# The Battle of Carbon Steel

Advantages of Eddy Current Array over Magnetic Particle and Penetrant Testing for Inspecting the Surface of Carbon Steel Welds

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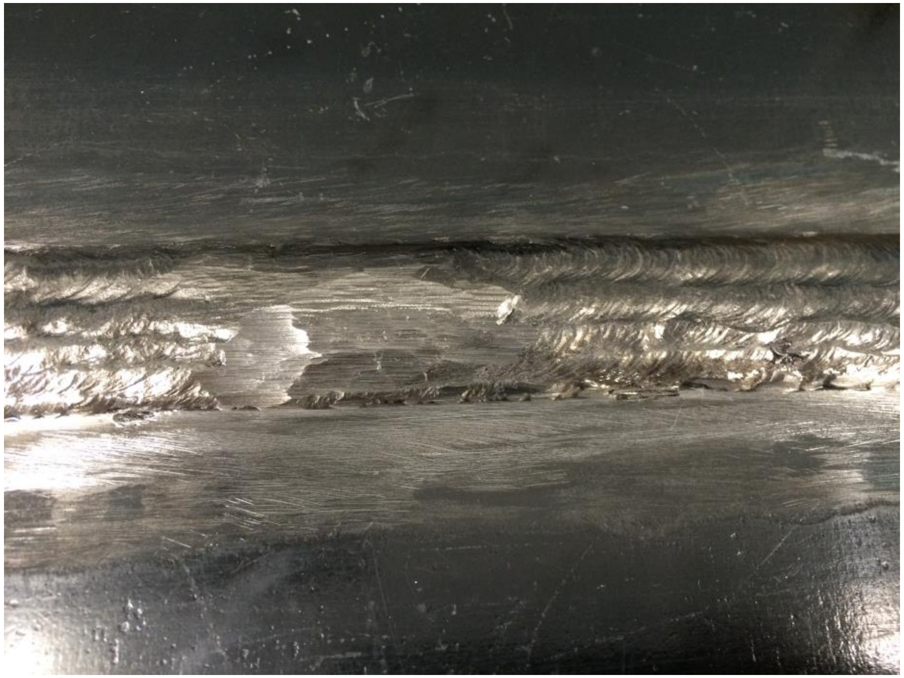
- Product Application Leader
  - Eddy Current (EC) and Bond Testing (BT)
- Based in Quebec City, Canada
- Responsible for:
  - New product development and marketing
  - Customer support
  - Application development
  - Product improvement

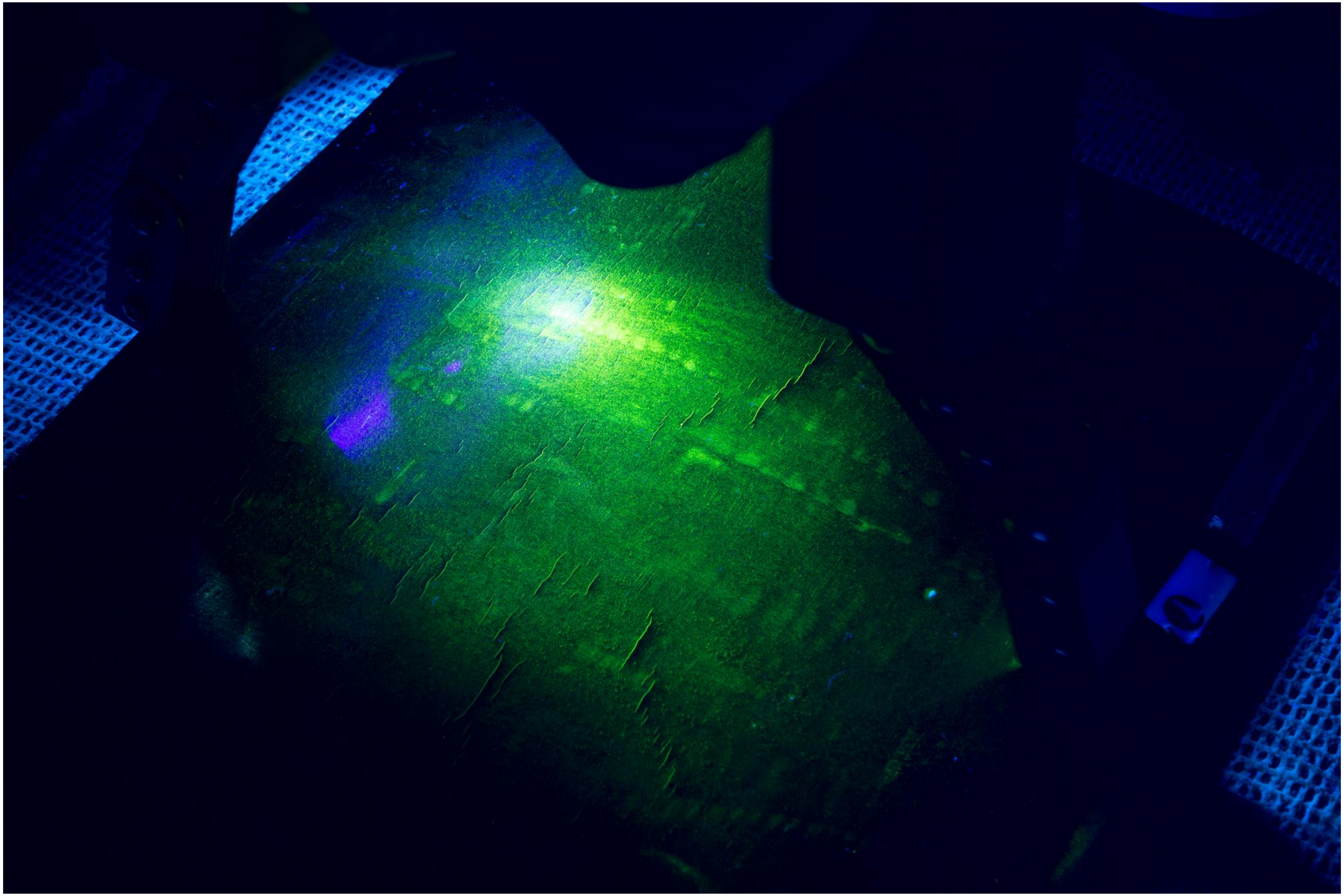
# How to Inspect Carbon Steel Welds

- 3 possiblities
  - Magnetic Particle Inspection (MPI)
  - Penetrant Testing (PT)
  - Eddy Current (ET)



