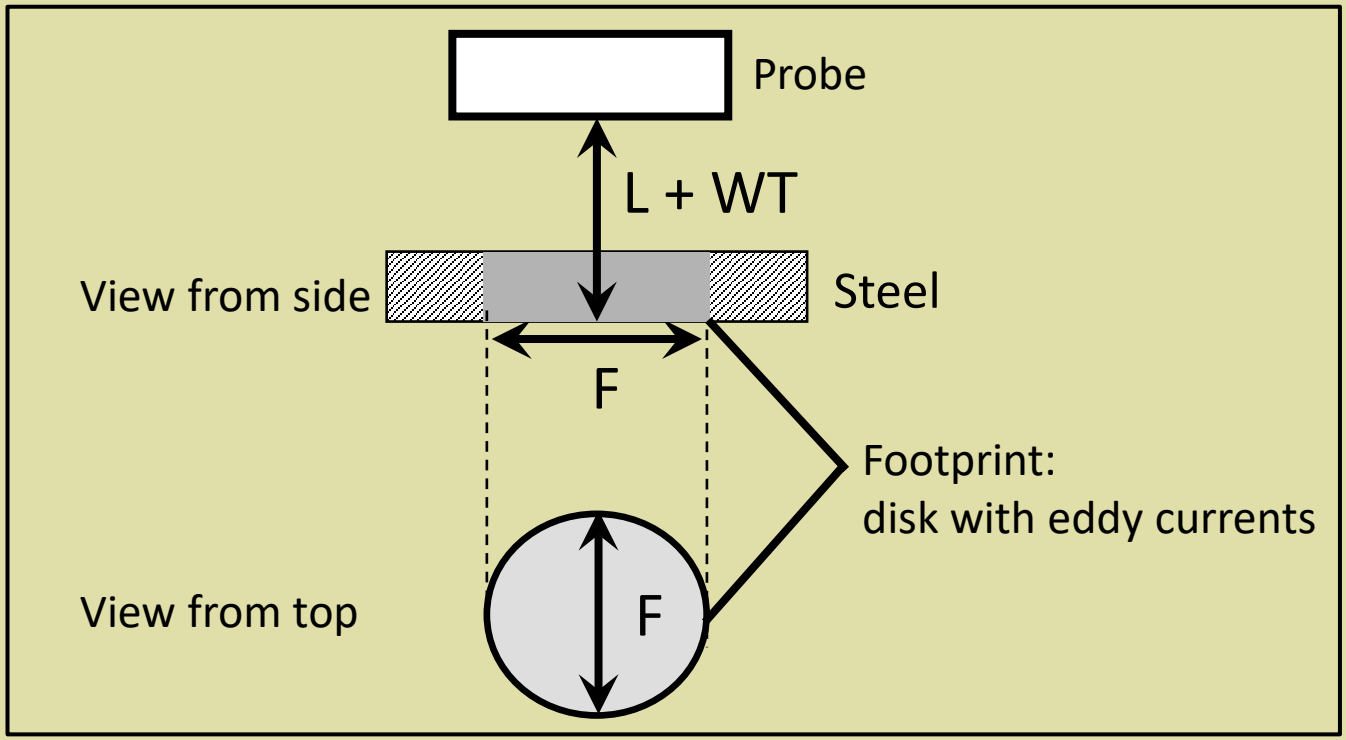
Essais non destructifs — Contrôle par courants de Foucault pulsés de composants métalliques ferromagnétiques

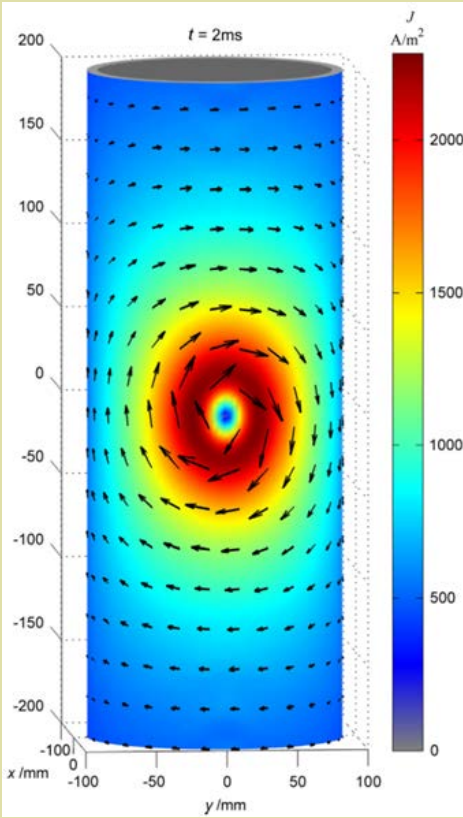
Reference number
ISO 20669:2017(E)

Has Pulsed Eddy Current Testing a future?



