TOFD Analysis
Flaw Sizing and Characterization

TOFD Analysis Overview

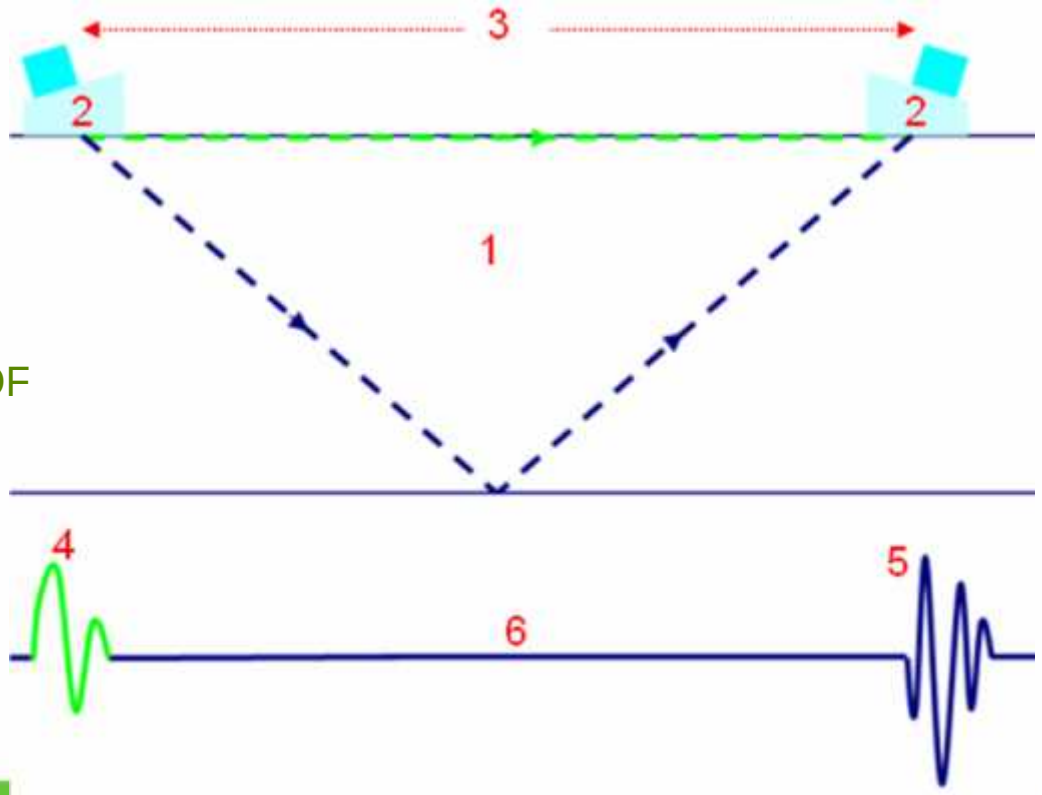
- This TOFD Analysis presentation is primarily based on information contained in ASME V, Art 4, non mandatory appendix N:Time of Flight (TOFD) Interpretation Appendix.

- The TOFD flaw analysis refers to the following:
  - Length sizing.
  - Depth\height sizing.
  - Flaw characterization. (Geometry, crack, LOF, IP, porosity, etc)
  - Accept\Reject Criteria

TOFD Analysis Overview

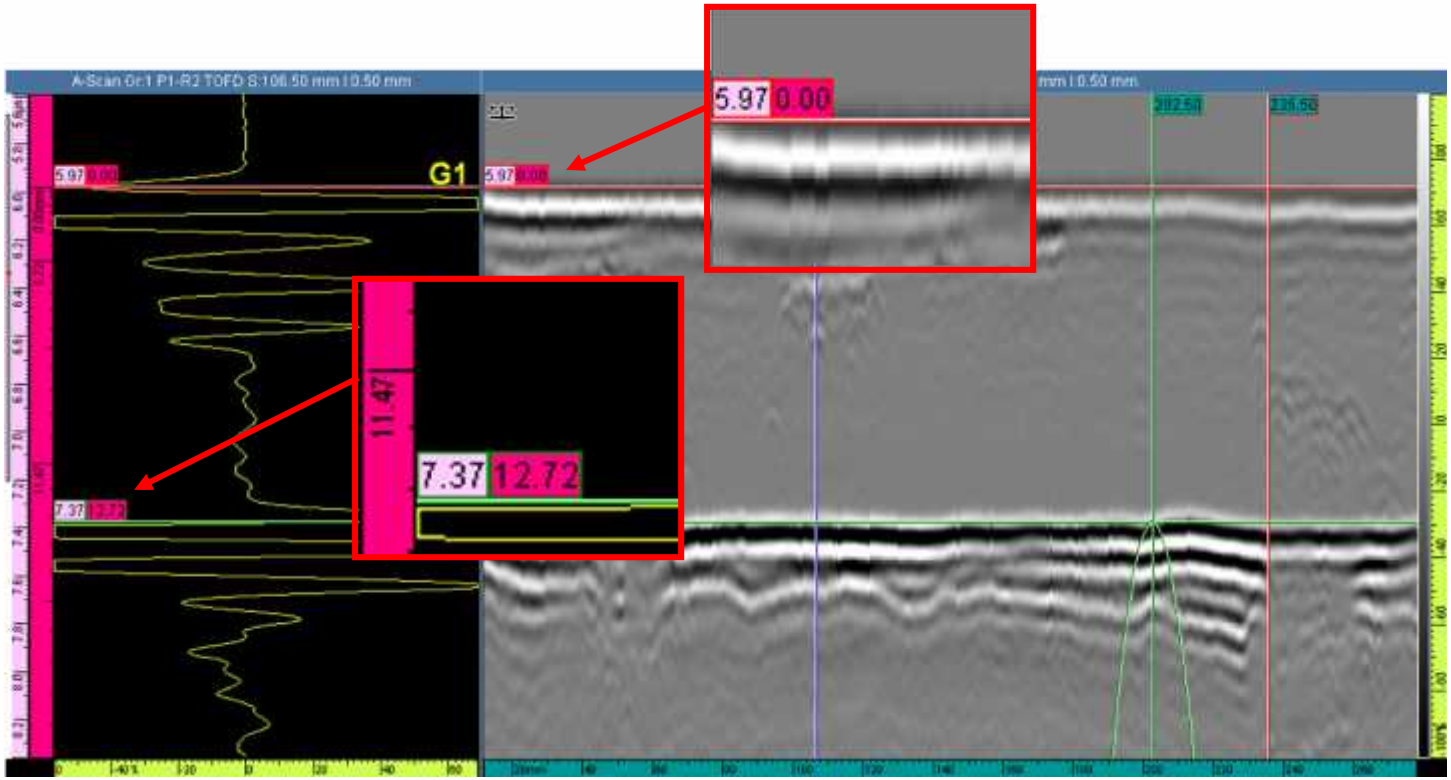
- TOFD measurements are based on software tools that calculate depth of indications or flaws based on one or more known values from the list below of TOFD variables.
- Not all variables must be known for precision measurements. The variables are:

1. Material thickness
2. Wedge delay
3. PCS (Probe Spacing)
4. Lateral wave TOF
5. Back wall TOF
6. Defect or calibration target TOF
7. Material sound velocity



