Is Pulsed Eddy Current (PEC) really necessary to detect Corrosion Under Insulation (CUI)?

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NDT in Canada
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- This week in History: “Anne Boleyn put to death”, Tower of London, May 19 1536.

- What similarities exist between Anne Boleyn's death and the detection of CUI?
  - Her King was distracted by other interests
  - Her "faults" were hidden from the king
  - She was "flirting with disaster"
  - She maintained secrecy while her faults grew more in severity
  - Her "punishment" was catastrophic

“Being distracted by other interests”

- Budgets?
- Price of oil?
- Stretching the shutdowns further apart?
- Selecting NDT Services based on lowest price?

Is plant integrity and safety not at the top of the list of plant priorities?

“Hidden faults”:

“Flirting with disaster”

(leaking pressure vessel after insulation removal):

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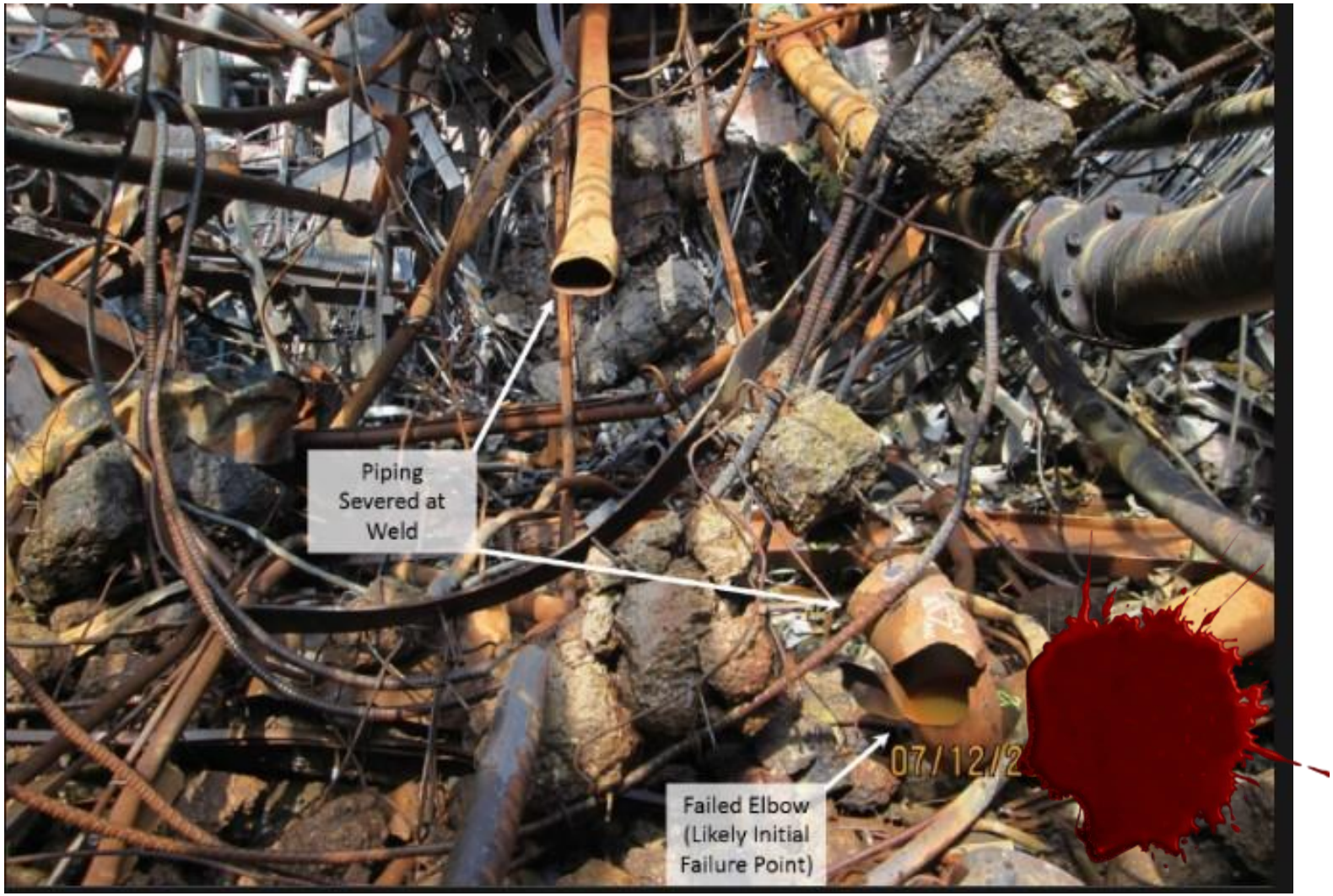
“Maintaining secrecy while problems grow worse”

(Ignoring little clues like rust stains on the cladding)

“Catastrophic punishments”

(Philadelphia 2019 refinery explosion):

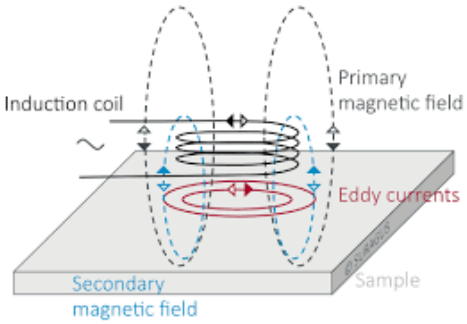


- *Seriously though…*
- How do we prevent CUI failures if we can't confirm pipe integrity through the insulation or fire-proofing?

