PHMSA – Casing and Cement Integrity

November 16th and 17th, 2016

Introduction

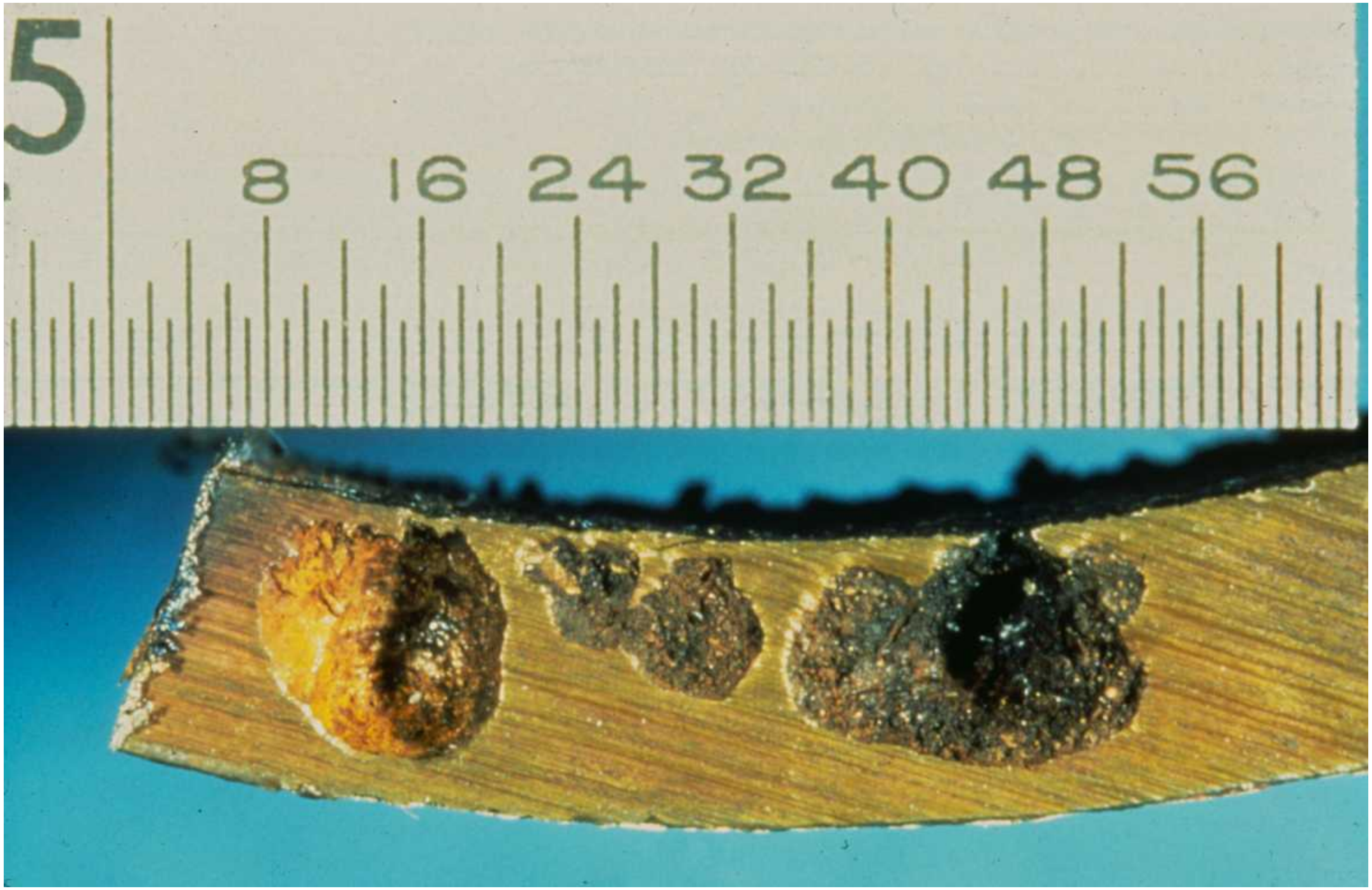
- Magnetic Flux Leakage (High Resolution Vertilog)
- Electromagnetic Eddy Current – Thru Tubing
- Integrity Explorer – Gas filled bond log

Casing Inspection

Corrosion

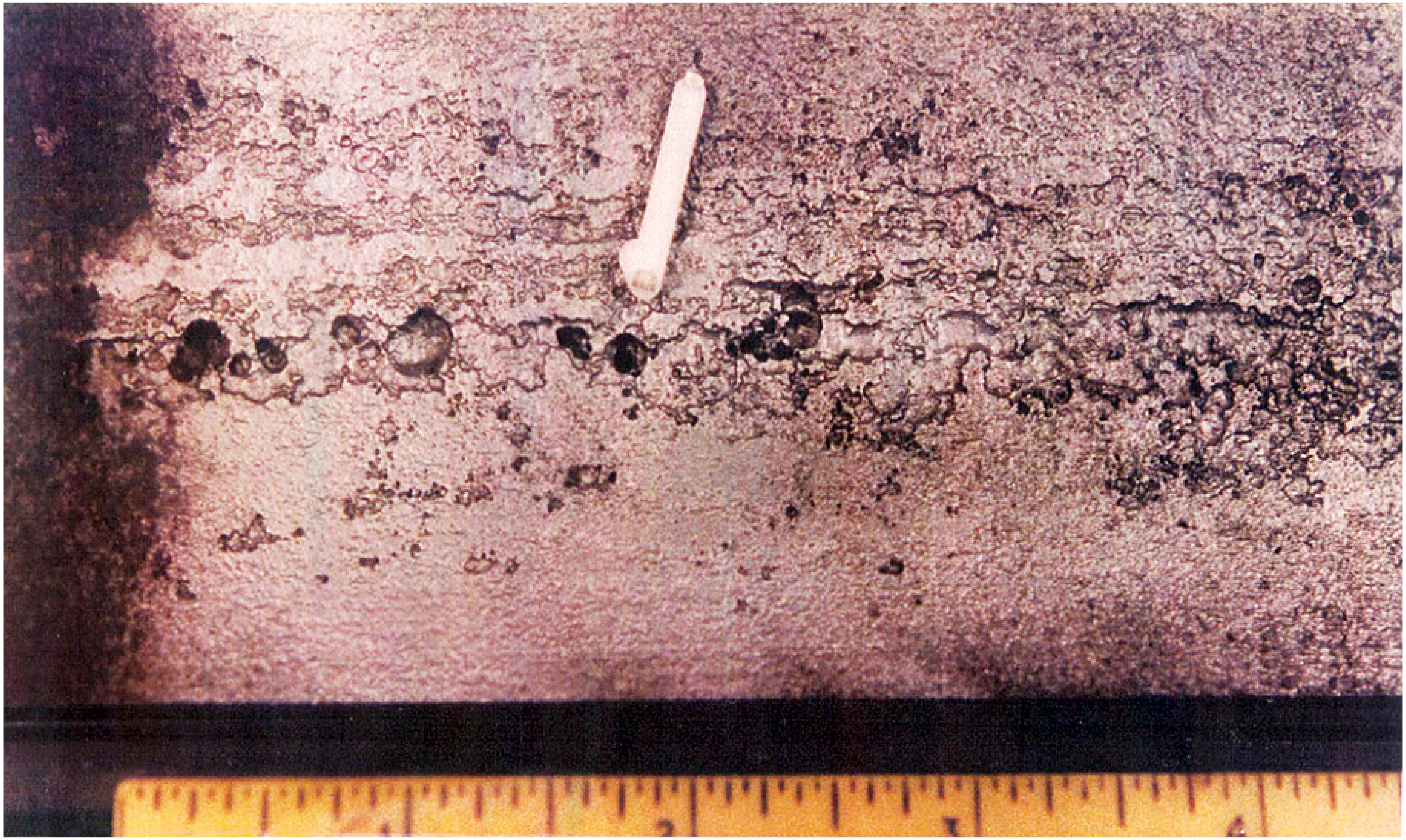
SRB (Sulfate Reducing Bacteria) Corrosion