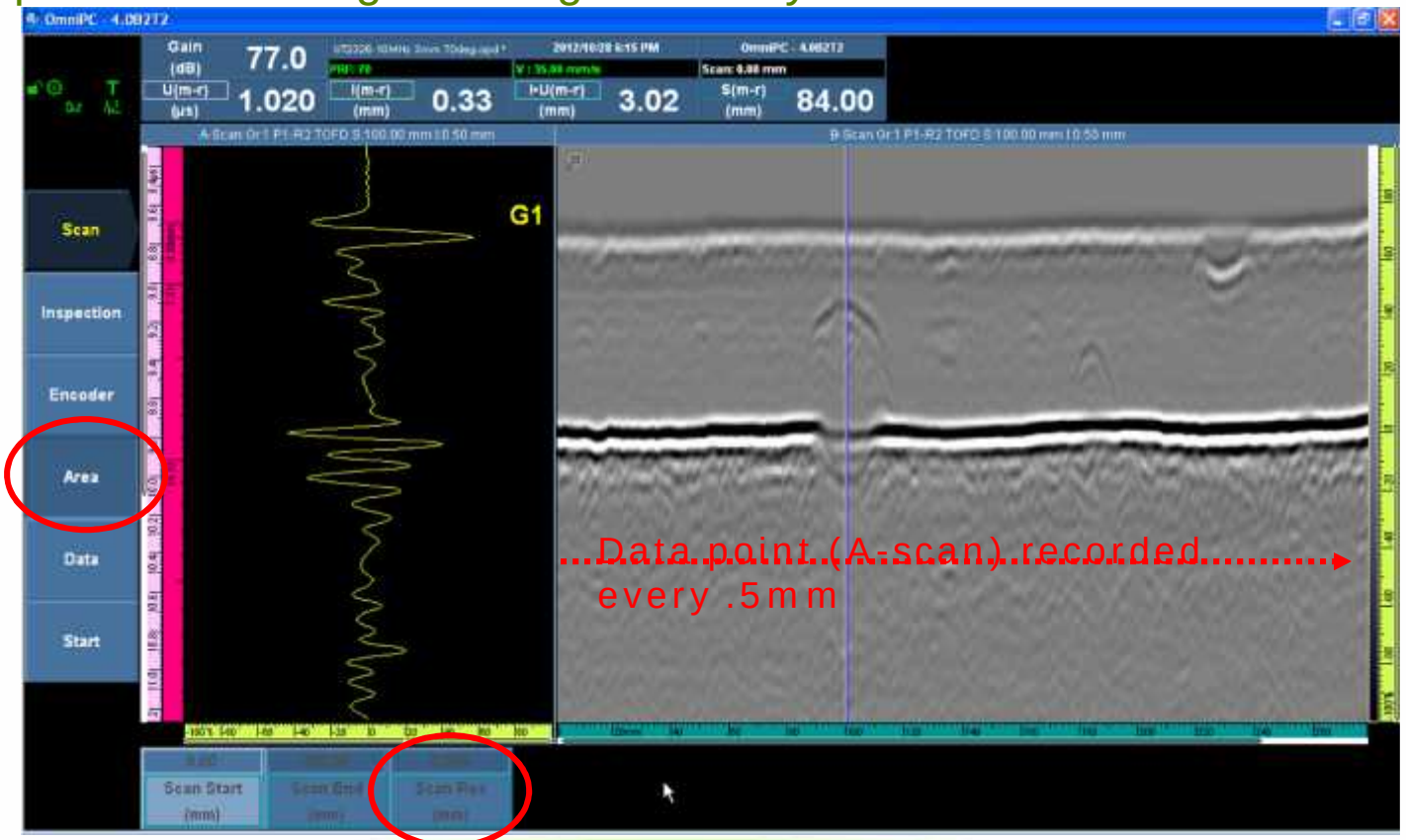
TOFD Analysis Overview

- Precision TOFD measurements and recording TOFD flaws requires that the UT axis of the data be calibrated to convert TOF into microseconds to distance in mm.



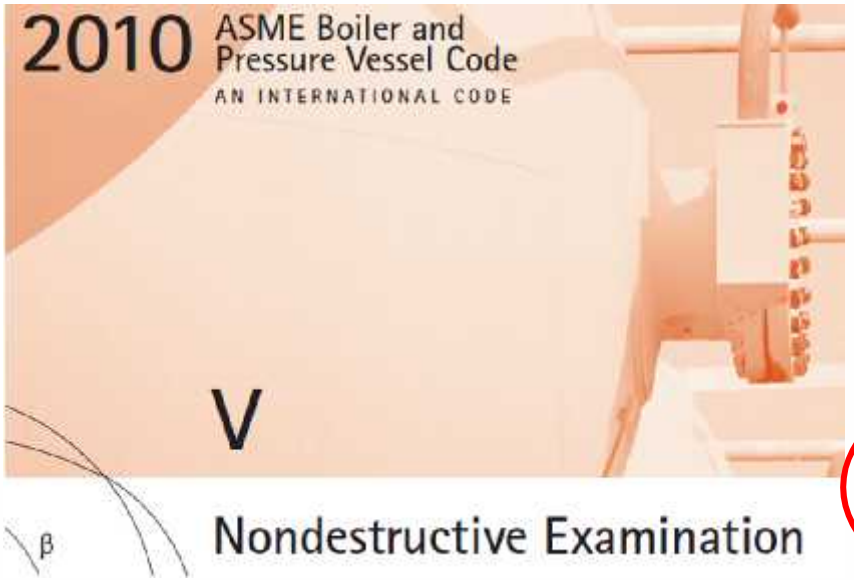
Scan Resolution

- The length sizing accuracy is directly related to the inspection resolution on the scan axis.
- In the example below, the inspection was performed with a scan resolution of .5mm. (Every focal law and group is recorded at intervals of .5mm on the scan axis)
- This equates to a length sizing accuracy of +\- 1mm.



ASME Scan Resolution

- The expected flaw length sizing accuracy is typically specified as the inspection resolution in the referencing code or procedure. ASME Sec V Art 4 (2010 Edition) requires a 1mm inspection resolution (Data sampling) for materials under 2 inches and 2mm resolution for materials over 2 inches.



APPENDIX III — TIME OF FLIGHT DIFFRACTION (TOFD) TECHNIQUE

III-410 SCOPE

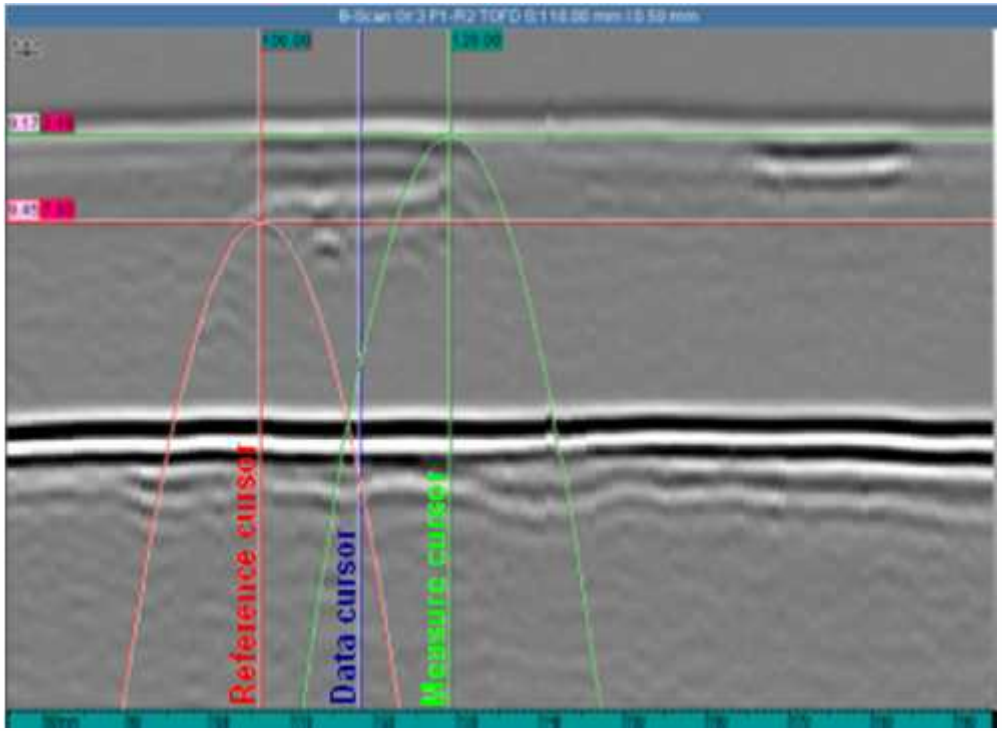
This Mandatory Appendix describes the requirements to be used for a Time of Flight Diffraction (TOFD) examination of welds.