# Magnetic Particle Inspection (MPI)

# How Does MPI Work?



# Advantages & Limitations

**Advantages**

- Surface and near-surface dicontinuities
- Low cost, easy to use and safe
- Fast inspection
- No post-inspection cleaning
- Many inspectors available

**Limitations**

- Ferrous materials only
- Limited to small inspections
- Magnetic flux alignment is important
- Requires removing coatings and paint
- Discontinuity needs to be perpendicular to the magnetic field

# Penetrant Testing (PT)

# Advantages & Limitations

**Advantages**

- Small surface dicontinuities
- Visual representation
- Large areas
- Inexpensive method
- Many inspectors available
- Complex geometries

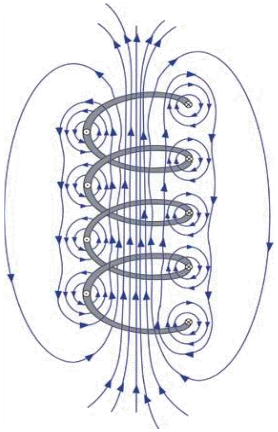
**Limitations**

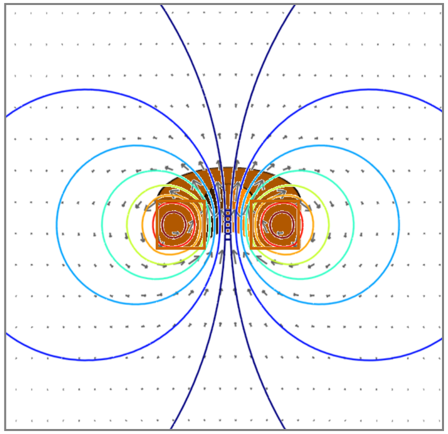
- Open discontinuities only
- Chemicals and fumes
- Multiple processes
- Cleaning is very important
- Requires removing coatings and paint
- Bleeding errors

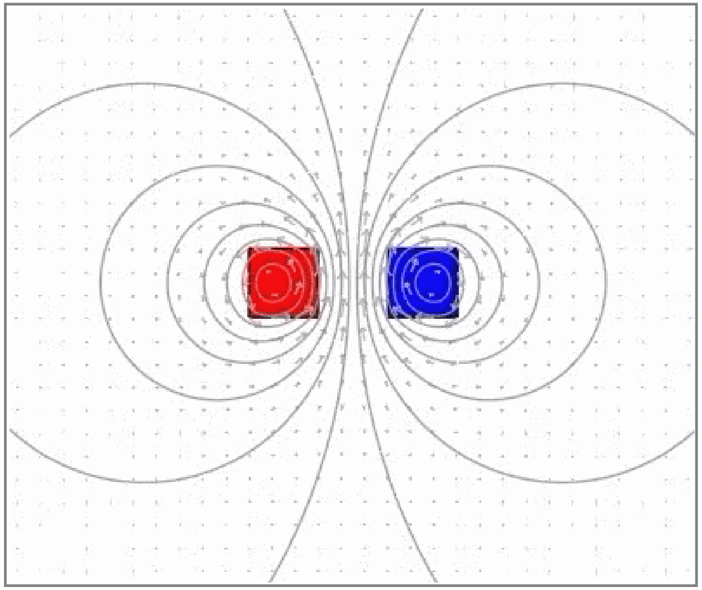
# Eddy Current
# (ECT)

# How Do Eddy Currents Work?

- Back to basics:
  - When the wire is shaped into a coil, the interaction of each turn produces a global magnetic field around the coil.
  - This magnetic field oscillates at the same frequency as the current injected into the coil.