Corrosion



APB (Acid Producing Bacteria) detail

Corrosion



CO_2 Corrosion

Corrosion

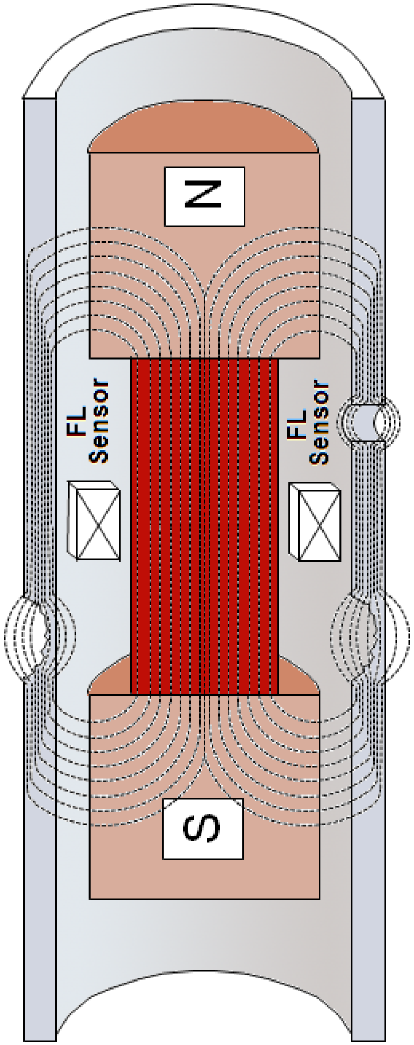
Complex corrosion

Corrosion

Tong marks with corrosion

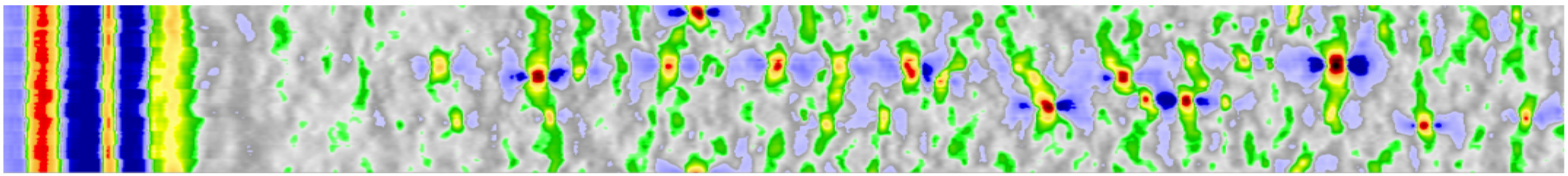
High Resolution Vertilog (HRVRT)

- Advantages:
  - Quantifiable inside and outside metal loss. Identifies holes, isolated corrosion, and defect depth of penetration.
  - 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 fluid/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.