III-475 Data Sampling Spacing

A maximum sample spacing of 0.040 in. (1 mm) shall be used between A-scans collected for thicknesses under 2 in. (50 mm) and a sample spacing of up to 0.080 in. (2 mm) may be used for thicknesses greater than 2 in. (50 mm).

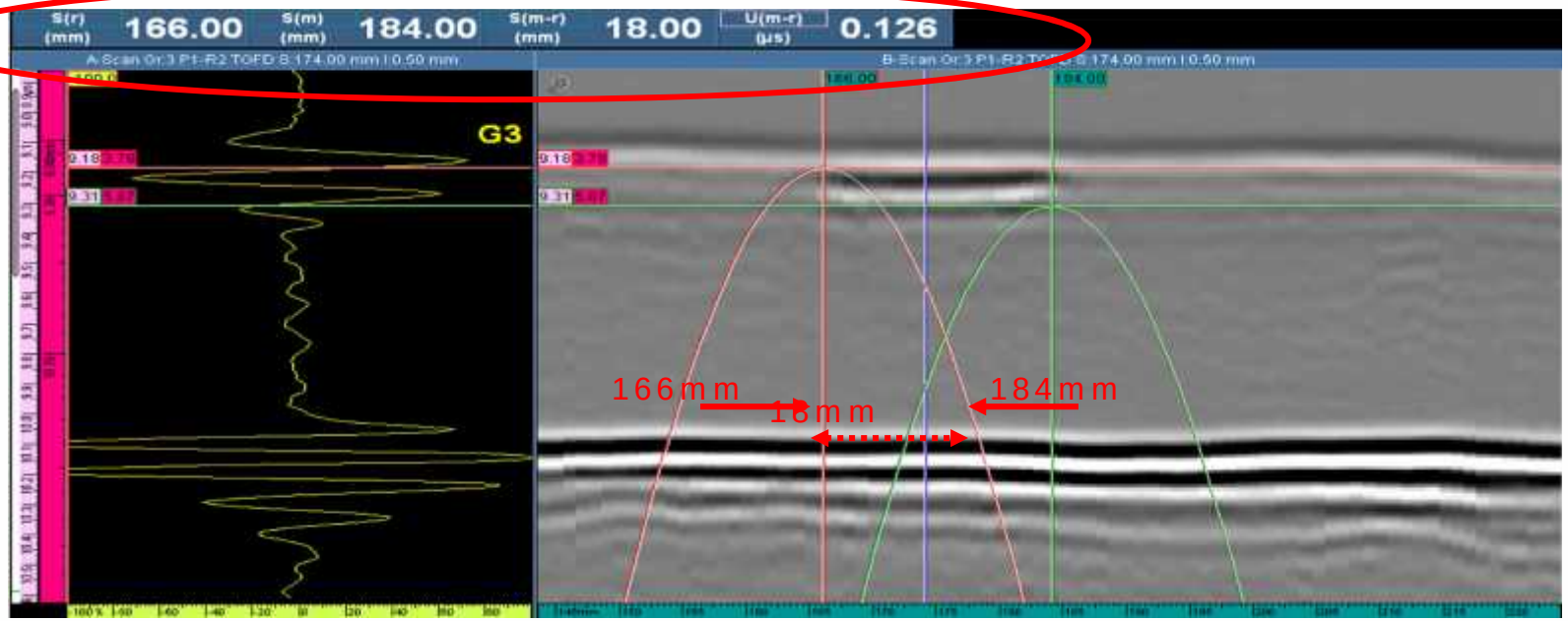
Analysis – Length Sizing Cursors

- TOFD flaw length sizing is performed on the weld line represented by the scan axis. (Pictured in blue below).
- Flaws parallel to the pipe surface can be measured on the B-scan by positioning the hyperbolic cursors at the start and stop position on the scan axis.
- The two cursors used for TOFD flaw length sizing are:
  - Scan axis reference cursor. S(r)
  - Scan axis measure cursor S(m)