- Let's consider two contenders for CUI detection: both electro-magnetic:

- Pulsed Eddy Current (PEC)

- Low frequency Eddy Current (LFECT)



(We realize that there are other techniques, such as real time radiography, Guided Wave and tangential radiography; however, this paper will focus on EM techniques)

Success of EM techniques for CUI:

- It's all about *FOOTPRINT* and *RESOLUTION*

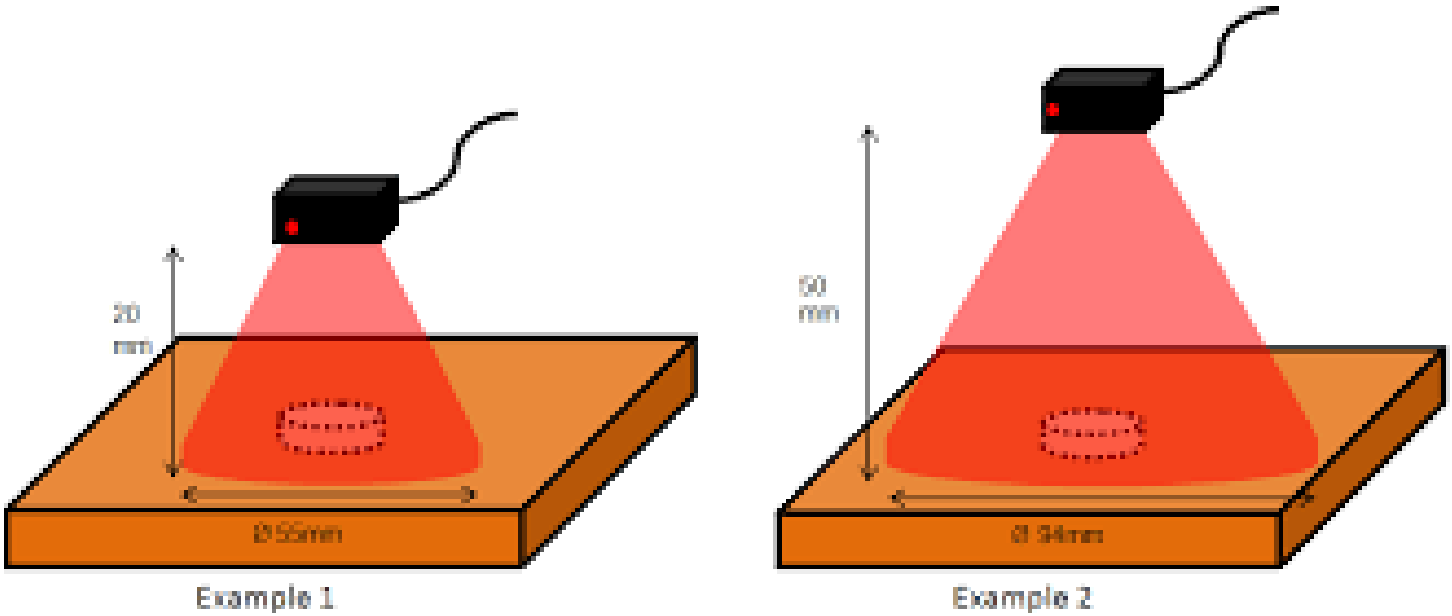
LARGE footprint = low resolution
SMALL foot print = high resolution

FOOTPRINT:

- Area covered by the coil
  - LARGE for PEC probes
  - Smaller for LFECT probes

- RESOLUTION:
- Smallest defect size sensed by the coil
  - Threshold of detection is much higher for PEC (Defect must be 2-3X bigger)

FOOTPRINT (grows with lift-off)



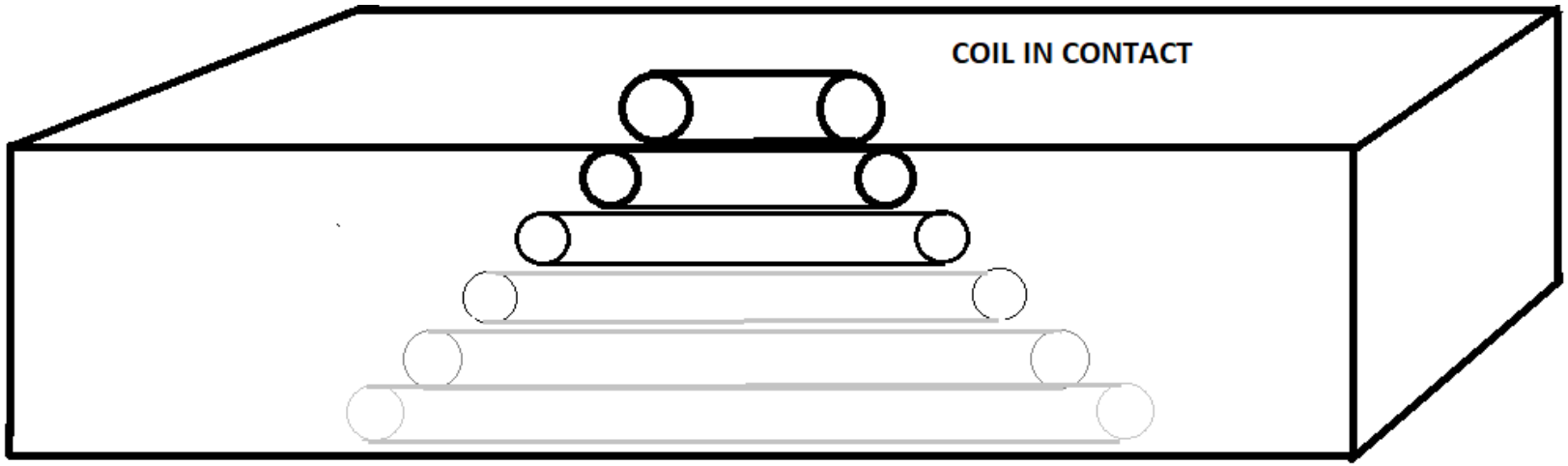
Source: Innospection

- LIFT OFF:
  - Effective footprint is 1.5x coil size if coil is in contact with material
  - As coil is lifted off (due to insulation) the footprint increases exponentially
  - As Footprint size increases, resolution to smaller defects decreases
  - More power from larger coils is needed for PEC in order for the signal to penetrate the material