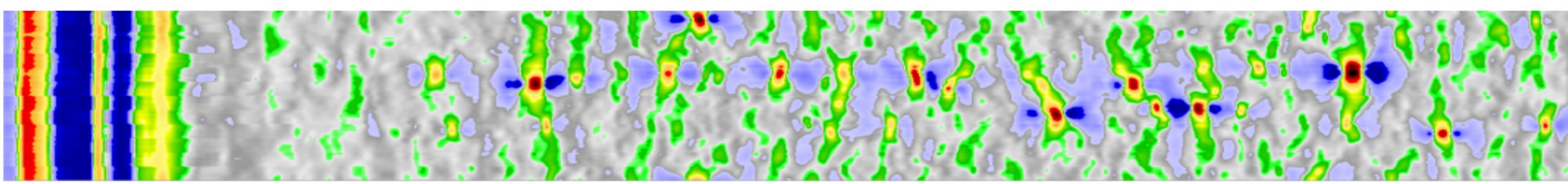
Immunity to Scale

Pre-sandblast 7" pipe



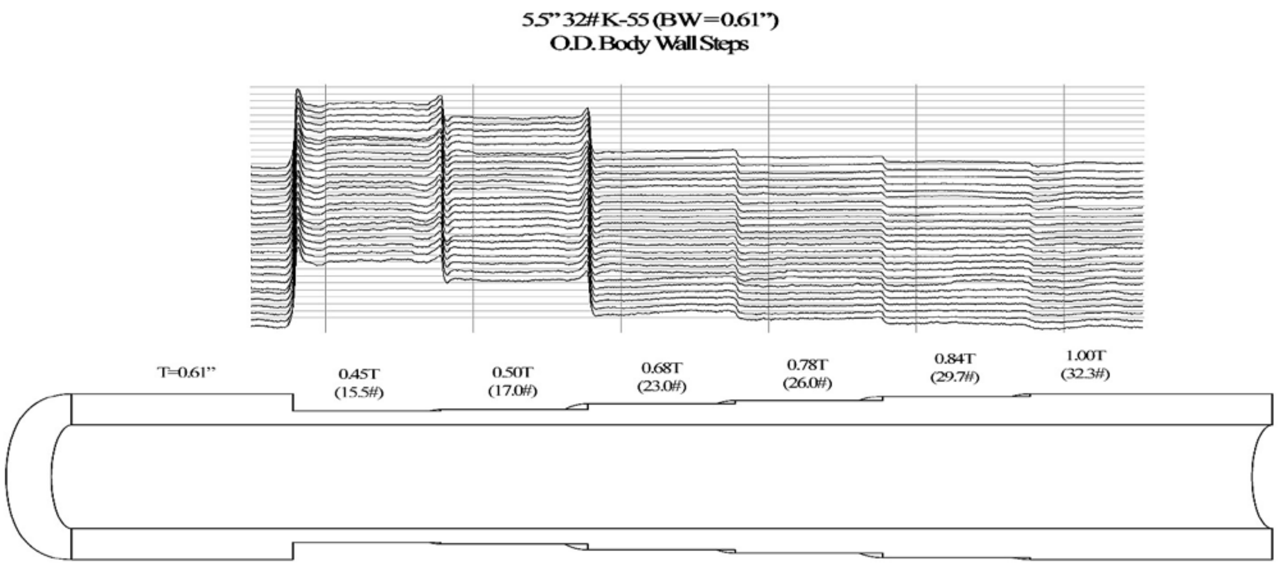
Pre-sandblast 7" axial image data

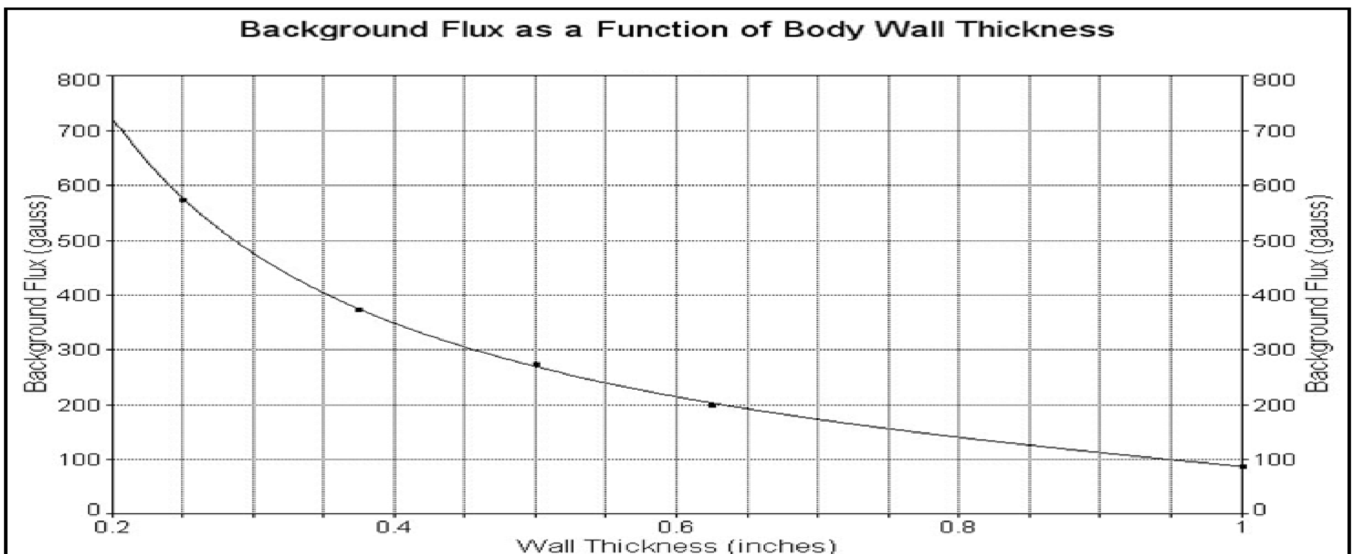
Post-sandblast 7" pipe



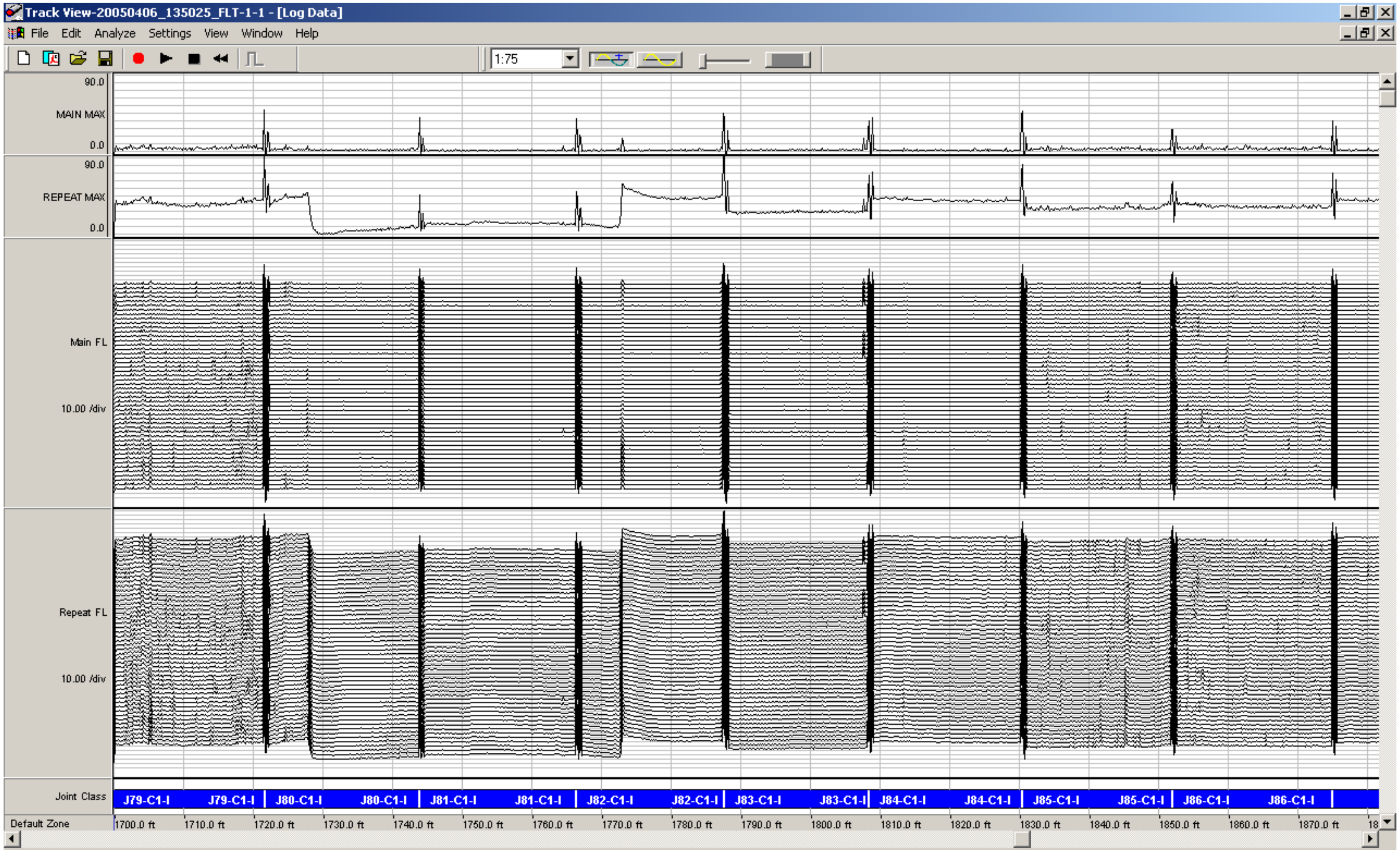
Post-sandblast 7" axial image data

Axial background field: Wall thickness response





External 7" Casing 1728' – 1773'