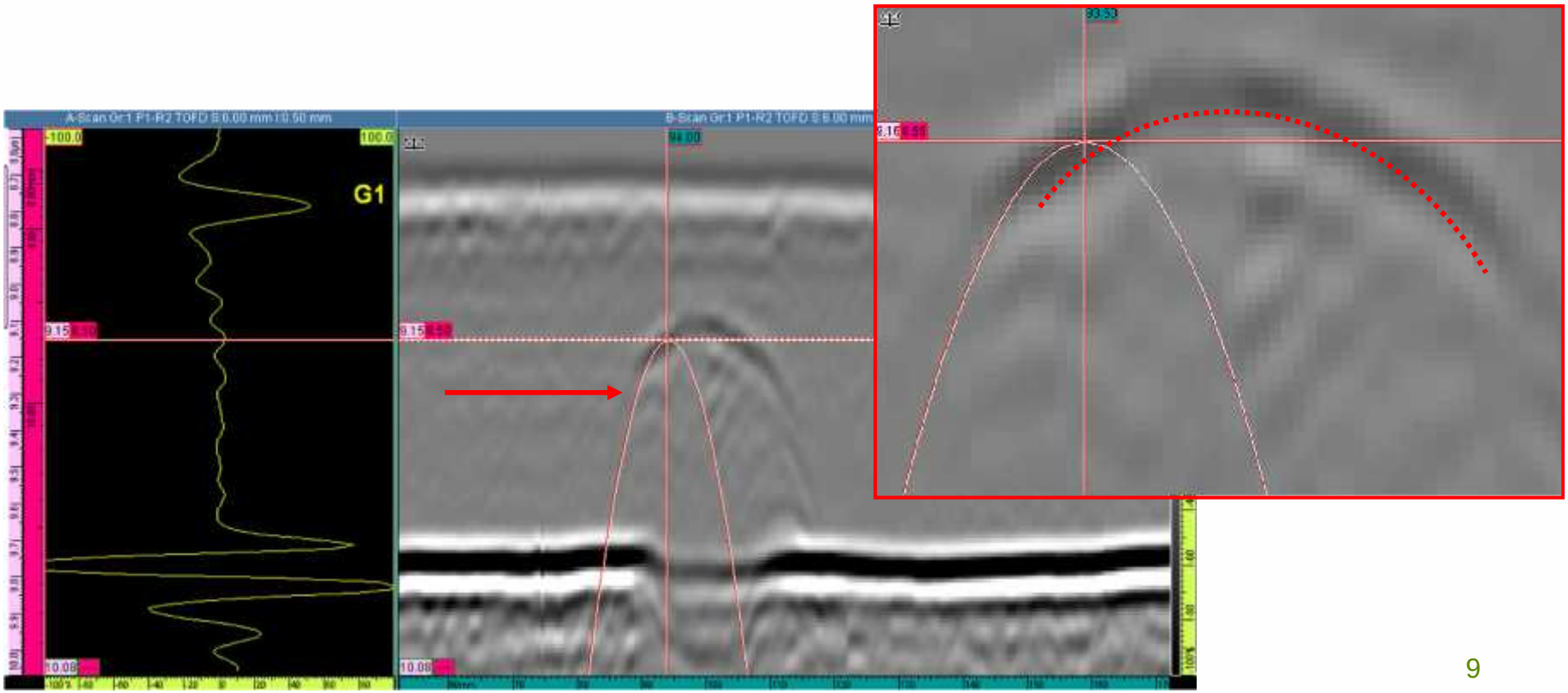
Analysis – Length Sizing Readings

- The primary readings associated with TOFD flaw length sizing are:
  - S(r) Position of the reference cursor on the scan axis.
  - S(m) Position of the measurement cursor on the scan axis.
  - S(m-r) The delta between the scan axis reference and measurement cursor.
- In the lack of side wall fusion example below, the data cursor is positioned on the data point in the center of the flaw at 174mm.
- The reference and measure cursors are positioned on the scan axis where the flaw starts and ends. (Sr = 166mm, Sm = 184mm, Flaw length or Sm-r = 18mm)



Analysis – Hyperbolic Cursors

- The hyperbolic cursors that are available after calibration assist in identifying the start and end position of the flaw in the TOFD data for improved length sizing accuracy.
- The curve of the cursor is aligned on the flaw to identify the length and prevents over sizing flaws.

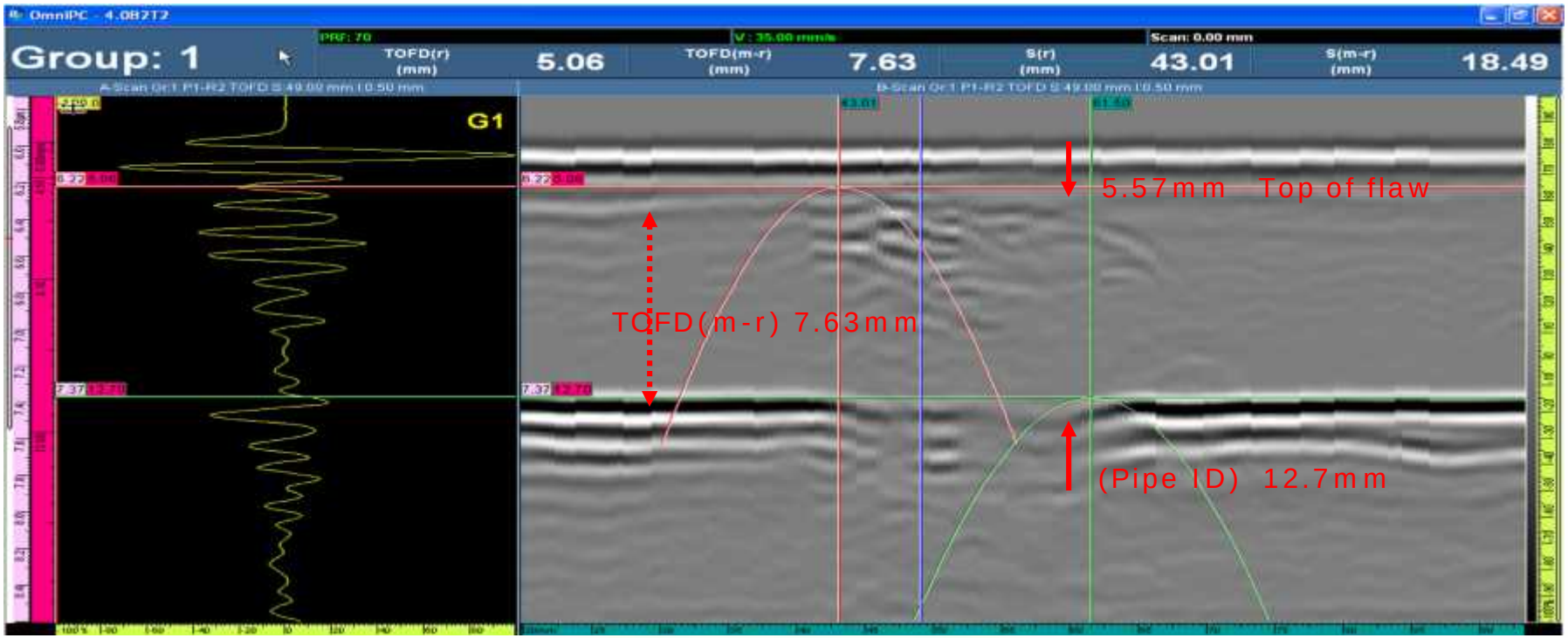


Analysis – Depth Sizing Cursors

- In TOFD inspection, flaw depth\height sizing is performed on the UT axis using the A-scan and B-scan after the data has been calibrated using the wizard.
- The two cursors used for TOFD flaw depth\height sizing are:
  - U(r) UT axis reference cursor. Identifies the top of the flaw.
  - U(m) UT axis measurement cursor. Identifies the bottom of the flaw.

