

# PHMSA – Underground Storage Wireline Logging

July 14<sup>th</sup>, 2016



# Introduction

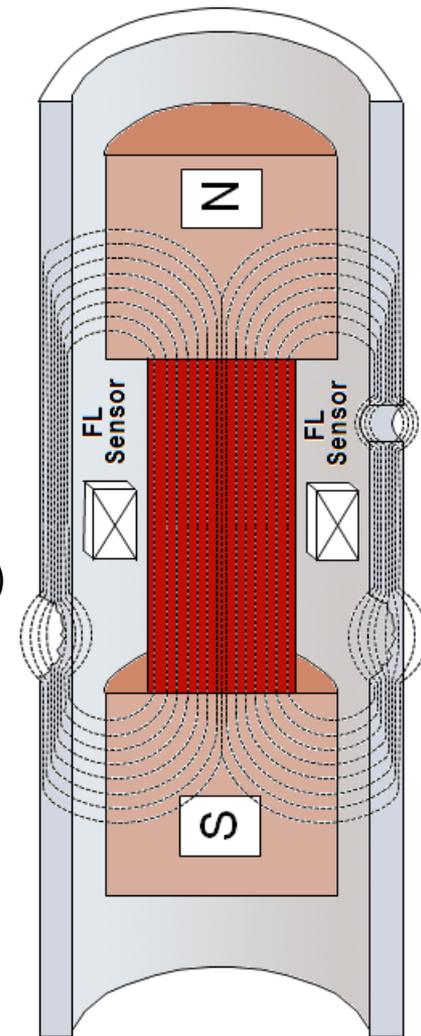
- Types of underground storage:
  - Depleted Gas/Oil Reservoirs
  - Aquifer reservoirs
  - Salt Cavern reservoirs
  
- 3 categories to well logging:
  - Programs suited to monitoring and well integrity
  - Programs suited to inventory verification
  - Logging programs suited to investigating well problems.

# Casing Inspection

# Magnetic Flux Leakage

## ■ Advantages:

- Quantifiable inside and outside metal loss. Identifies holes, isolated corrosion, and defect depth of penetration.
- High Resolution Vertilog (HRVRT) measures in 3 axis to quantify geometric measurement of the defect allowing advanced burst pressure calculations. Calculation methods employed:
  - Barlow (onset of plastic deformation, without geometry)
  - Canadian Z341 (onset of plastic deformation with 15% FS)
  - ANSI/ASME B31G (failure pressures, using geometry of defect and interaction)
  - ASME Modified B31G (failure pressures)
  - Effective Area (River Bottom Analysis for defect interaction)
- Can be run in any liquid/gas environment and log in wax/scale (if minimal)
- High Resolution Vertilog (HRVRT) can log up to 200 fpm logging speeds with excellent resolution.
- Unaffected by wax/scale/debris left in pits after bit scraper runs.
- Signal to Noise Ratio increases with ageing wells and presence of corrosion.
- Can identify top and bottom of external casing strings.



# Magnetic Flux Leakage

- Disadvantages:
  - Magnets can restrict deployment if deviated or restrictions encountered.
  - Limited to ferrous or magnetic permeable casing strings.
  - Several tool sizes necessary for casing ranges.
  - Tool OD is generally large and scaling can be an issue if significant enough.
  - Cannot detect long axial splits or gradual casing wear or erosion.

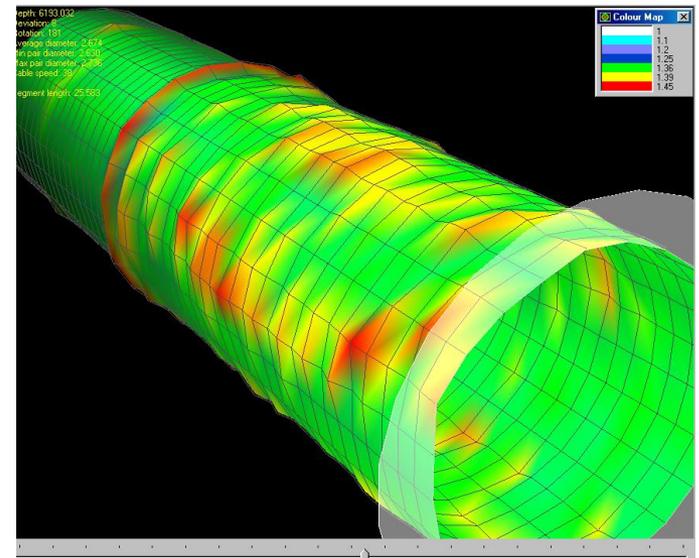
# Imaging Calipers

## ■ Advantages

- Independent measuring arms give a 3D image with processing software.
- Can be run in any liquid/gas environment.
- Reasonable logging speeds.
- Excellent for evaluating mechanical damage and deformation.