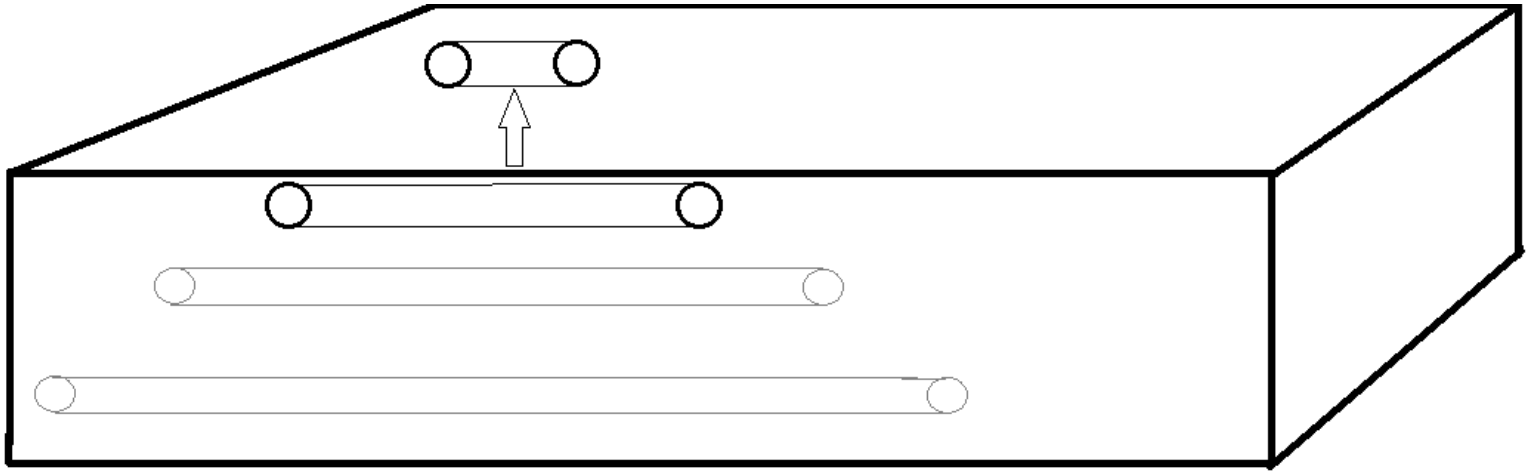
PEC requires larger, more powerful coils to penetrate material at large lift-off