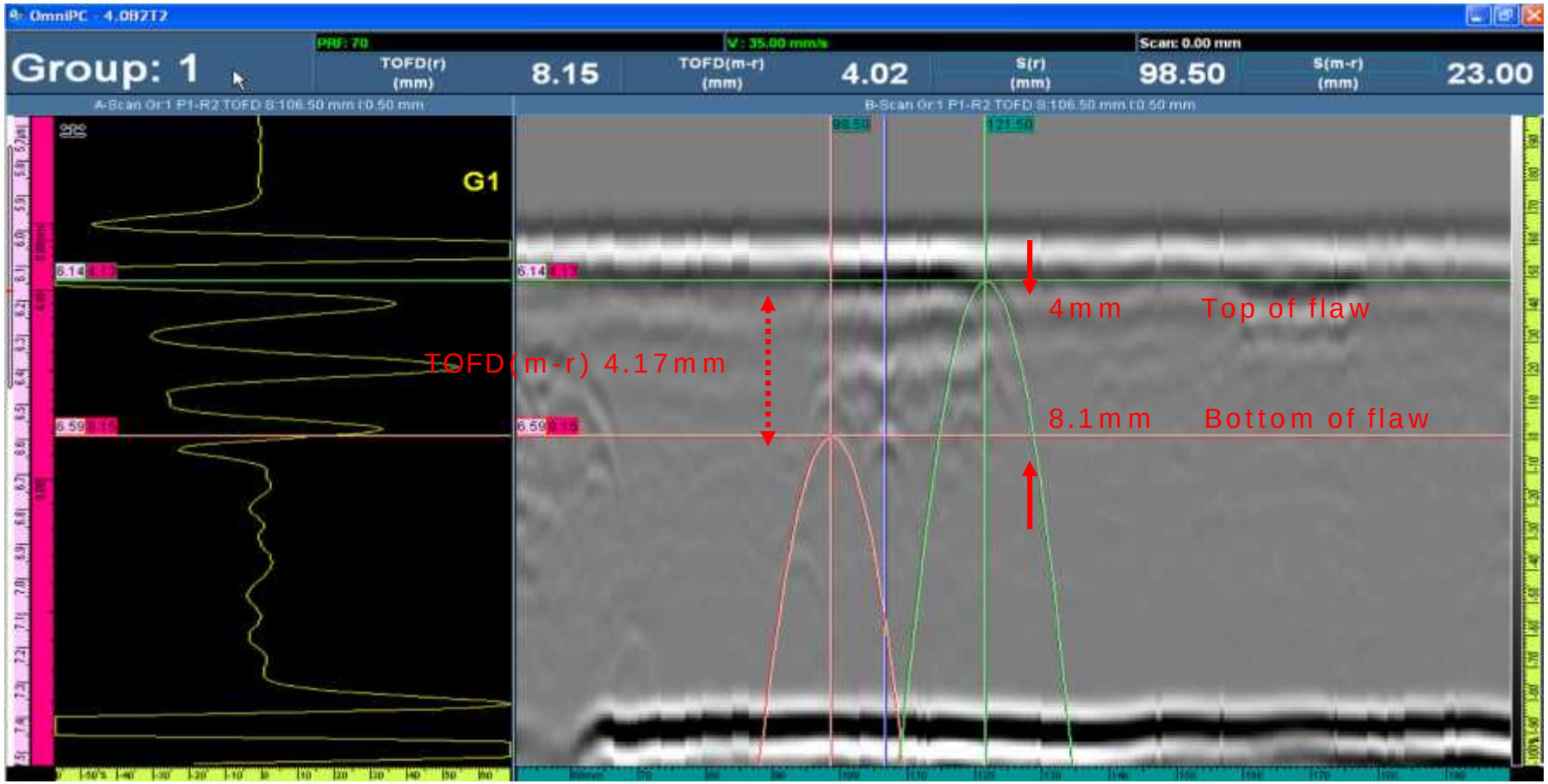
Analysis – Depth Sizing Readings

- The primary readings associated with TOFD depth\height sizing are:
  - TOFD(r) Depth of the flaw. Functions the same as U(r).
  - TOFD(m-r) Through wall dimension of the flaw. Functions the same as U(m-r).
- In the ID connected crack example below, the reference cursor is positioned at the top of the flaw at 5mm and the measurement cursor at the pipe ID at 12.7mm.
- TOFD(m-r) is the flaw through wall dimension of 7.63mm.

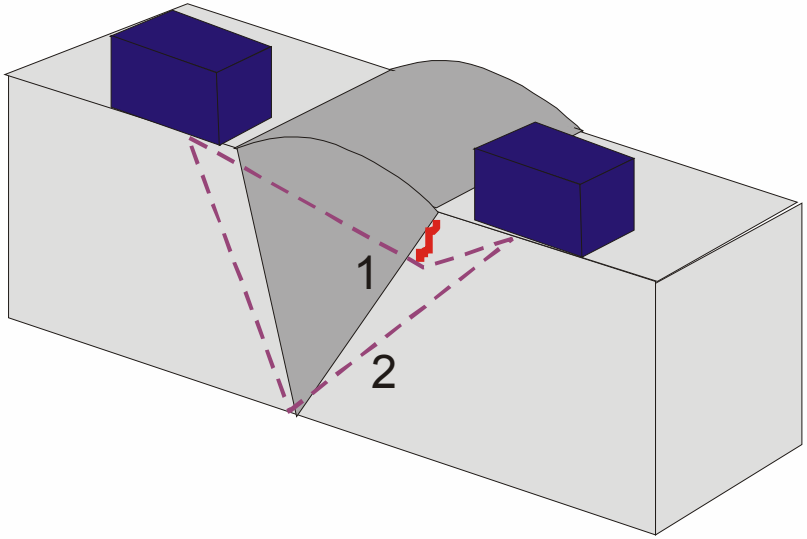


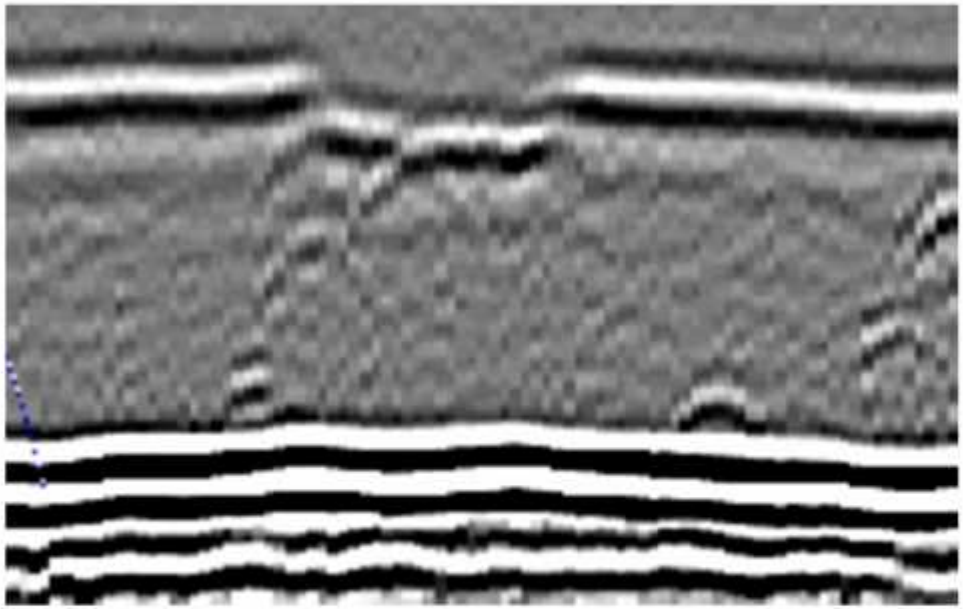
Analysis – Depth Sizing Readings

- In the embedded side wall lack of fusion example below, the reference cursor is positioned at the bottom of the flaw at 8.15mm and the measurement cursor at the top of the flaw at 4.1mm.
- TOFD(m-r) is the flaw through wall dimension of 4mm.