## ■ Disadvantages

- Can only assess internal defects.
- Resolution limited to the width/height of the fingers and the distance between them.
- Scraper run necessary to evaluate pipe with scaling. Scaling left in pits cannot be distinguished from un-corroded pipe.
- Debris in the well can interfere with fingers open/closing.



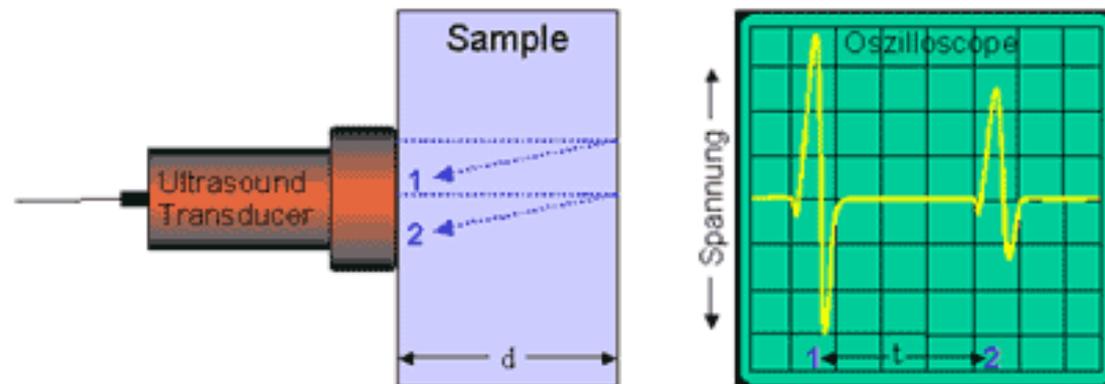
# Pulse Echo Tools

## ■ Advantages

- Can provide cement evaluation and casing thickness in a single run.
- Measures independent of metallurgy of pipe.
- Good accuracy.

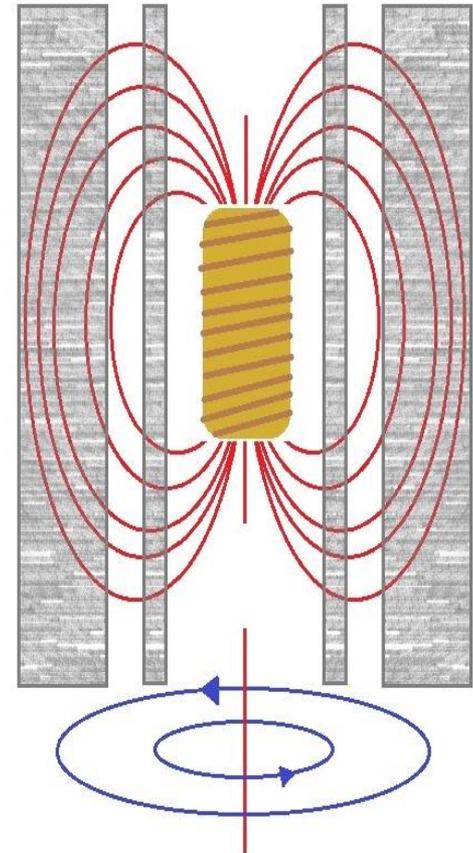
## ■ Disadvantages

- Requires a liquid filled borehole.
- Large casing size or heavy weight borehole fluid can be limiting on signal quality.
- Logging speed relatively slow to MFL tools.
- Signal to Noise Ratio decreases with surface roughness caused by debris, corrosion, paraffin wax.