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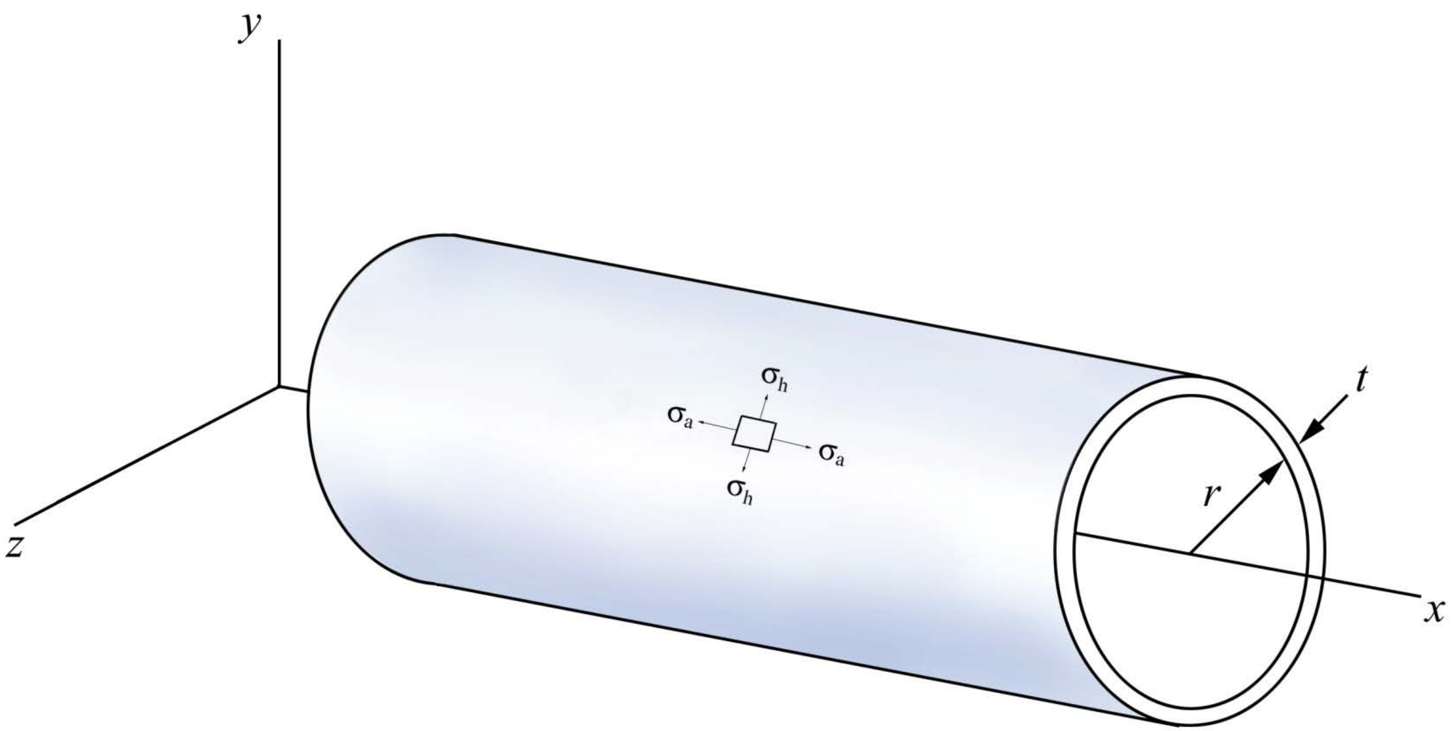
Defect Assessment: Stresses in pipe under pressure



Axial stress

$$\sigma_a = \frac{Pr}{2t}$$

Hoop stress

$$\sigma_h = \frac{Pr}{t}$$

Defect Assessment Breakdown

- **Barlow Equation.** Assumes burst = elastic limit. Uses only thickness and pipe diameter to calculate.
- **B31G Method.** Uses area and thickness to calculate. No clustering or multi-feature analysis.
- **Modified B31G (0.85 dL).** Removes excess conservatism from B31G. Same formulae as Effective Area method but without iterative algorithm. Clustering and interactions of nearby features are evaluated. Standard output for BHI.