Source: Eddyfi marketing material

LIFT OFF ILLUSTRATED

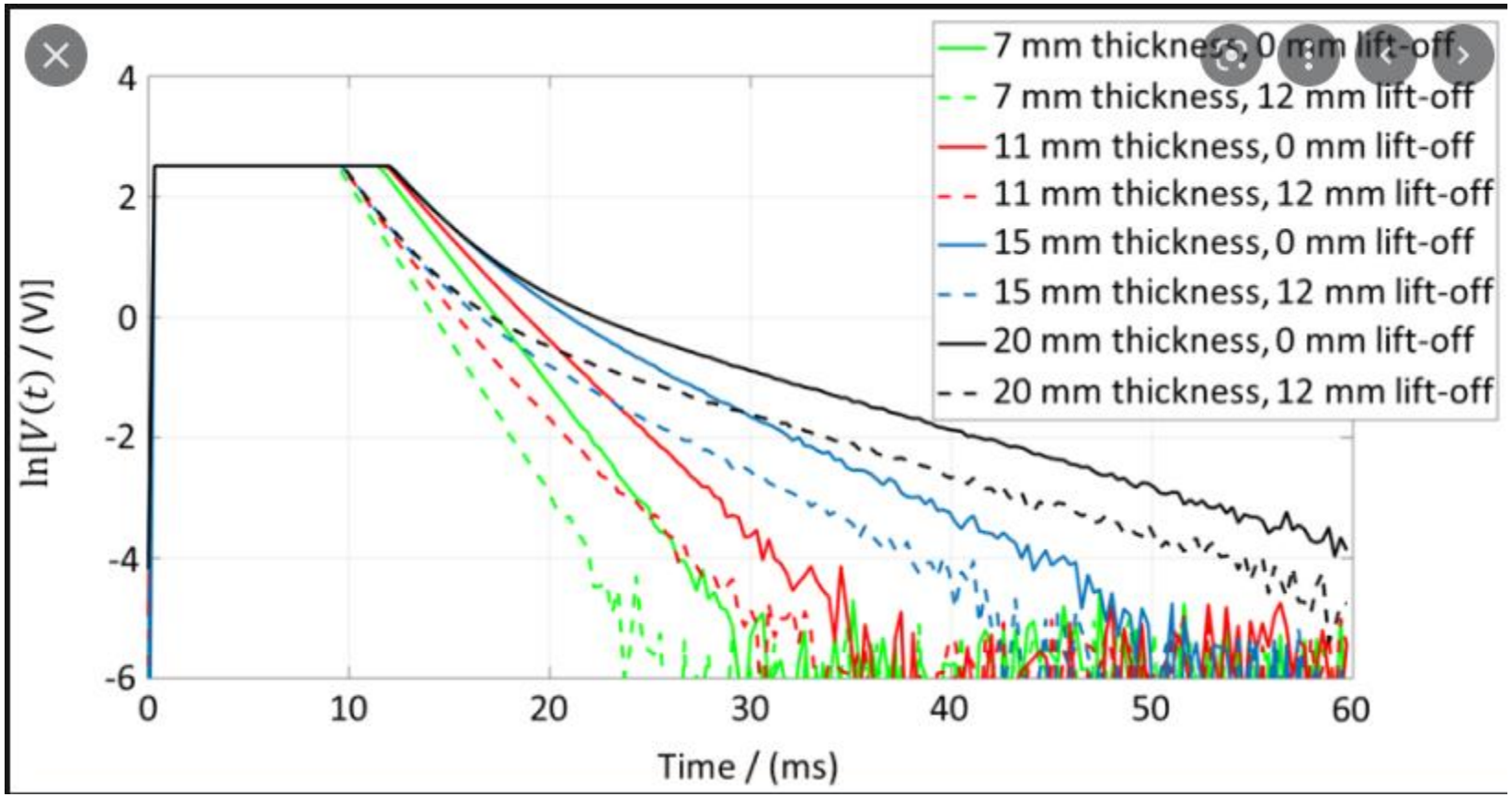


EDDY CURRENTS GET WEAKER AND SPREAD OUT AS THEY PENETRATE THE MATERIAL



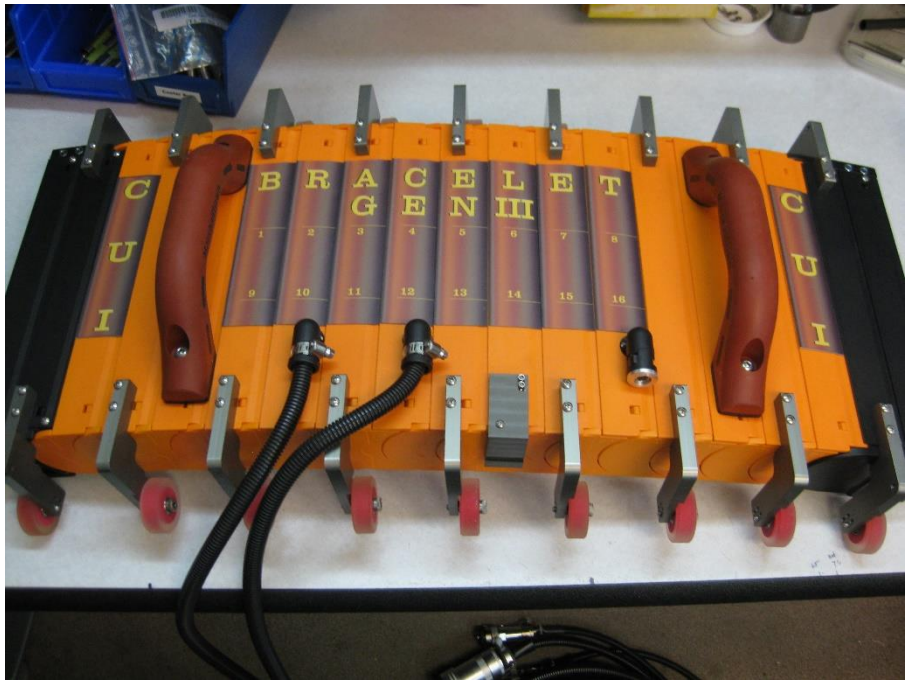
MOVING PROBE AWAY FROM MATERIAL CAUSES FOOTPRINT TO ENLARGE

- LIFT-OFF effect on PEC thickness curve



Source: MDPI

- LFECT probes have smaller coils
  - Much higher resolution than PEC probes
  - Very little ability to detect ID defects.
  - Offered only in array format



- LFECT Probes can detect ID wall loss on bare or coated pipe
  - Not suitable for CUI
  - High resolution and sensitivity on bare or coated pipe to ID defects
  - Practical wall thickness limit = 5/8”

- CUI Management Challenges

Aging infrastructure: CUI is fast becoming one of the largest threats and greatest risks for safe plant operations.

Limited cost-effective and proven NDT options available.

Most asset owners rely on either a risk-based or time-based find and mitigate program.

Regardless of the approach, success of any CUI Integrity Management program depends on ***the efficacy of the NDE method(s) utilized for the detection process.***

The CUI Challenge

- Although the mechanism (the chemical reaction) resulting in CUI is well understood and the source of the main protagonists are known, ***finding CUI is not that easy.***

- Once moisture gets into the insulation, it is ***very hard to predict where it will start pooling and initiate CUI.***

The CUI Challenge:

Relying solely on visual searches for sources of moisture ingress into the insulation system *is largely ineffective.*

Moreover, there are not always externally-visible signs of CUI presence.

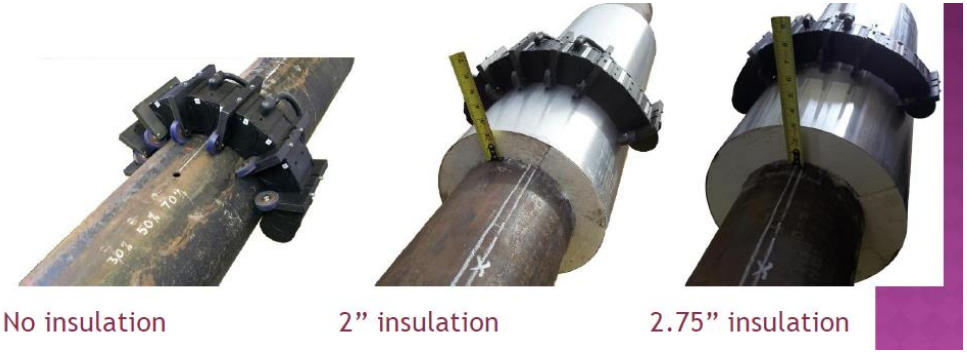
What is needed is a technique that covers a large surface area of pipe/tank/vessels rapidly at a reasonable cost

Only EM techniques offer a solution to this challenge:

Large area coverage through array probes
Rapid scan speeds = low cost

External EM Techniques:

Low frequency eddy current array “LFECT”



Similar to PEC arrays, but only sensitive to external corrosion. Advantage is small footprint for high resolution