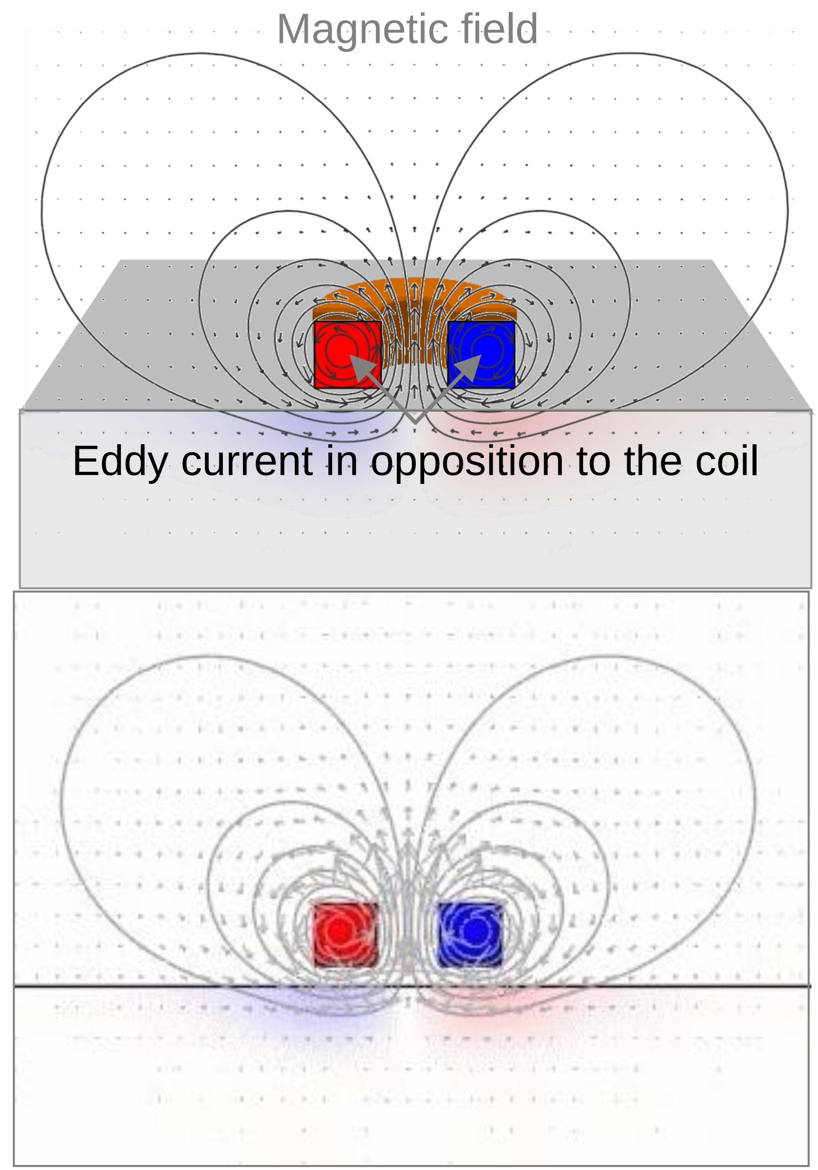






# How Do Eddy Currents Work?

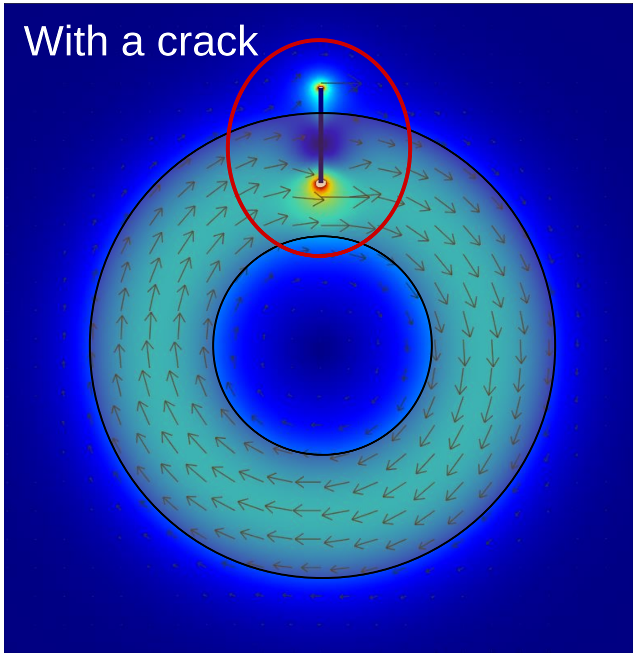
- Back to basics:
  - When this coil is placed over a conductive part, opposed alternating currents are generated; these are the eddy currents.
  - The eddy currents oscillate at the same frequency as the current injected in the coil but with a small delay; this is the phase lag.



# How Do Eddy Currents Work?

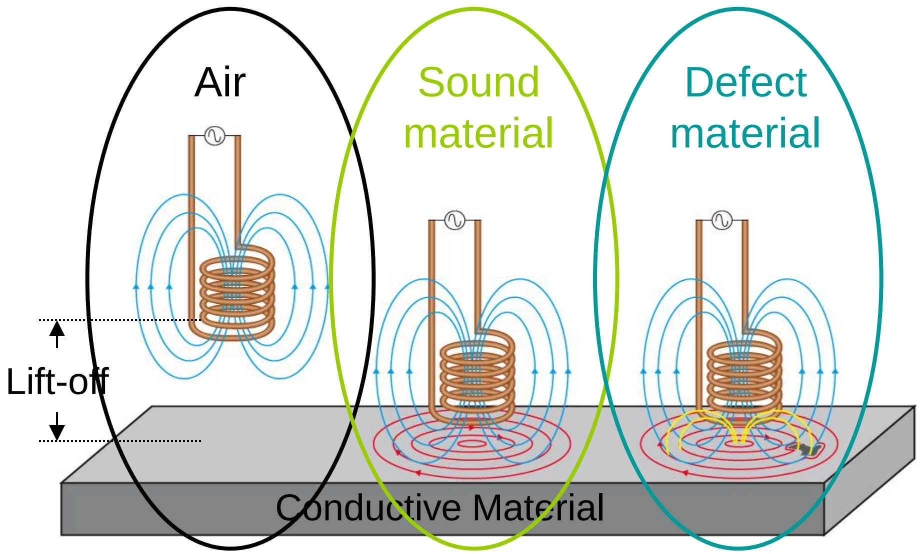
- Back to basics:
  - If a defect in the part disturbs the path of the eddy currents, it creates a local magnetic field that changes the balanced condition of the system.
  - Such changes can be detected by monitoring variations of the coil impedance.