# Electromagnetic (Eddy Current/Phase Shift)

- Advantages:
  - Can be run in any liquid/gas environment.
  - Can measure metal loss in multiple casing strings without intervention. This can provide indication of catastrophic failure without removing inner pipe string.
  - Can locate top and bottom of external casing strings.
  - Determine axial split in inner casing strings.
  - Detect general wall thinning due to corrosion/erosion or mechanical wear
- Disadvantages:
  - Resolution for features in external casing strings is low. No burst calculation available.
  - Small diameter and early corrosion features may not be detectable.
  - External hardware and additional casing strings further complicate measurement and resolution.



# Leak Detection

# Gamma Ray - Neutron

## ■ Advantages:

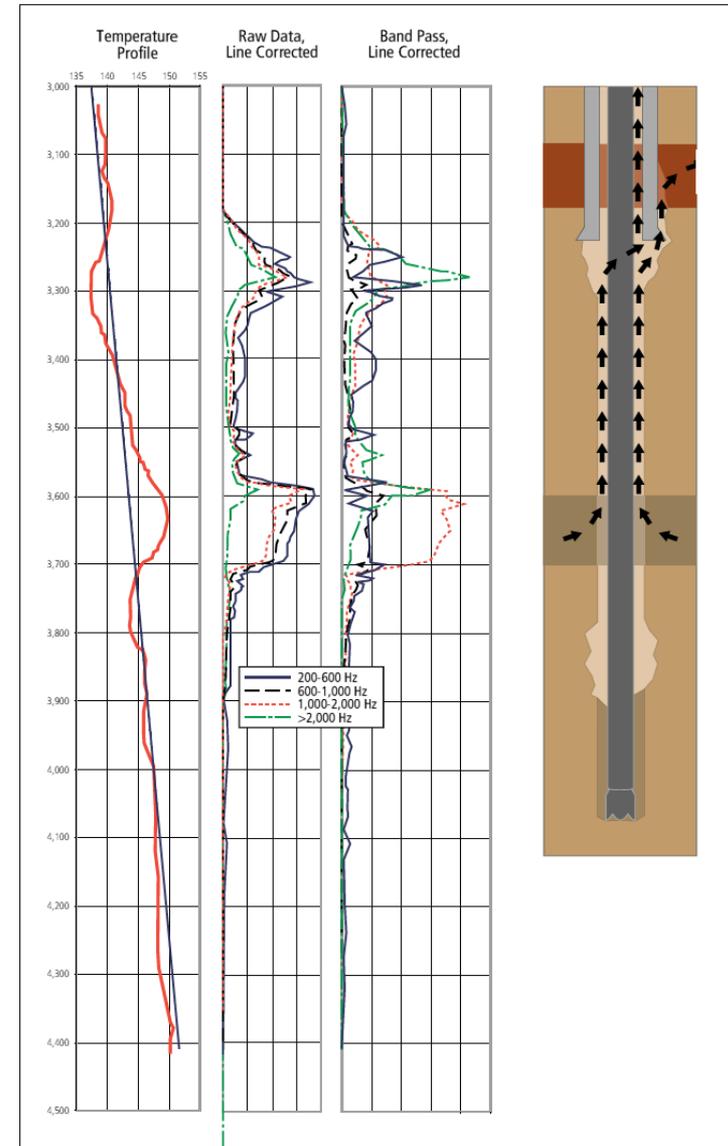
- Robust and can “see” through multiple strings of casing.
- Determine annular fluid level changes
- As a monitor, periodic logging can identify gas accumulation and gas migration behind casing.
- GR can indicate fluid entry as a result of NORM build up

## ■ Disadvantages:

- Has a chemical source with significant half-life, not recommended for cavern storage operations. For cavern wells or wells with risk a pulsed neutron and/or a tracer fluid with low half-life can be substituted.
- Reciprocity required for transport of chemical neutron sources across state lines and can delay operations.

# Noise Logs

- Advantages:
  - Noise tool can identify small leaks inside and/or channeling behind casing.
  - Field deliverable results possible and relatively inexpensive.
- Disadvantages:
  - Can be influenced by “noise” from external sources.
  - Ran as a stationary log.
  - Can be difficult to distinguish between inside or outside leaks.