Main limitation: PECT averages over a footprint





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

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

Main limitation of PEC: averages over a footprint

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

When to apply PECT?

Condition 1: It is not important to be able to detect isolated pitting;
General corrosion is relevant degradation mechanism,
e.g. structural supports

Condition 2: Conventional techniques (UT, Radiography) not possible

Top applications

- Original intention: CUI (vessels and piping)
- Corrosion under fire proofing of supporting legs of storage spheres
- Inspection of column skirts
- Flow accelerated corrosion (power plants)
- Splash zone of offshore structures and risers

Other applications

- Sheet piling (port structures, jetties)
- Subsea pipelines
- Remaining ligament under corrosion
- Repair wraps
- Well casings
- Ship hulls
- High-temperature wall thickness monitoring

CUI on piping and vessels

What to consider

- Sheeting type – problematic for galvanized sheeting
  Otherwise OK (incl. Aluminum, Stainless)
  loose chicken wire: is seldom found.
- PECT will not find defects with diameter < 1.5 x insulation thickness → general wall loss or
- PECT as follow-up with Long range UT
- Dead zones near supports, obstructions, re-enforcement pad
- Access: scaffold, poles, rope access
- Economics: is delagging more cost effective (and better) ?
  (depends on criticality, required coverage, piping vs vessels and storage tanks)
- Modern PEC tools are much quicker than old instruments, scan mode

CUI is most difficult PECT application

Corrosion under fire proofing

- Water ingress under the fireproofing: rain cap & cracks
- Footprint averaging no longer a drawback; high tolerance against localized wall loss
- Skirts: temperature of column determines location of corrosion on skirt
- Skirts: inspection of bottom from the inside
- Economics for PECT are much more favorable compared to CUI → PECT is used a lot for CUF

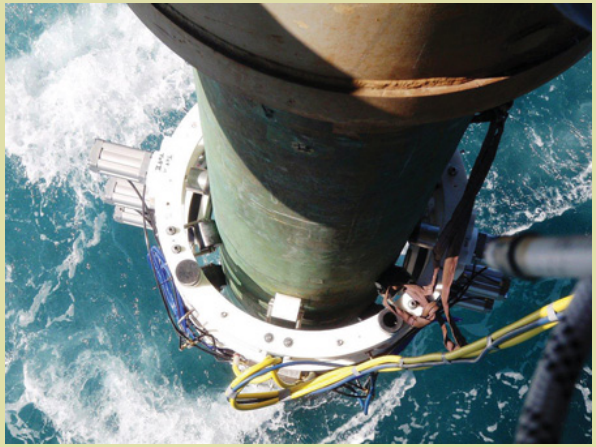
PECT inspection of supporting legs

Repair wrap

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



PEC Tool of MAXWELL ndt

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

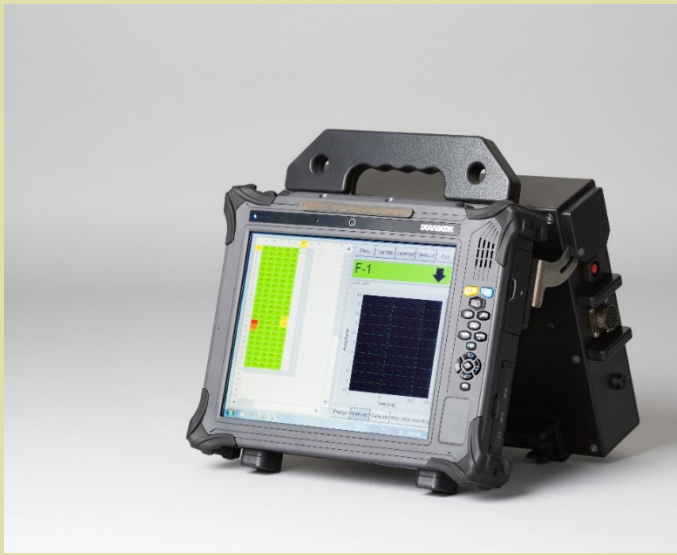
Field Reports: excel spreadsheet

Color legend

	larger than		14.9	mm
	11.2	to	14.9	mm
	9.9	to	11.2	mm
	8.7	to	9.9	mm
	less than		8.7	mm
	Calibration			
	Obstruction			