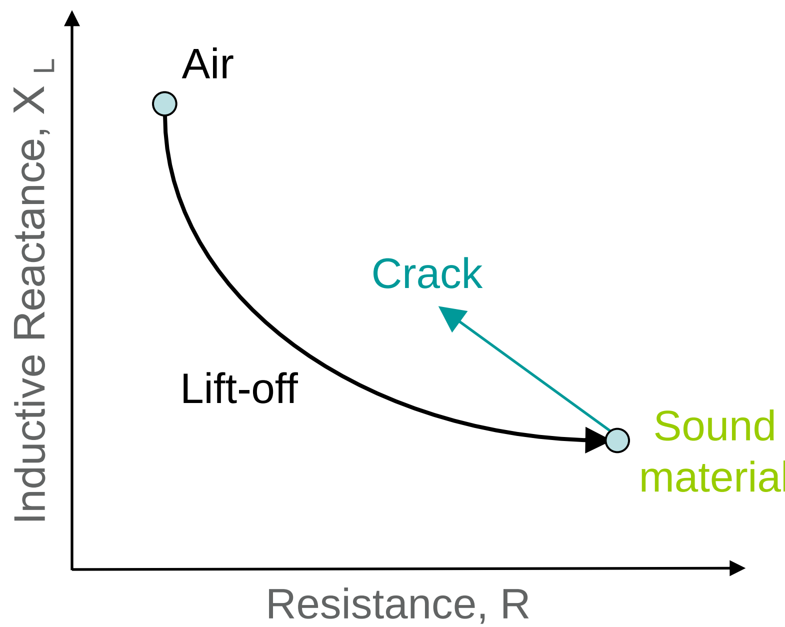
Top view:
Eddy current path and density



# How Do Eddy Currents Work?

- Representation in impedance plane:
  - A coil in the air has an impedance, which results from a resistance and a reactance.
  - If the coil moves closer to a conductive material, the impedance of the coil changes (because of the eddy currents) and follows the *Lift-off* path.
  - When the coil is over the surface of the material, the impedance stabilizes to its sound value.
  - If the coil passes over a defect in the material, the impedance of the coil changes and follows the *Crack* path.



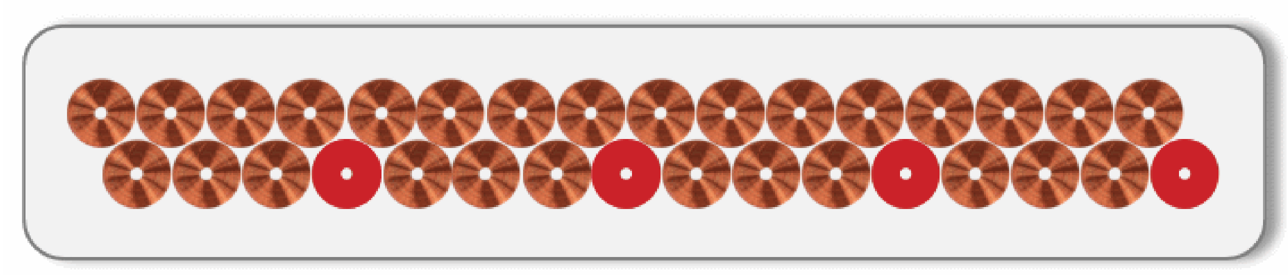



# Conventional Eddy Current Probe

# Eddy Current Array (ECA)

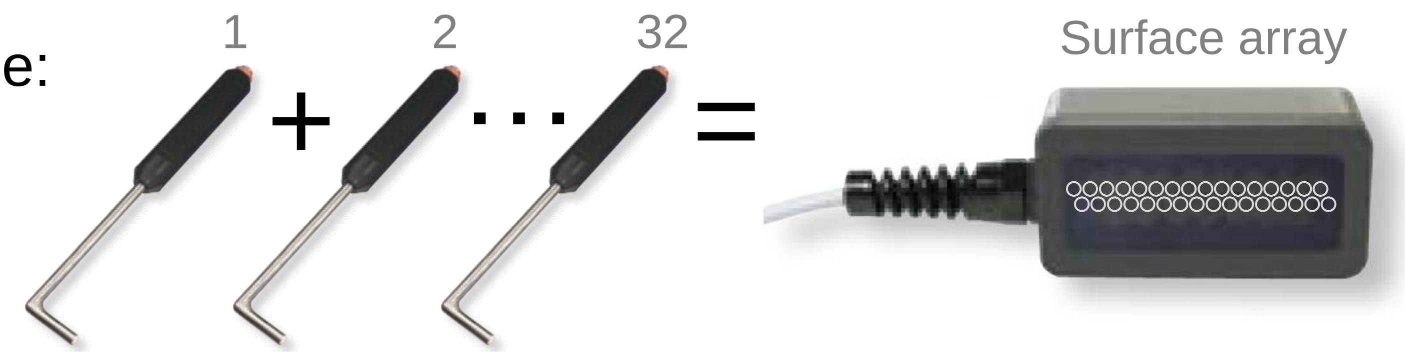
# What is ECA?

- ECA is ECT
  - Same depth of penetration
  - Same probe configuration available (Absolute, reflection, etc..)
- Multiple ECT coil in one probe
- C-Scan imagery; allow to show information about all channel at the same time

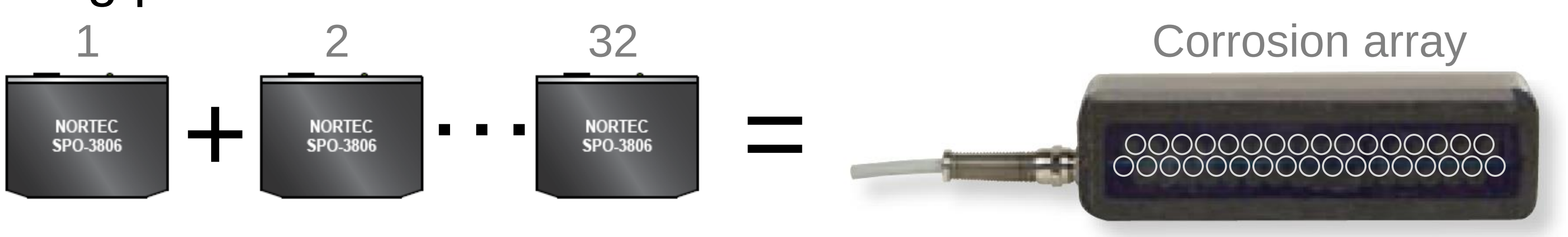


# Elements in ECA Probes

- Elements are the individual EC probes used to make the array probe.
- Any type of EC probe can be used as an element. For example:
  - Pencil probe:



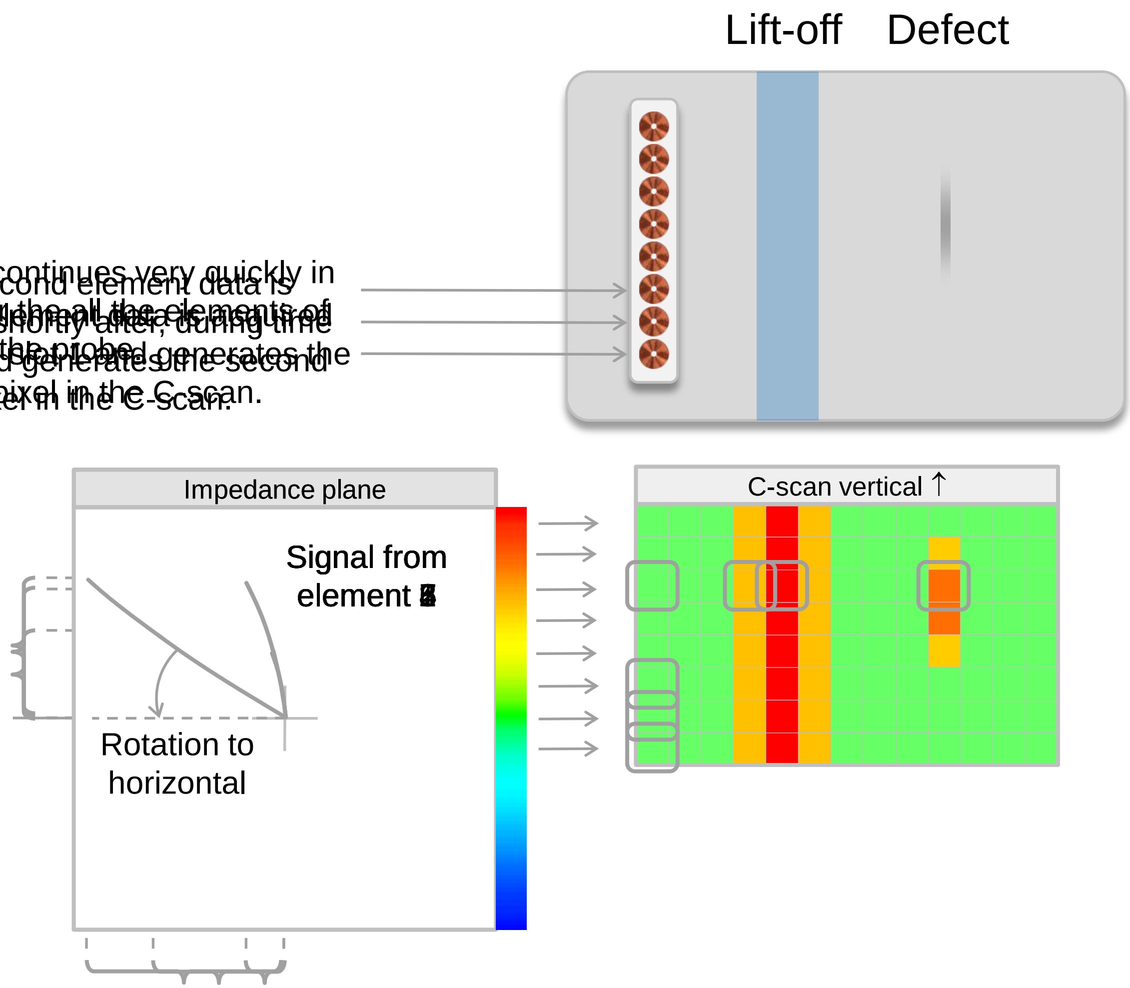

  - Sliding probe:



# C-Scan Representation

## Before calibration

- To calibrate, the signal from each element is rotated in order to bring the lift-off signal to the horizontal axis of the impedance plane.