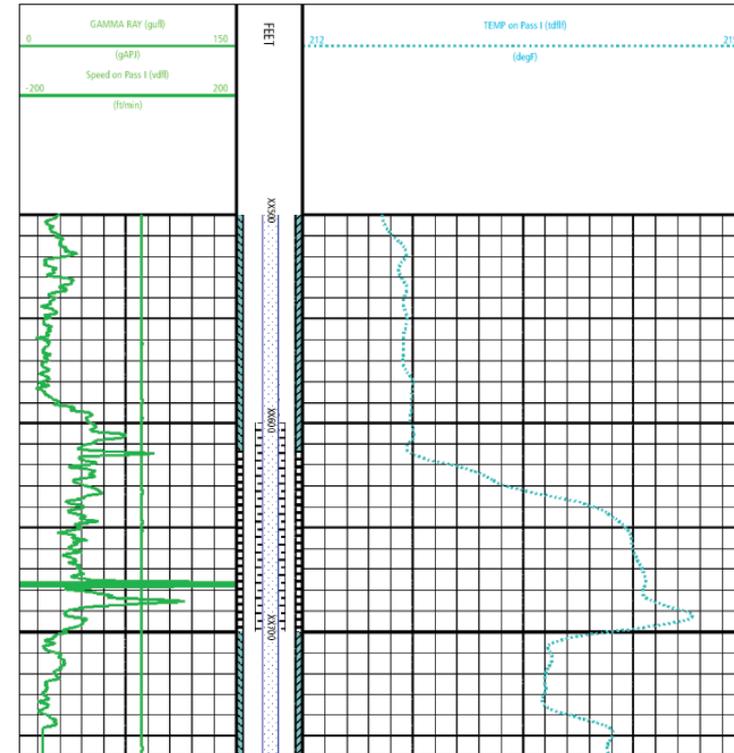
# Temperature Logs

## ■ Advantages

- Can be logged continuous and in combination with other services.
- Temperature gradient is obtained to identify gas leaks from the cooling affect by expansion.

## ■ Disadvantages

- Can be difficult to find annular leaks, especially small ones.
- Small leaks can be difficult to measure.
- Can be difficult to distinguish between inside or outside leaks.



# Cement Evaluation

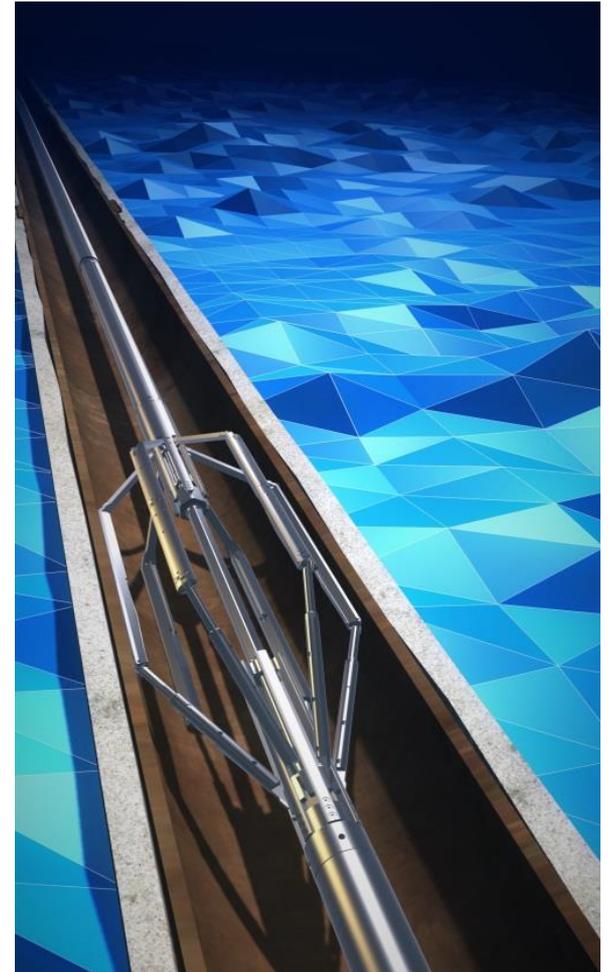
# Integrity Explorer

## ■ Advantages:

- Can log in any liquid/gas environment.
- Can identify cement bond in lightweight cement as low as 7 ppg.
- Can identify micro-annulus effect without pressure pass and independent of wellbore fluids.
- Only shear measurement of cement in the industry.