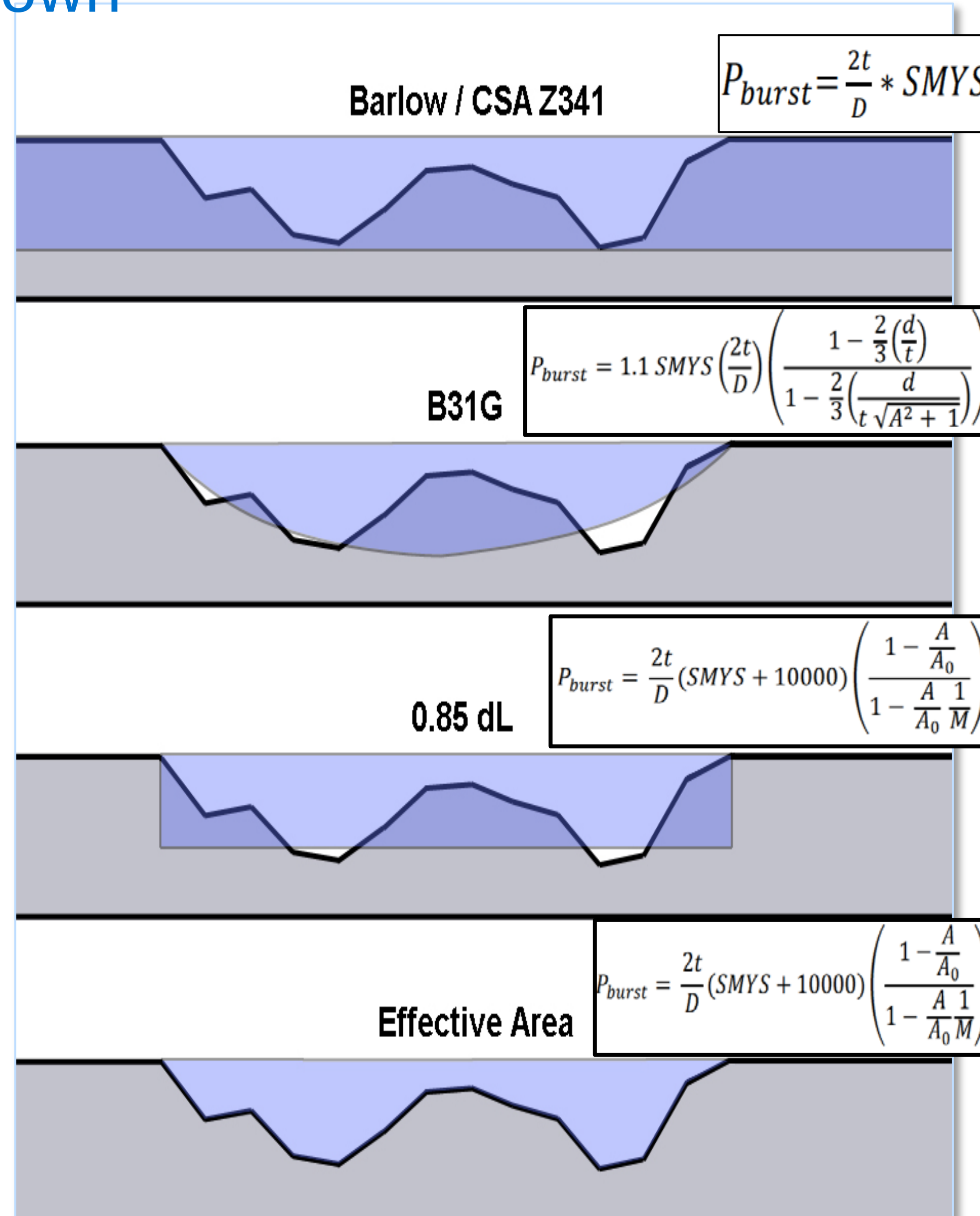
  If $\frac{L^2}{Dt} \leq 50$, the Folias factor, M, is defined as

  $$M = \sqrt{1 + 0.6275\frac{L^2}{Dt} - 0.003375\frac{L^4}{D^2t^2}}$$

  But if $\frac{L^2}{Dt} > 50$, M is defined as

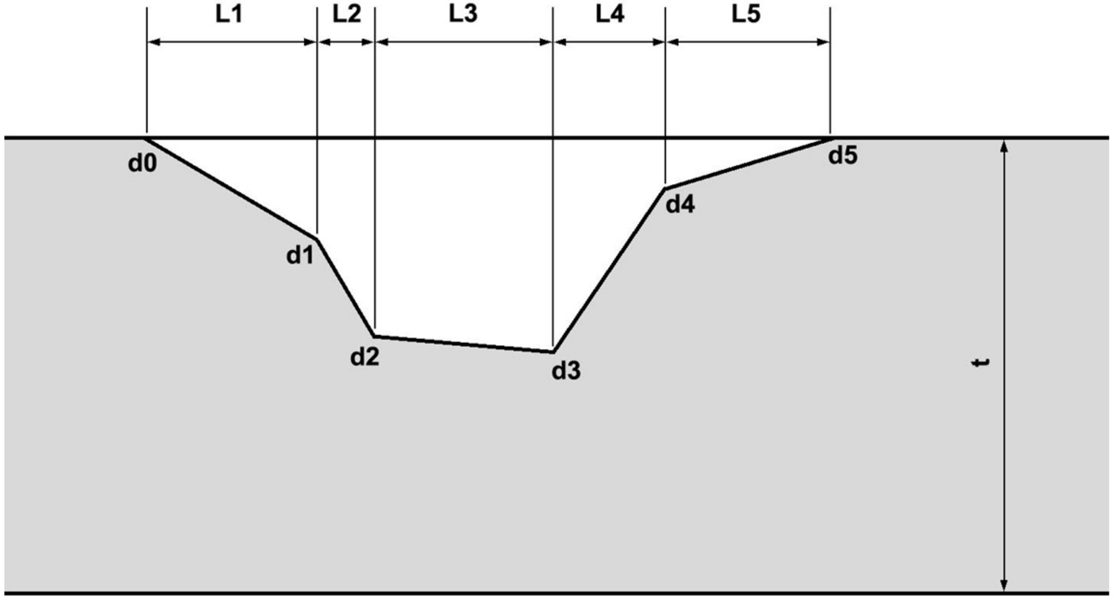
  $$M = 0.032\frac{L^2}{Dt} + 3.3$$

- **Effective Area Method.** Least amount of conservatism. Same formulae of Modified B31G and uses clustering and interactions to evaluate burst pressures. However, in addition uses river bottom profile to divide defects into intervals. For each interval the burst pressure is calculated and the least amount of burst is the final feature burst pressure.



Effective Area (RSTRENG™)

A simple defect:

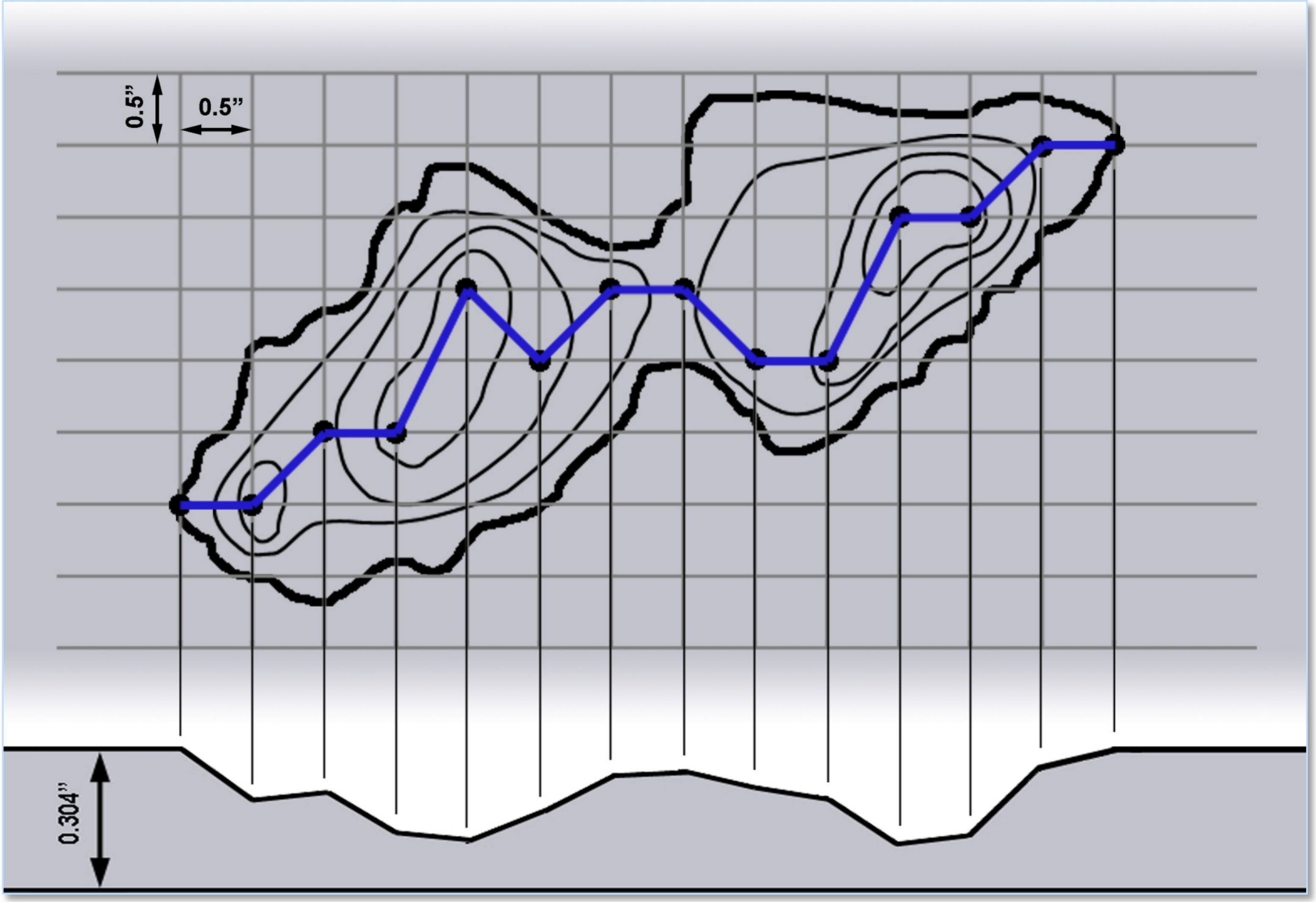


- A burst pressure is computed for each area
- Minimum selected as final burst pressure

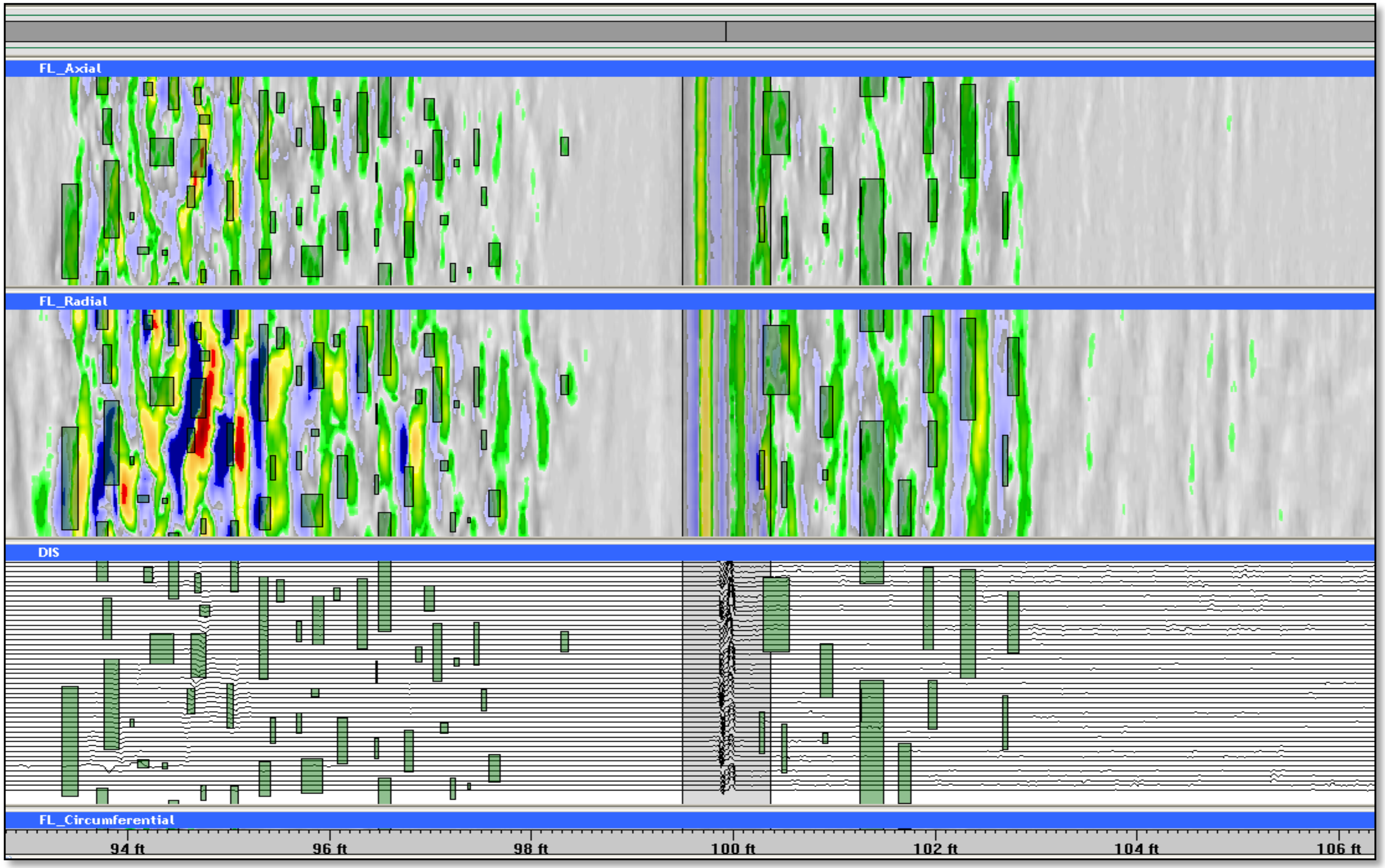
RSTRENG™ computes all possible combinations of contiguous areas:

L1
L1 + L2
L1 + L2 + L3
L1 + L2 + L3 + L4
L1 + L2 + L3 + L4 + L5
L2
L2 + L3
L2 + L3 + L4
L2 + L3 + L4 + L5
L3
L3 + L4
L3 + L4 + L5
L4
L4 + L5
L5

Effective Area: River Bottom Profile



Clustering or Interactions



- Defects in close proximity can interact with each other and produce an outcome similar to a larger defect. Interaction algorithms assess whether these features are evaluated as one or separately.