# C-Scan Representation

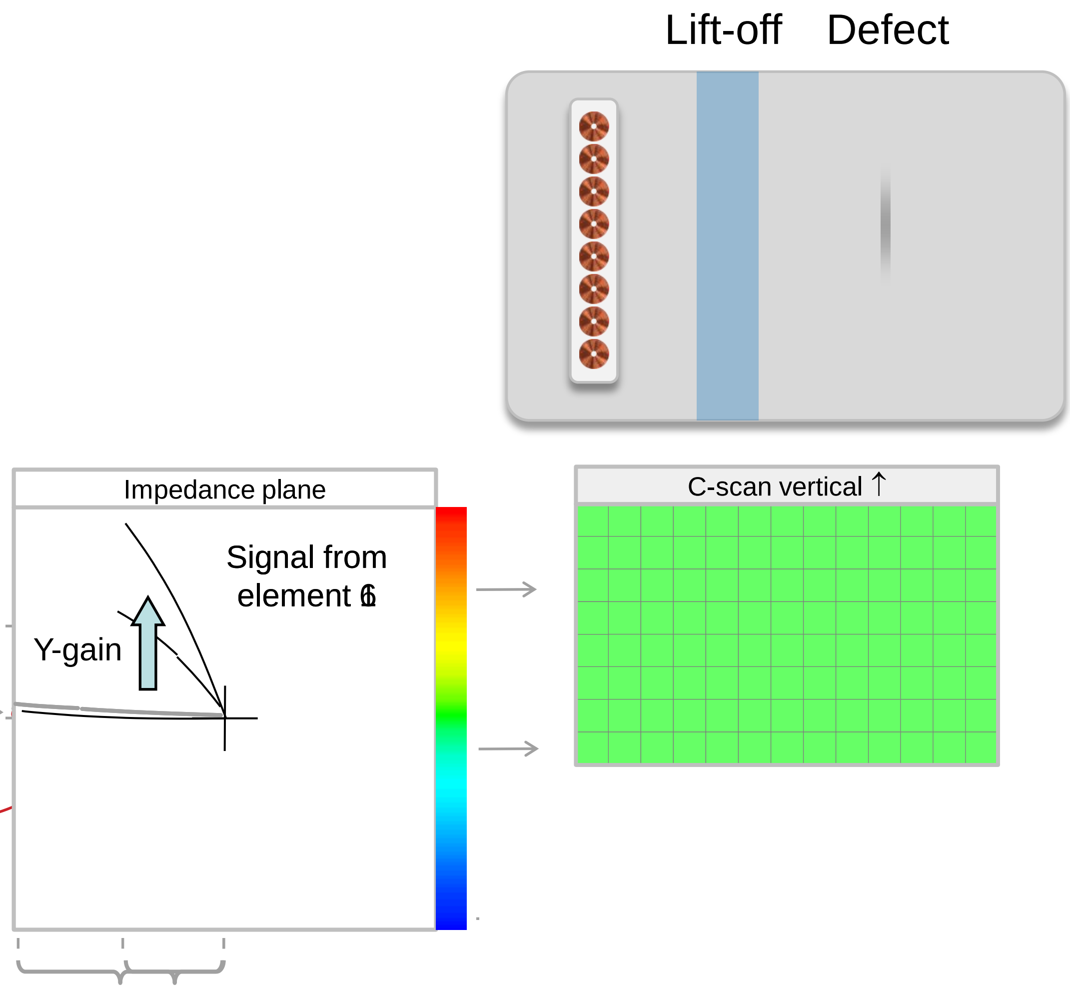
## After calibration

- The elements show a horizontal lift-off signal in the impedance plane.
- Defects have a strong vertical component.
- Additional gain may be used on the Y-axis to increase the defect signal and improve the color contrast in the vertical C-scan.

Large lift-off variation may have a small positive vertical component, that creates a yellow color in the vertical Cscan.

The defect is easily detected on the vertical C-scan while the small lift-off variations are not seen.

However, a small lift-off variation remains horizontal and are not seen in the vertical Cscan, which is very useful for defect detection.

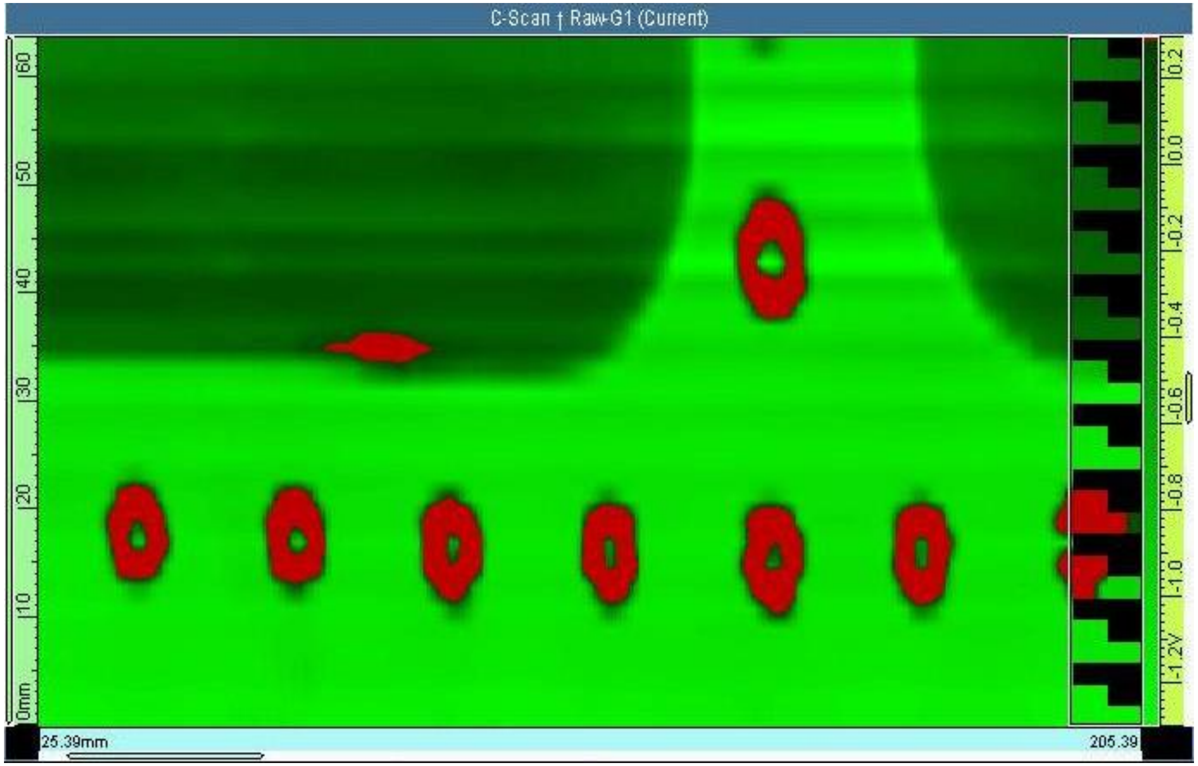



The horizontal lift-off signal produces a clear blue color in the horizontal C-scan.

The defect signal is seen in blue, like the lift-off variation.