LFECT Technology Background

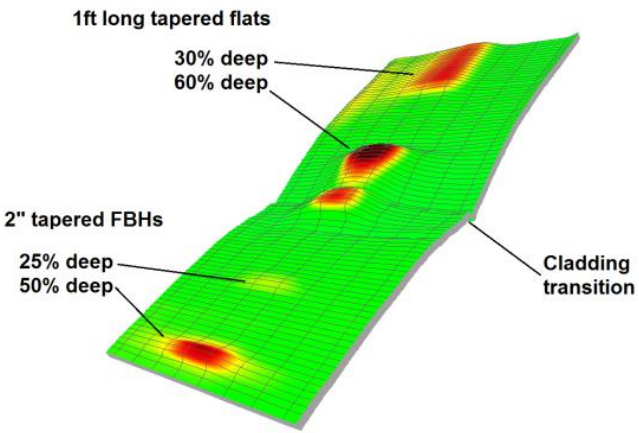
- An early version “LFECT array Probe” was introduced in 2008 for CUI detection and the technology has been continually updated since.
- It has been successfully used by U.S. and Canadian companies for CUI and CUF (Corrosion under fireproofing)
- A third generation of the Technology has now been deployed in the field, some with magnetic, motorized crawler-wheels for use on bare pipe
- It has passed industry trials in the U.K. and the U.S
- It has enjoyed good customer acceptance (Refining/Mid-Stream)

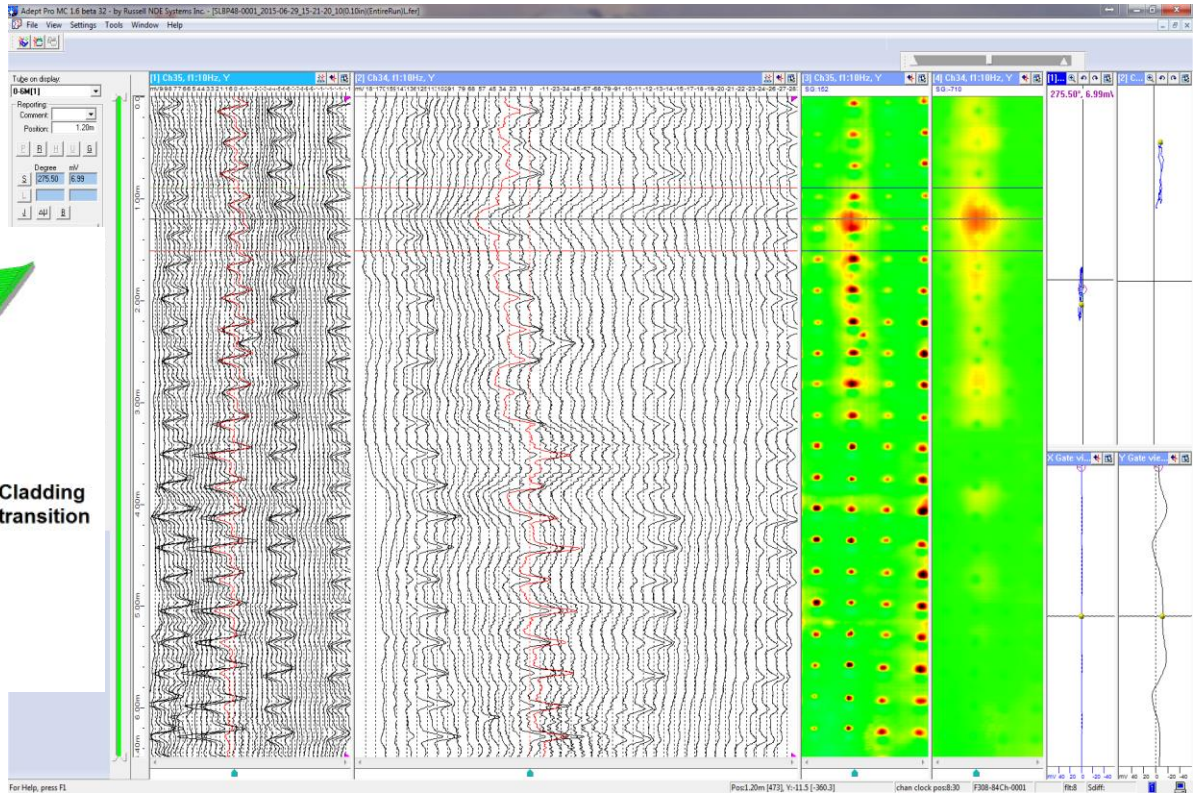
LFECT Technology:

- Concept is simple: large area scanning at reasonable speed
- 16 sensors spread across 10” scan path, giving relatively high resolution to small areas of CUI on the outside of pipe, tank or vessel with 1”-5” of insulation
- Aluminum, stainless and cloth covers are acceptable
- Results are semi-quantitative within +/- 15% accuracy for local pits and +/- 10% for larger areas

LFECT Results:

Easy to understand graphical representation of data using "traffic signal" colour scheme