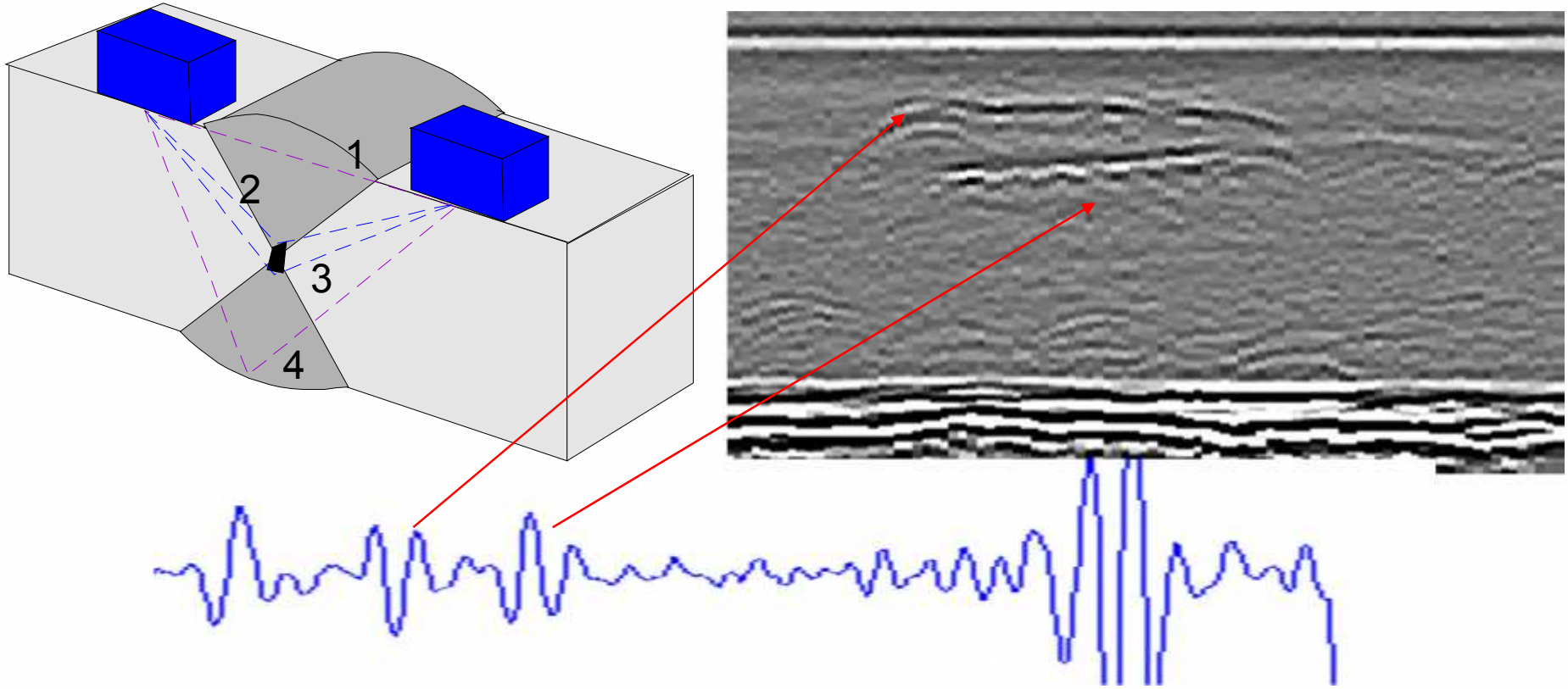
Flaw Characterization Near Surface Crack





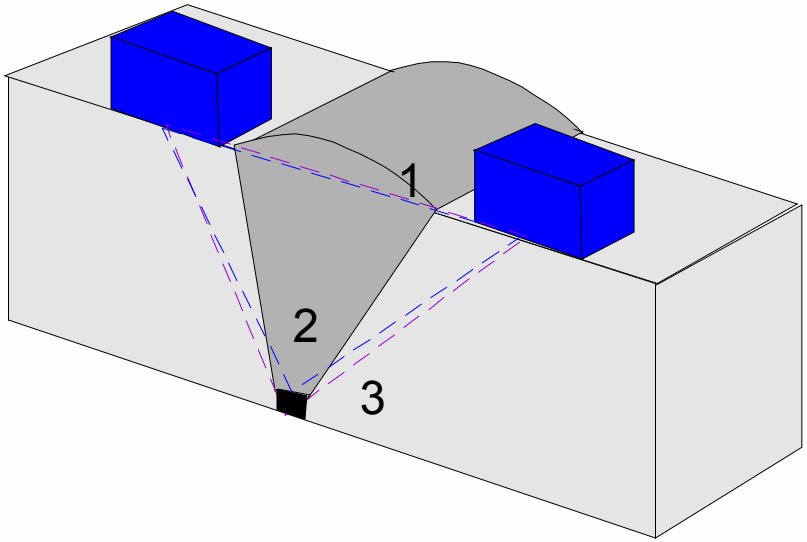
The crack blocks the Lateral Wave
And the lower tip appears on the A-scan

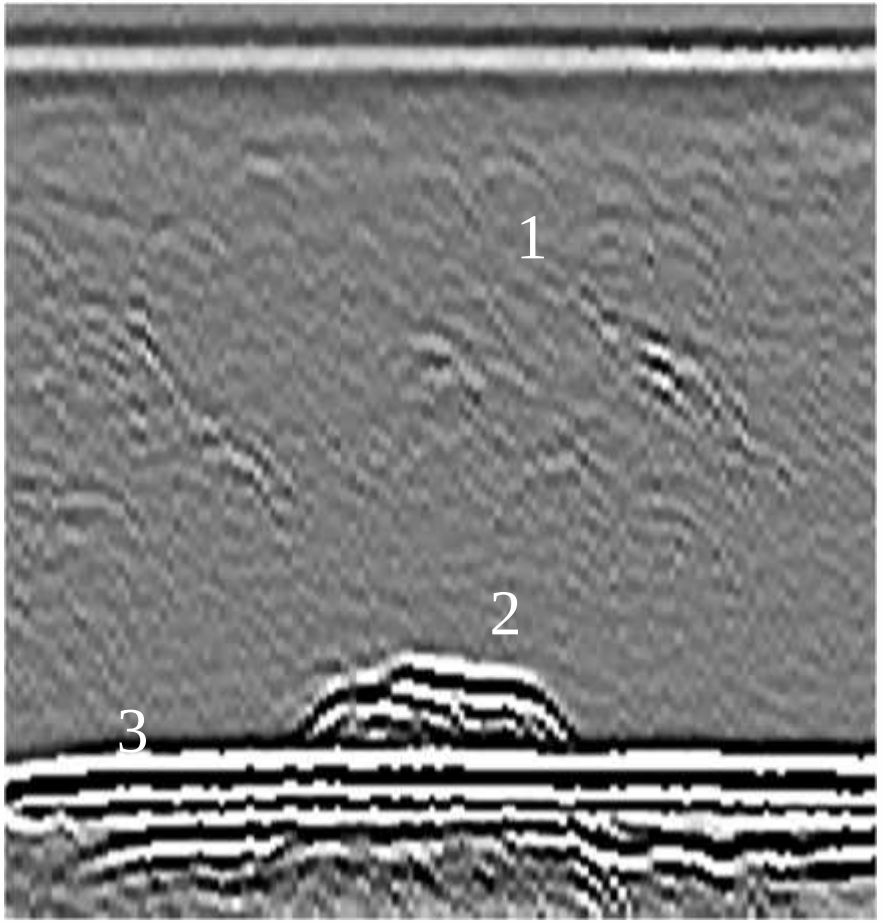
Flaw Characterization Lack of Root Fusion



Note the two signals from the top & bottom

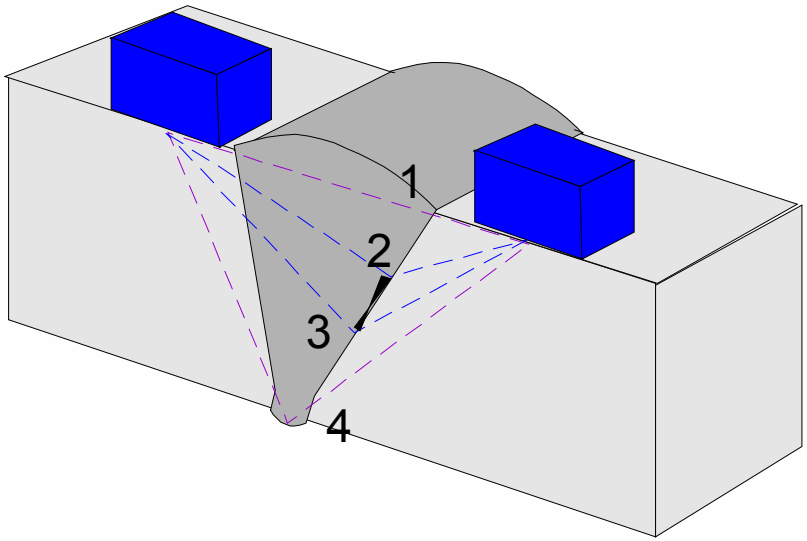
Flaw Characterization Lack of Penetration