Pipe Characterization - High Resolution Defect Set

- Pipe characterization relies on observed correlation between defect size and the signal produced by flux leakage measurements. These correlations are used to develop sizing algorithms.
- High-resolution defect set
  - Approximately 10 times the samples as the low-res calibration points
  - Non-axisymmetric
  - Pinhole through General Corrosion (< 1t x 1t through > 8t x 8t)
  - Defects are produced in a wide range of length, width and depth. Both internal and external defects are produced.

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Pipe Characterization

Tool Calibration and Pipe Characterization Lab

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High Resolution Vertilog Disadvantages

- 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. Small OD and Large OD currently not available.
  - 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.

Defect Example: 5.5", 14# H40, 0.244" Wall

	Measured	MVRT Isolated Model	MVRT Generalized Model	HRVRT InSight
Length	**2.5**	1.9	1.9	1.7
Width	**5.0**	~	~	3.7
Depth	**19.7%**	83.5%	56.0%	22%
Method	**Burst Pressure**			
Barlow	**2850**	586	1562	2768
CSA-Z341	**2493**	512	1366	2422
B31G	**3610**	Repair mandatory	3096	3655
0.85dL	**4039**	2273	3277	4107
Effective Area	**3963**	1501	2976	4042

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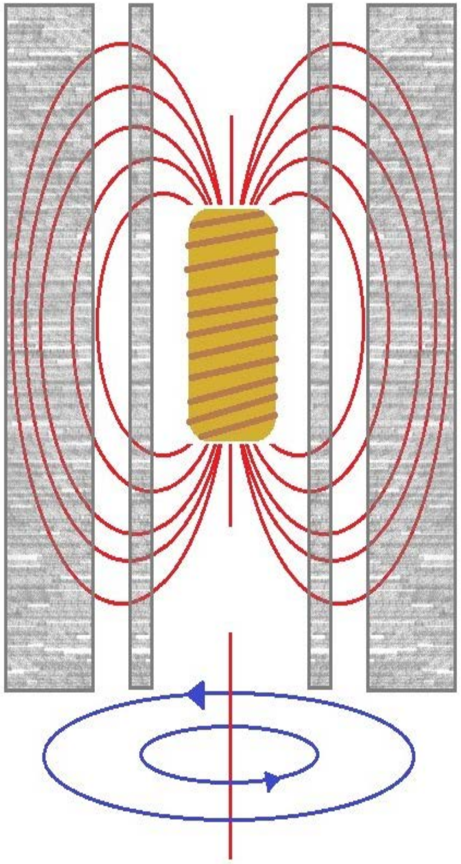
Electromagnetic (Eddy Current/Phase Shift)

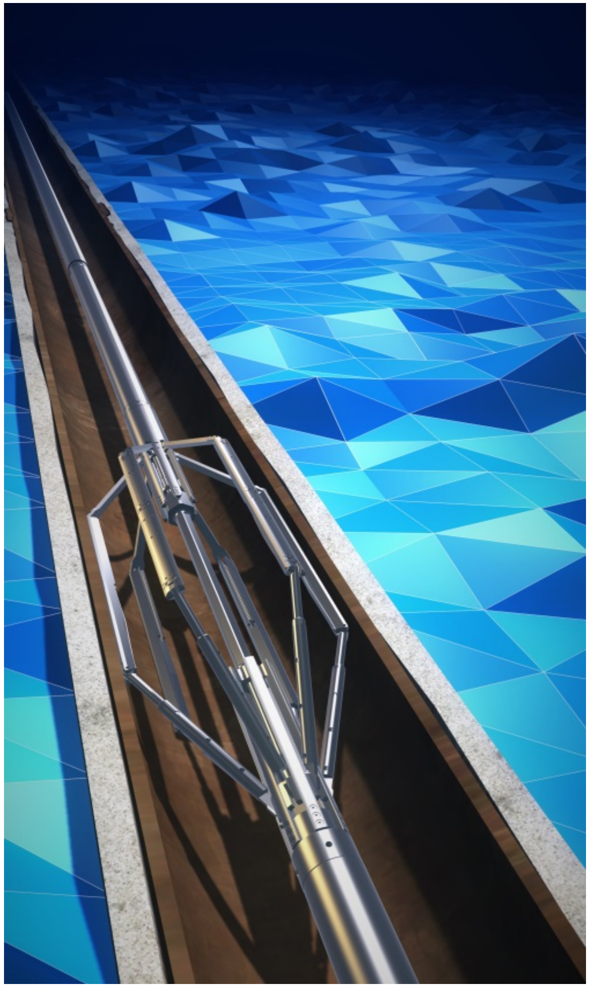
- Advantages:
  - Can be run in any fluid/gas environment.
  - Can measure metal loss in multiple casing strings without intervention. This can provide indication of catastrophic failure without removing inner pipe string.
  - Can locate top and bottom of external casing strings.
  - Determine axial 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.
  - Produces average metal loss with no segmentation. Small diameter and early corrosion features may not be detectable.
  - External hardware and additional casing strings further complicate measurement and resolution.



Cement Evaluation

Integrity Explorer

- Advantages:
  - Can log in any fluid/gas environment.
  - Can identify cement bond in lightweight cement as low as 7 ppg.
  - Can identify microannulus effect without pressure pass and independent of wellbore fluids.
  - Only shear measurement of cement in the industry.
- Disadvantages:
  - Requires pipe that is electrically conductive.
  - No VDL available in gas filled borehole.



Tool Specifications

- Pad Mounted transducer design
  - Deployable in highly deviated boreholes
- Each pad has a SHEAR and LAMB transceiver
- Measurement made in the same horizontal plane
- Variable density Log tool (VDL) provide bond with formation

Integrity eXplorer Specifications	
Make up Length	19’ 11 ¼ ”
Minimum Casing Size	O.D: 4.5 in, I.D: 3.92 in
Maximum Casing Size	O.D 16 in, I.D: 15.5 in
Maximum tool diameter	3 5/8” closed, 17” open
Maximum logging speed	30 ft/min
Maximum pressure	20,000 psi
Maximum temperature	350˚ F