## ■ Disadvantages:

- Tool is relatively long.
- Requires pipe that is electrically conductive.
- No VDL available in gas filled borehole.



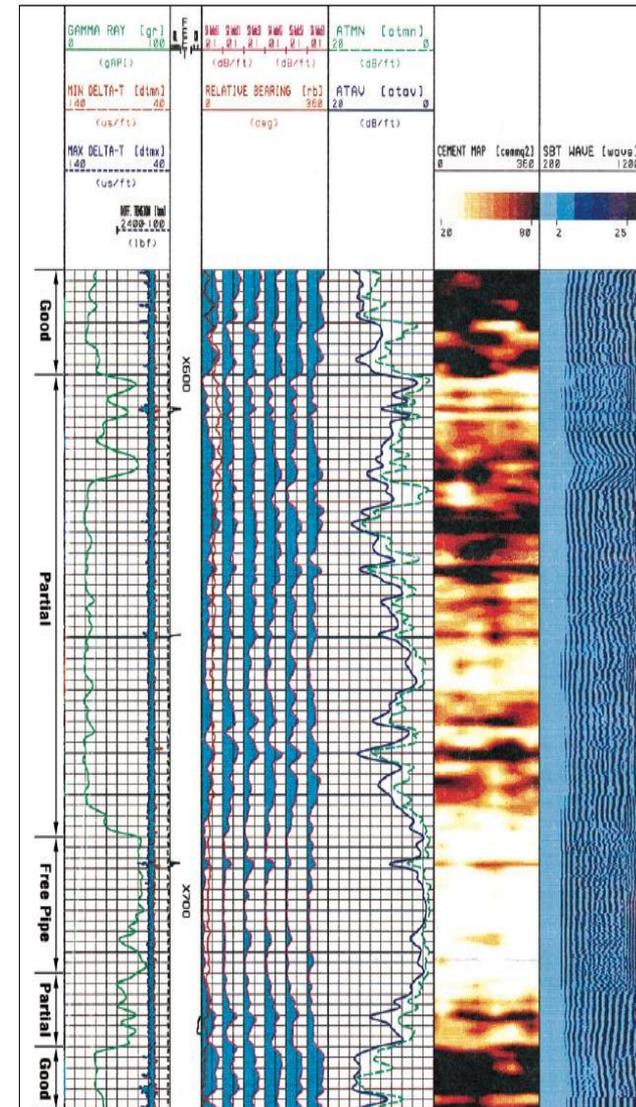
# Pulse Echo and Pad Type Cement Bond Tools

## ■ Advantages:

- Good resolution in “normal” weight cements (>11 ppg).
- Applicable to large range of pipe sizes. Pad type tools (SBT) up to 24”.
- Field deliverable with post processing services available.

## ■ Disadvantages:

- Requires static liquid filled hole.
- Pulse echo is affected heavy weight muds and high solid content.
- Requires pressure pass to identify microannulus effect.
- Affected by internal debris or cement sheath/scale etc.



# Best Practices/Recommendations

# Well Monitoring and Integrity

- Junk Catcher and Gauge Ring or Imaging Caliper. Measure maximum depth of well and ID (drift) to assess safe well conditions for future runs.
- GR/Neutron/TEMP to look for gas levels, annular fluid levels and/or gas migration.
- Casing Inspection log. HRVRT or equivalent (Pulse Echo, or other MFL). Benchmark and quantify corrosion in casing or tubing.
- Cement evaluation. Reassess occasionally to ensure cement integrity is sufficient.

# Well Investigating

- Junk Catcher and Gauge Ring or Imaging Caliper. Measure maximum depth of well and ID (drift) to assess safe well conditions for future runs.
- GR/Neutron/TEMP/Noise to identify gas level and leaks. Seek annular leaks.
- Casing Inspection to evaluate inner casing string for internal/external corrosion or holes.
- DMAG/MTD or equivalent to evaluate outer casing strings (if present) for indications of corrosion or large metal loss. Especially if inner string is removable.
- Camera run to identify issues in inner string.
- CPP (Casing Potential Profile) to assess general corrosion trends to validate other logs. Also assess the effectiveness of existing cathodic protection systems or if they can be implemented.
- Cement Bond Log if required to evaluate cement integrity.

Thank you