CUF scan of sphere leg, 48" wide, using large LFECT

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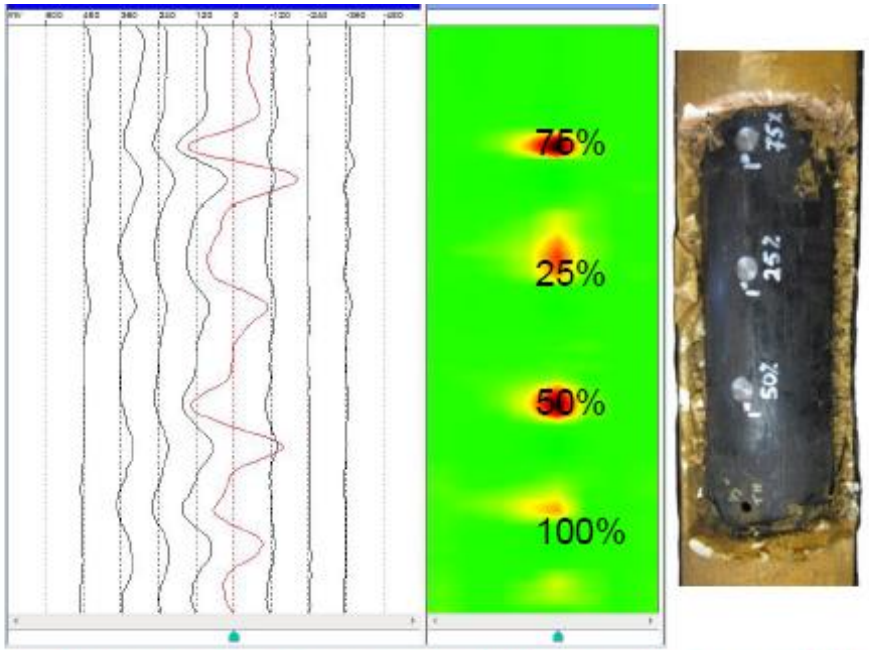
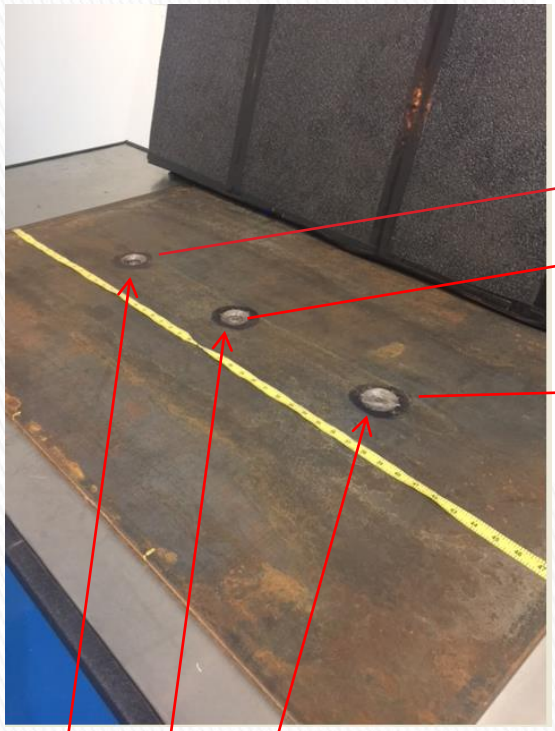
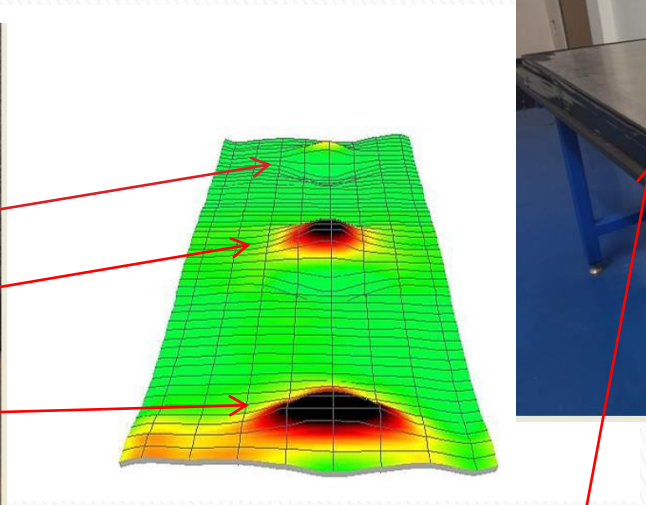
LFECT Calibration example

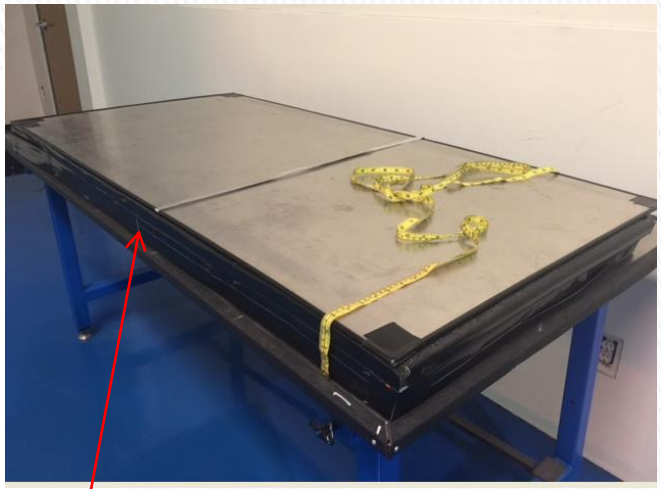


∅1” 25%, 50%, 75% and ∅1/2” 100% deep OD FBHs on 0.200” wall ∅6” CS pipe with 1” thick foam insulation and outside aluminum cladding (removed in photo)

Calibration ½” Plate (3.5” Insulation with 1/8” Aluminum clad)