PECT wall thickness readings [mm]

			Horizontal													
			A	B	C	D	E	F	G	H	I	J	K	L	M	N
			0.0m	0.5m	1.0m	1.5m	2.0m	2.5m	3.0m	3.5m	4.0m	4.5m	5.0m	5.5m	6.0m	6.5m
Vertical	1	2.7m	12.1	12.1	12.0	12.0	11.6	11.4	11.2	11.4	11.3	11.5	11.5	11.7	11.8	
	2	2.2m	11.7	12.1	12.0	12.2	12.4	11.9	11.3	11.3	11.2	11.2	11.3	11.4	11.7	
	3	1.7m	9.7	9.9	11.0	12.0	12.3	11.9	11.4	10.8	10.6	11.1	11.0	11.0	10.3	
	4	1.2m	9.9	10.1	10.8	11.9	12.5	12.0	11.4			10.8	11.2	11.2	10.7	
	5	0.7m	9.8	10.1	10.7	11.6	12.0	12.2	11.2			11.2	11.0	10.9	10.5	



Customers quotes on the MAXWELL PECT

- “A delight to work with, keeps on going”.
- “We carried out a test at XXXX [an oil major in the USA] on a spool with grooving issues. We were able to find the defect [with the MAXWELL PECT], where the YYY equipment and the ZZZ system fell short”
- “We have participated at X (= a research body in the USA) against other PEC like tools and the Maxwell tool in a one to one comparison and we are told that our results were substantially better than the other results.”
- “We had a demo […] in “dynamic” scanning with the XXXX system [= a PECT system of a competitor]. While at 15.0mm maximum lift-off the continuous scanning the date appeared to be quite good, but then we insisted that they increase the lift off to 3 “ lift off and in dynamic scanning the result was very poor…also the scanning time was very slow, with the Maxwell we would have scanned 5 x the amount they would have covered in the same time…also the continuous scanning did not really seem to add any real value […] I can tell you we are very happy with the Maxwell PECT system.”

References

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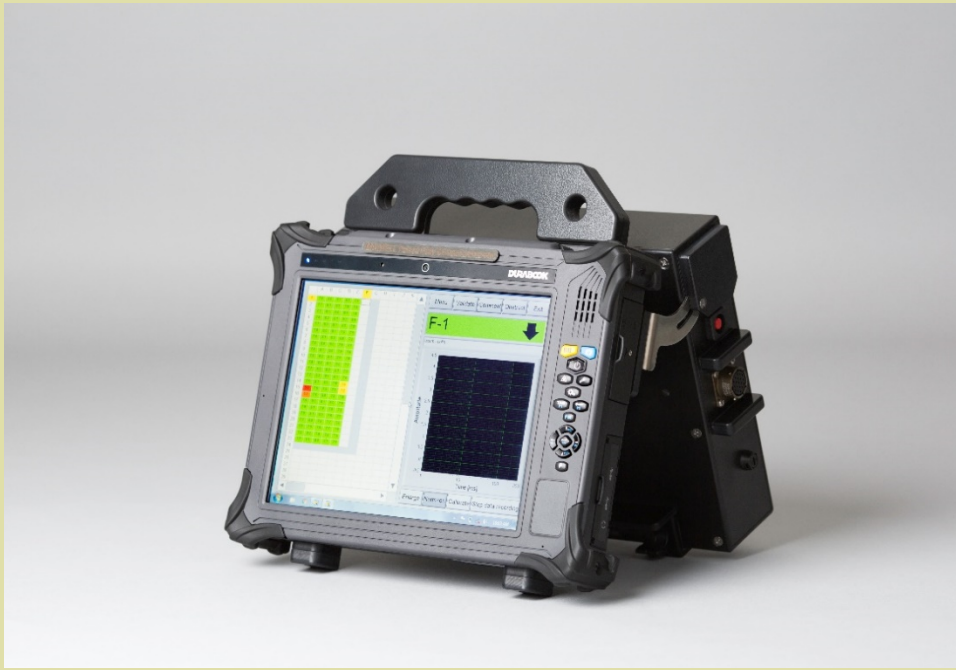

Who is Maxwell?

James Clerk Maxwell 1831 – 1879
(Edinburg, Aberdeen, Cambridge)
Physicist, founder electromagnetism