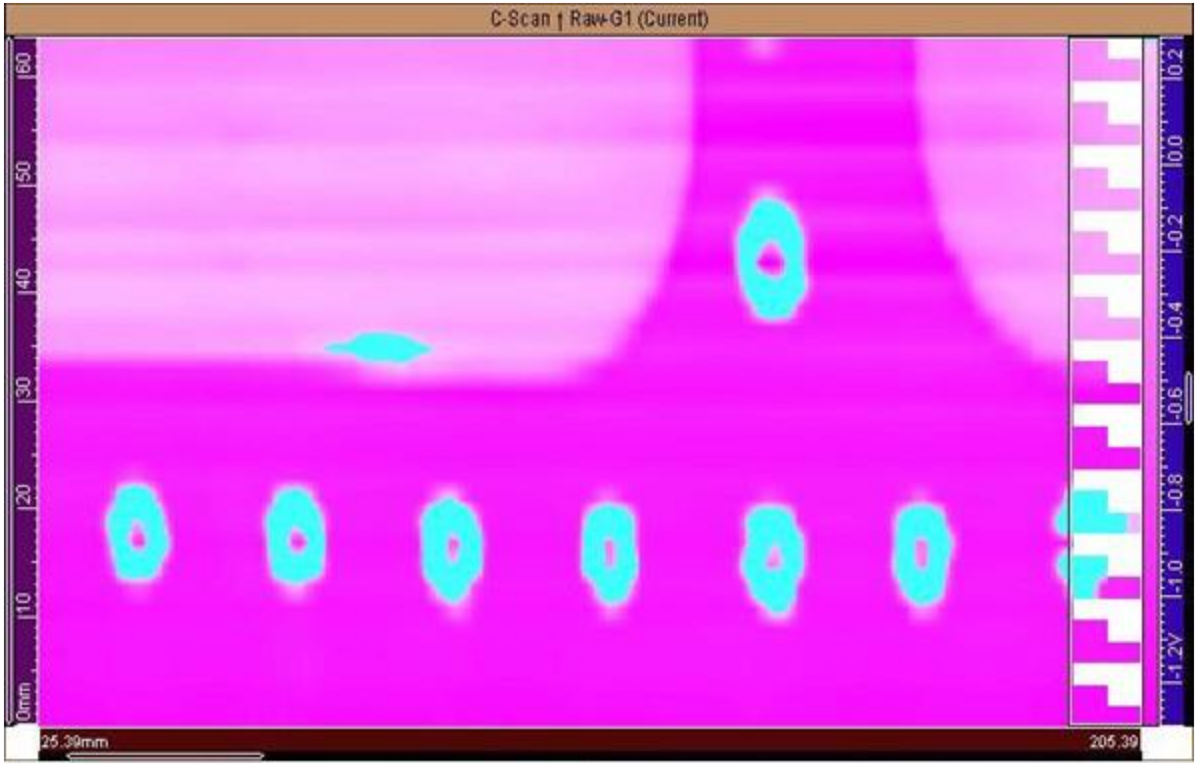
# ECA Advantages

- ✓ Time saving
- ✓ Large probe coverage
- ✓ Easy Imagery (C-Scan)
- ✓ Better POD



# ECA Limitations

- ✓ Few Inspectors
- ✓ Training
- ✓ Lift-off Variations



# ECA Probes

- Standard Probe


# Comparison of Methods

# Comparison of Methods

**Eddy Current Arrays**

- Simple to use (similar to ECT)
- Minimal surface preparation needed
- No de-magnetization or post cleaning required
- Not affected by weather conditions
- “Green” method

**MPI, PT**

- VERY simple to use
- Very clean and dry surface; needs paint or coating stripping
- Exterior test requires more preparation
- Environmental concerns (paint or coating removal and re-application, waste disposal)

# Comparison (cont'd)

**Eddy Current Arrays**

- Reject Criteria (relevant or non-relevant indications)
- Excellent PoD on large surfaces & dirty cracks
- Instant results and Rapid coverage of large areas (high productivity)
- Encoded Scan capability
- Imagery and Archiving
- Post-Process Analysis

**PT, MP**

- Indications only; no reject criteria
- PoD highly dependant on surface preparation & crack cleanliness
- Pre and post cleaning (de-mag) time, dwell time