25%,50%,75% – 1”x 2” Tapered FBH

3.5” Insulation with 1/8” Aluminum clad

Industry Trials with Real World CUI

Note: on CUI this large, PEC would do as good a job as LFECT

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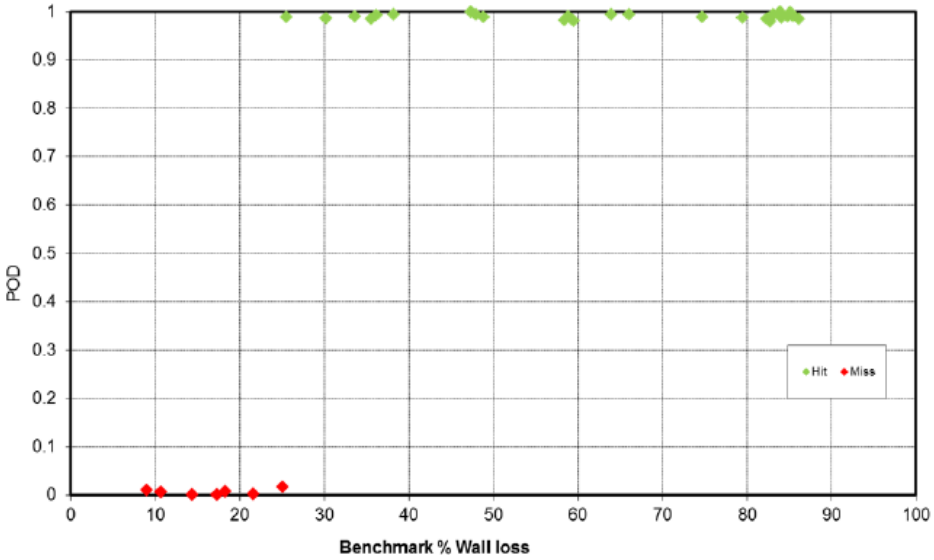
Industry Trial Performance

Application has undergone extensive client-specific blind and field trials, in addition to having participated in industry-sponsored trials