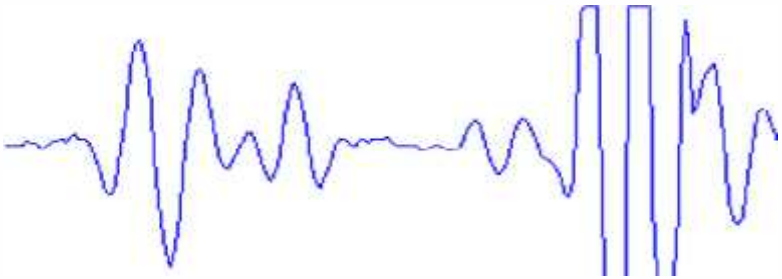


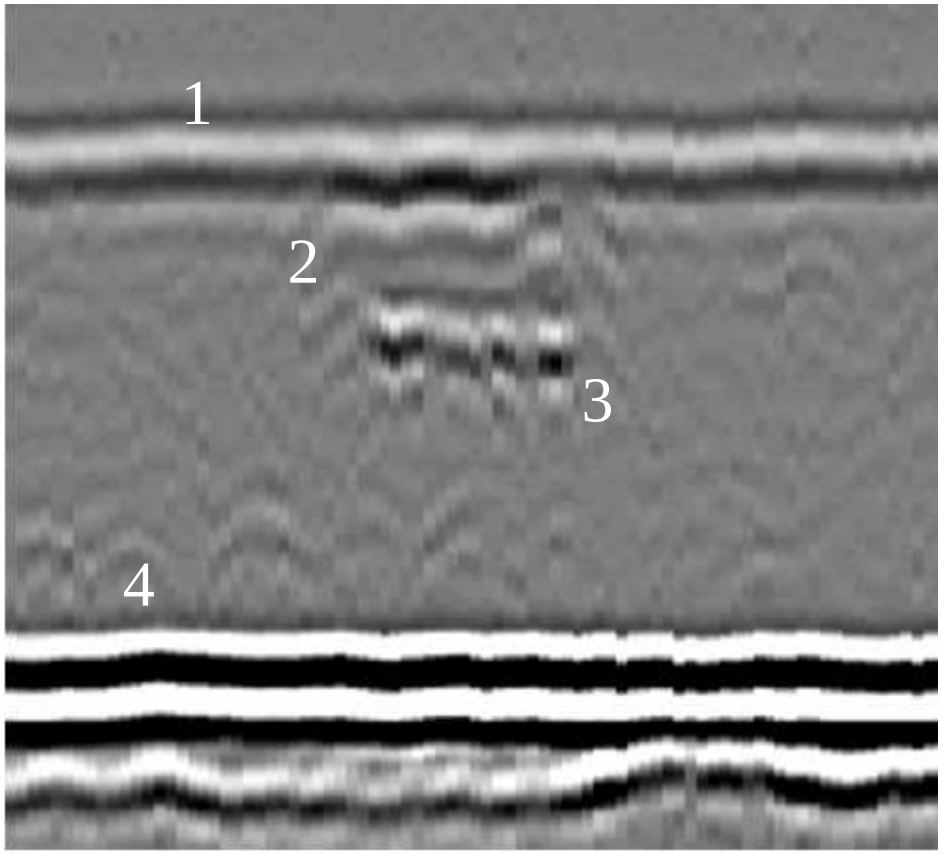


Note the inverted phase between LW and defect

Flaw Characterization Lack of Sidewall Fusion

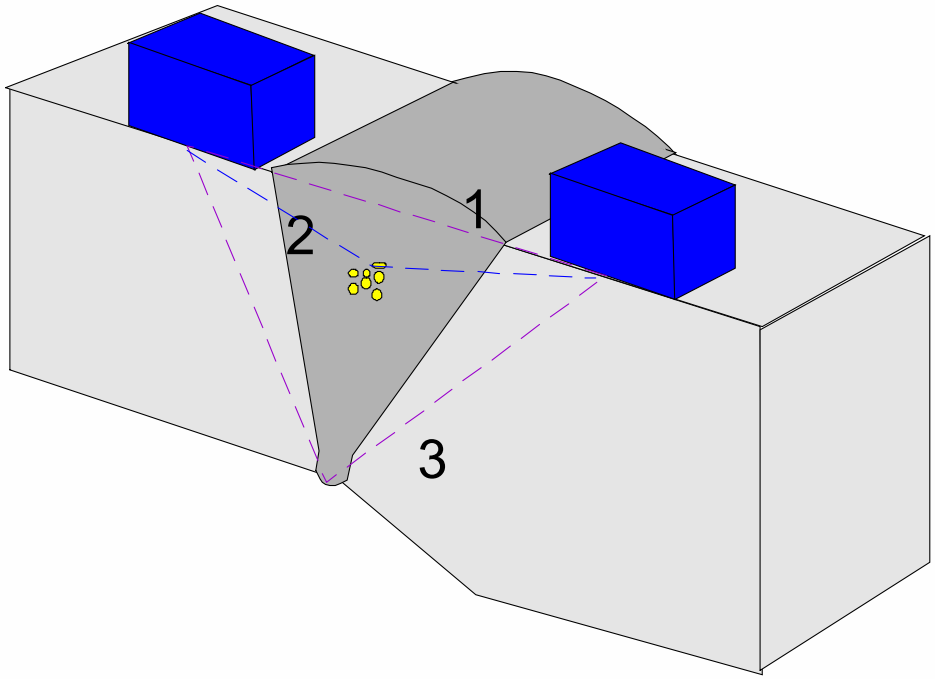


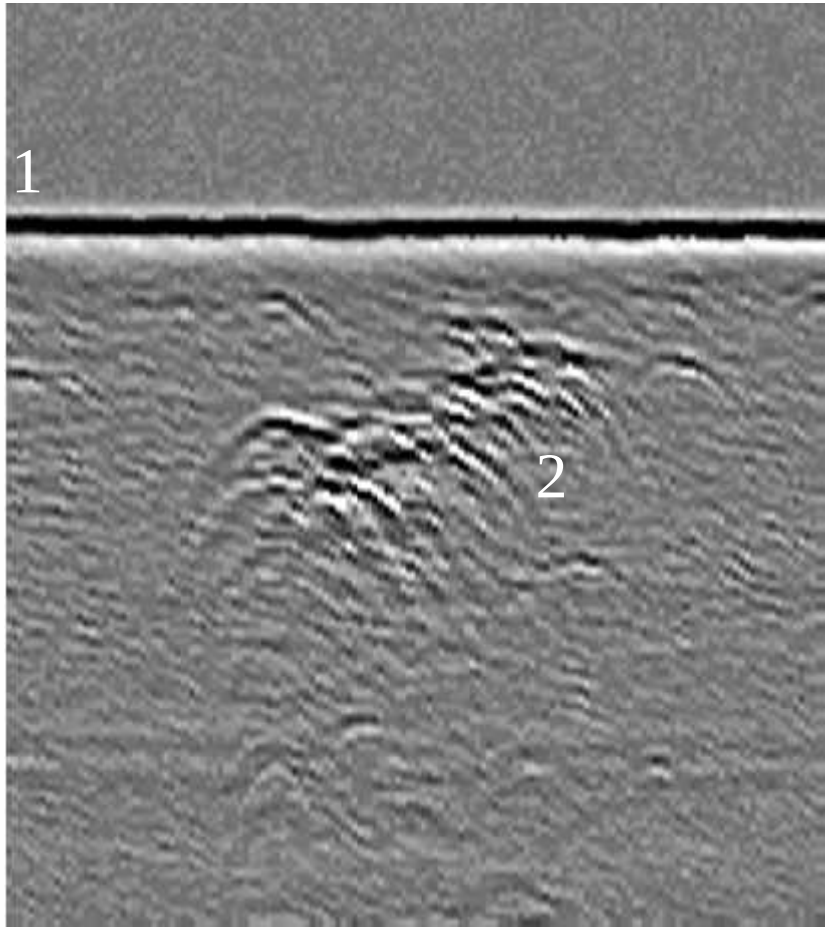