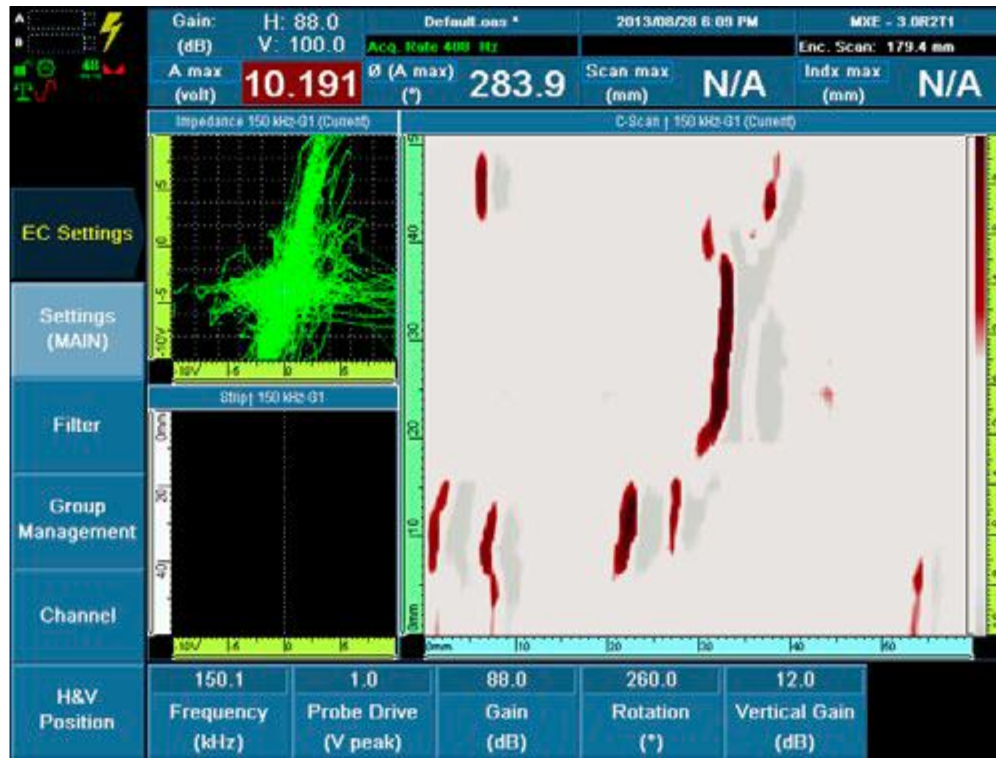
# Other Examples

Carbon Steel Inspections

# Replacement of Traditional NDT methods

ECA can be a good replacement of traditional NDT method such has Liquid Penetrant and Magnetic Particle, for surface defect detection. ECA can also be use without removing paint or thin coating on over the surface.

Picture of Red dye penetrant indications

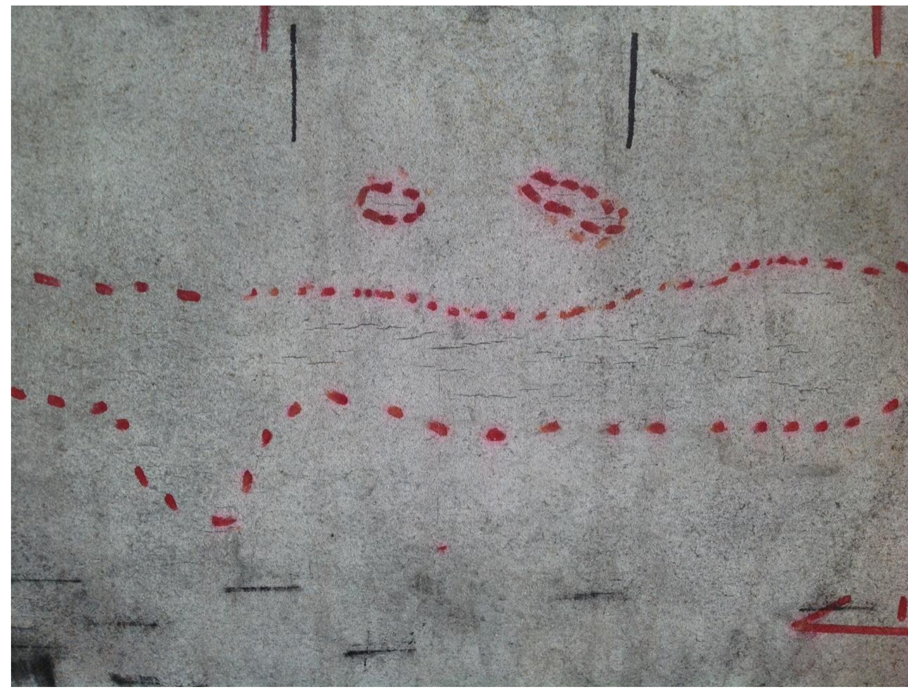



Eddy current array indications with red dye color palette

# Stress Corrosion Cracking

SCC (Stress Corrosion Cracking) is a very good application where ECA can be use to treplace conventional NDT method. This application consist to detect surface crack over carbon steel or stainless steel material.

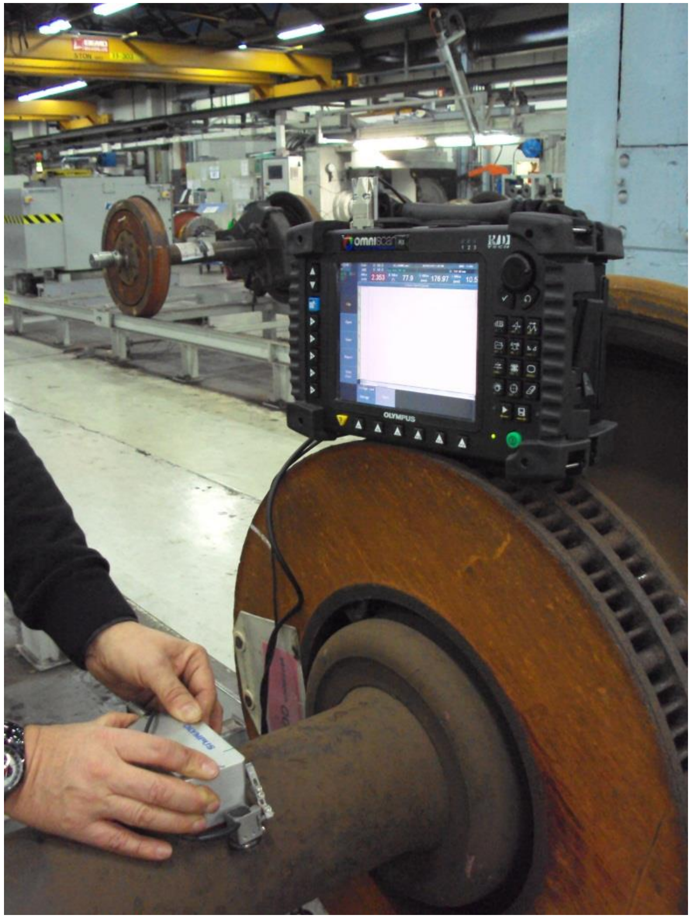
# Stress Corrosion Cracking
# On buried carbon steel pipe



# Stress Corrosion Cracking On buried carbon steel pipe

# Train Axle Inspection

Train axle inspection is also a very good application for ECA, MPI can be replaced by ECA for faster surface inspection and archiving possibility.



# Conclusion

# Thank You

Questions? Comments?