Results of blind trials showing 90% POD for local damage exceeding 25% wall loss

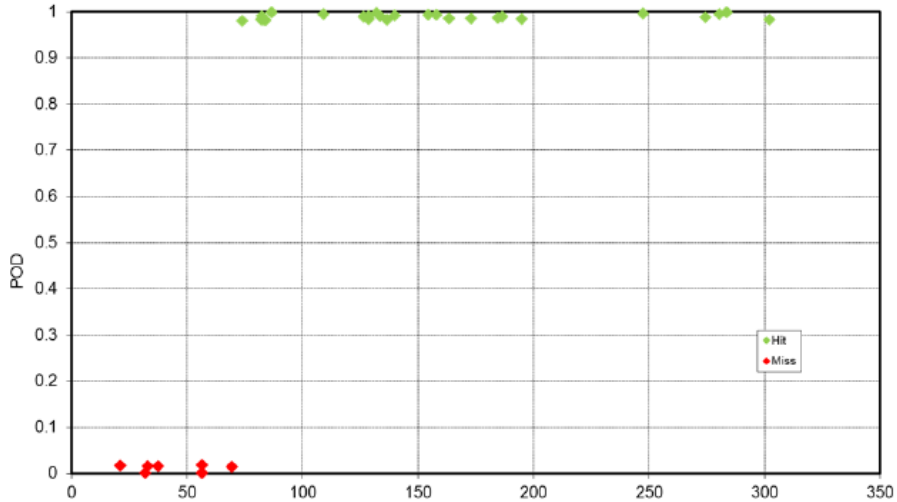


Industry Trial Performance

Results as a function of average circumferential & axial extent

Again no overlap between hits & misses

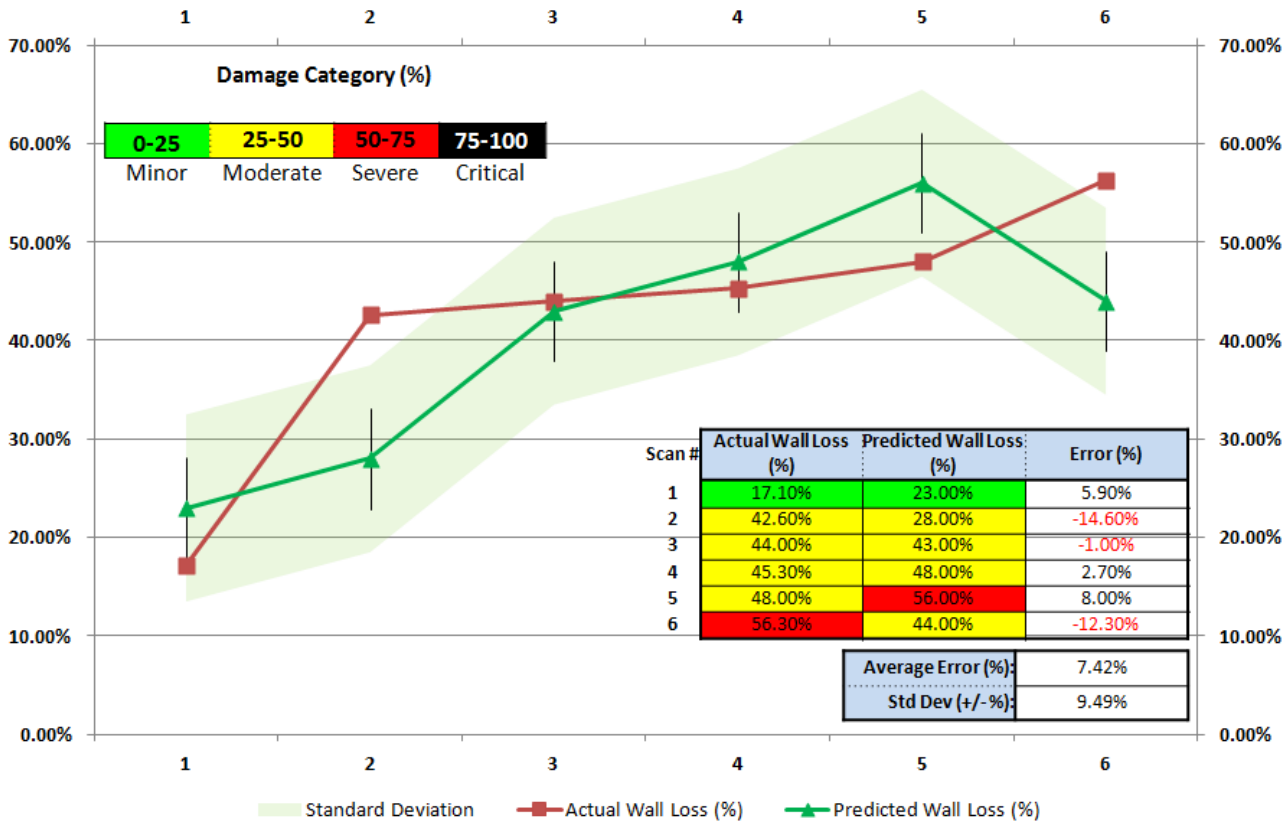
Abrupt transition at 75mm



For these scabs, average extent and wall loss are highly correlated

Primary detection parameter likely to be wall loss for scabs >25mm in extent

Client Blind Trial Performance

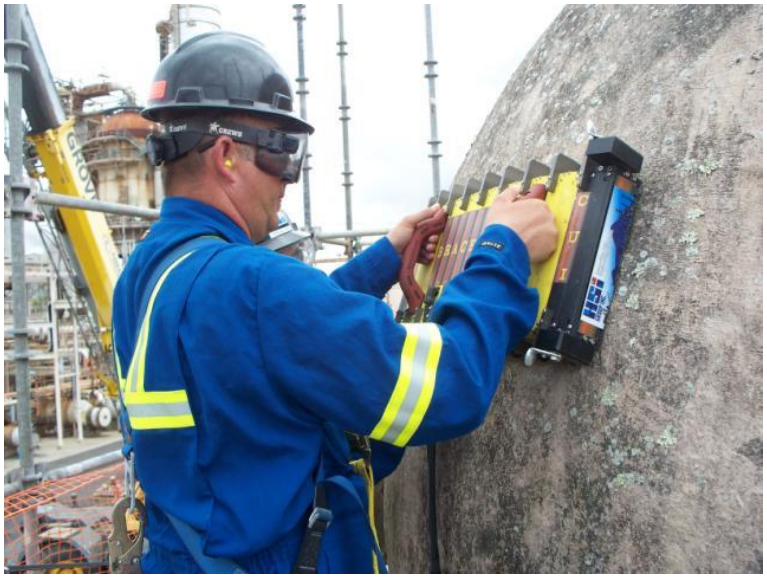


Scan #	Actual Wall Loss (%)	Predicted Wall Loss (%)	Error (%)
1	17.10%	23.00%	5.90%
2	42.60%	28.00%	-14.60%
3	44.00%	43.00%	-1.00%
4	45.30%	48.00%	2.70%
5	48.00%	56.00%	8.00%
6	56.30%	44.00%	-12.30%

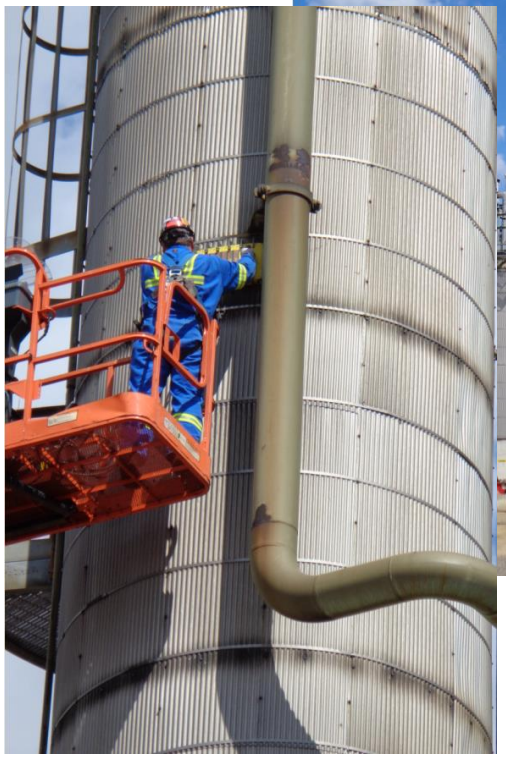
Average Error (%):	7.42%
Std Dev (+/-%):	9.49%

Applications Include:
Insulated facility piping.
Insulated or fire-proofed vessels and storage tanks

- Application on insulated tanks and vessels provides a means for active CUI screening where none existed before.
- Able to handle corrugated non-ferromagnetic weather-proofing.



Further applications:



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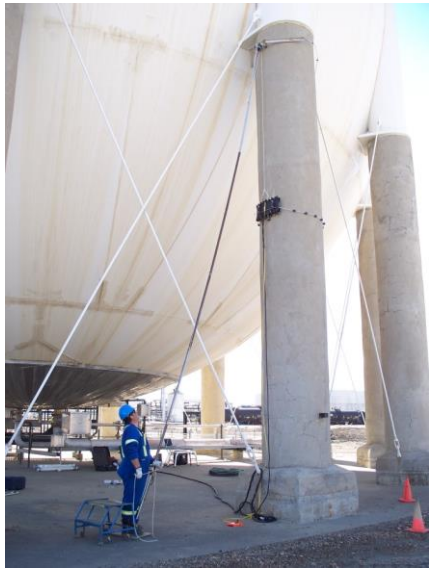
- Insulated facility piping.
- Insulated vessels and storage tanks
- Sphere legs – with fireproofing.



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A major benefit of the system is in the data it provides to the end user.

Due to the nature of the application, a CUI location is *fully mapped with length and width, in addition to an estimate for wall loss.*

These are metrics that can be fed into a fitness for service calculation and used to articulate a response to the find.

A response based on sound engineering judgment, with input providing a whole picture of the damage being assessed.

- Final Thoughts…

  – Both PEC and LFECT have their place

  – Both are valid and valuable NDE techniques

  – Footprint and resolution limitations of PEC may make LFECT the better choice if internal corrosion is not suspected

  – LFECT is less expensive equipment and therefore the service should be less expensive

QUESTIONS?

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