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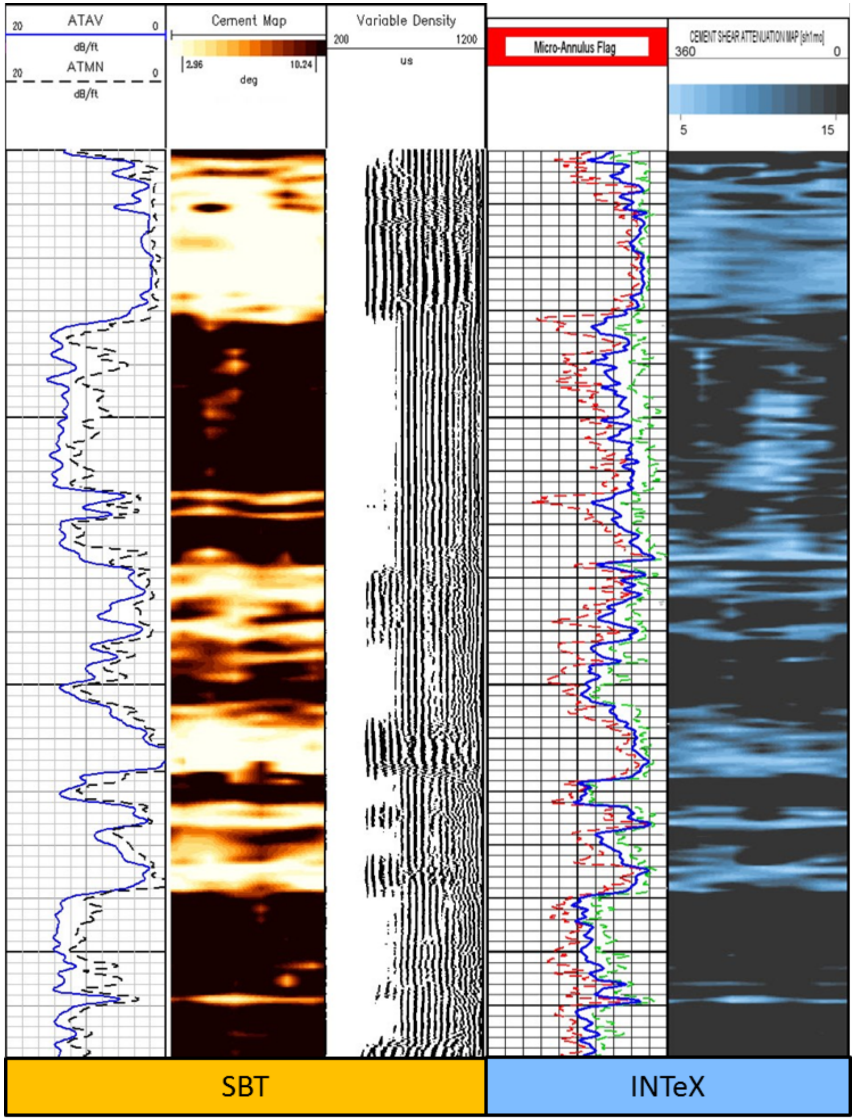
Cement Evaluation with no borehole fluids

- First INTeX log was performed and the data was compared to the conventional cement evaluation tool data.
- Electromagnetic-acoustic transducers sensor technology makes it possible to log air-filled borehole for Cement evaluation
- SBT log performed in Fluid filled environment, vs INTeX log in air
- This can affect other wells where fluid losses compromises cement evaluation



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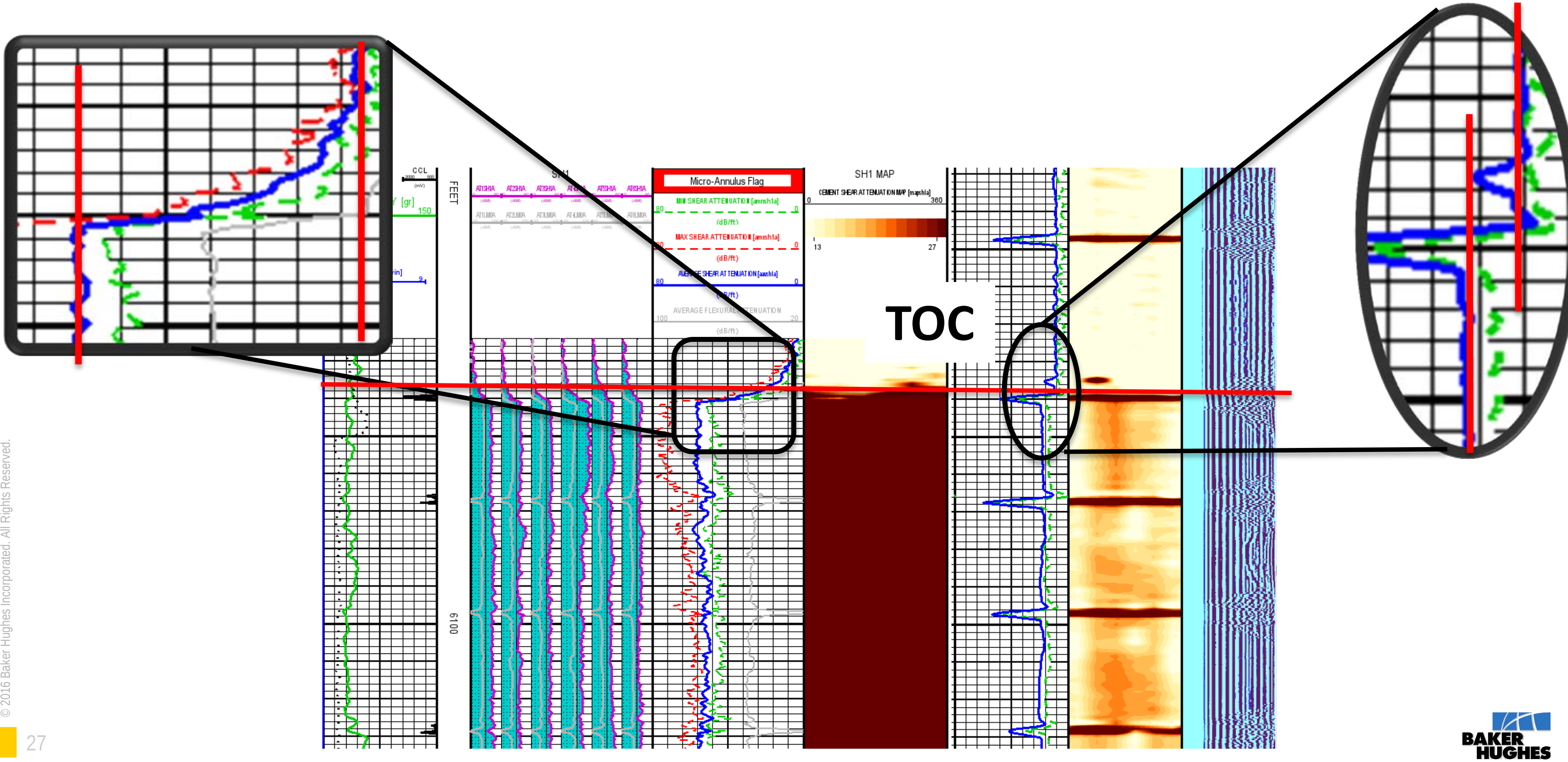
INTeX Sensitivity

- INTeX Shear data shows ~**50 db/ft** attenuation
- Whereas the conventional Compressional wave based technology shows ~2 **db/ft** attenuation.



Thank you