Note the two signals from the top & bottom

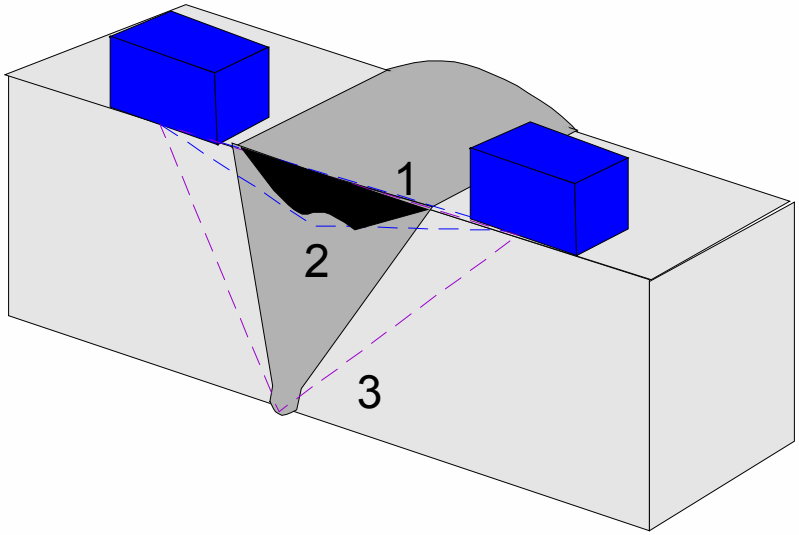
Flaw Characterization Porosity

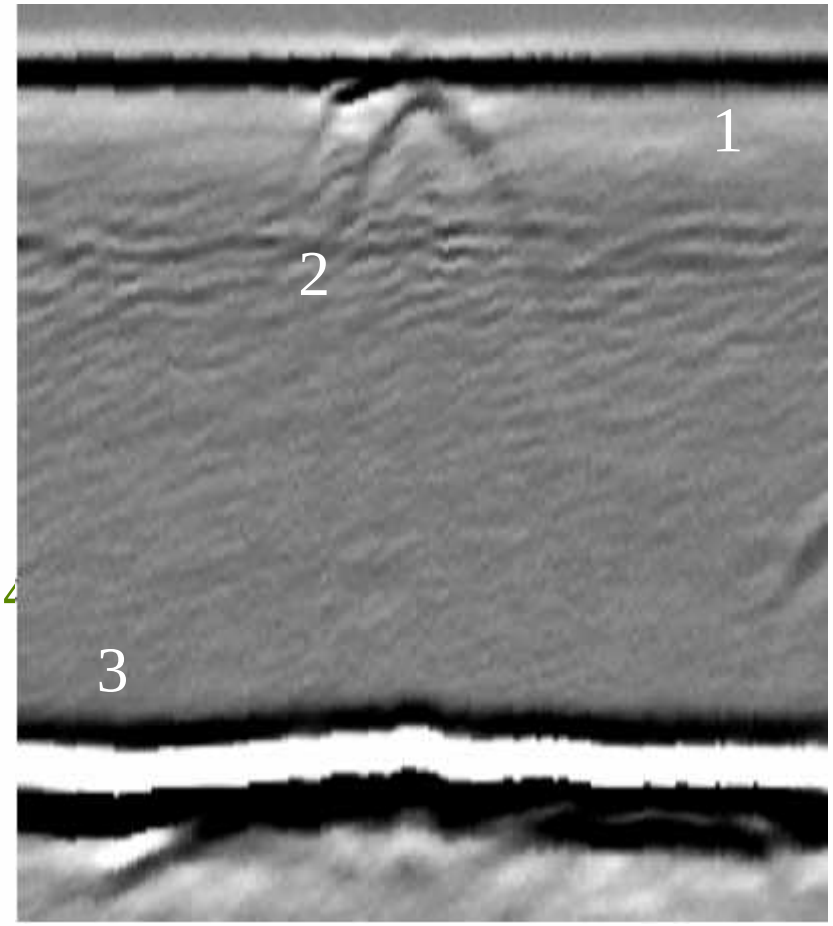




Porosity may image in many forms whether individual or cluster

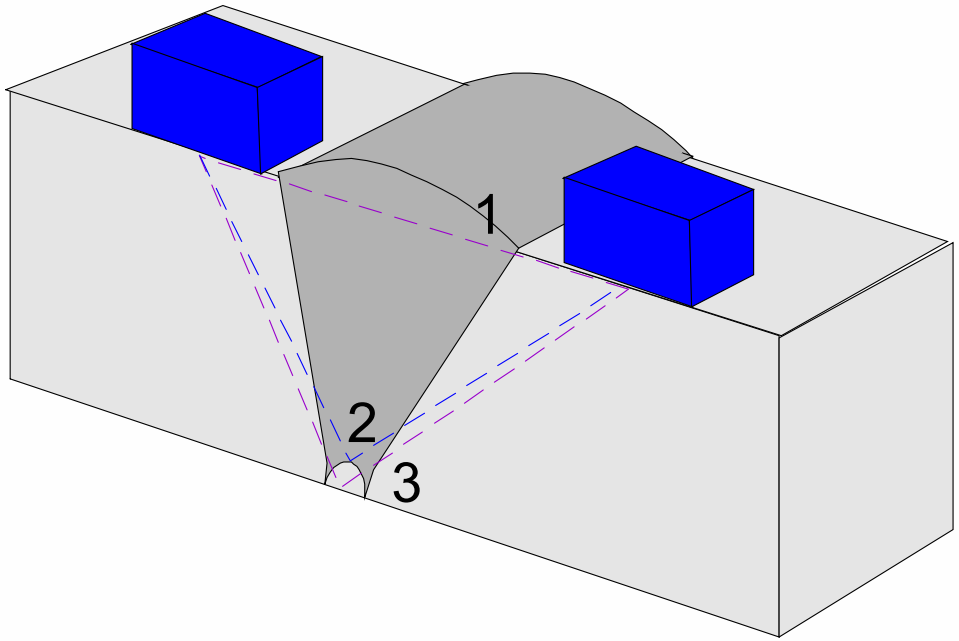
Flaw Characterization Transverse Crack

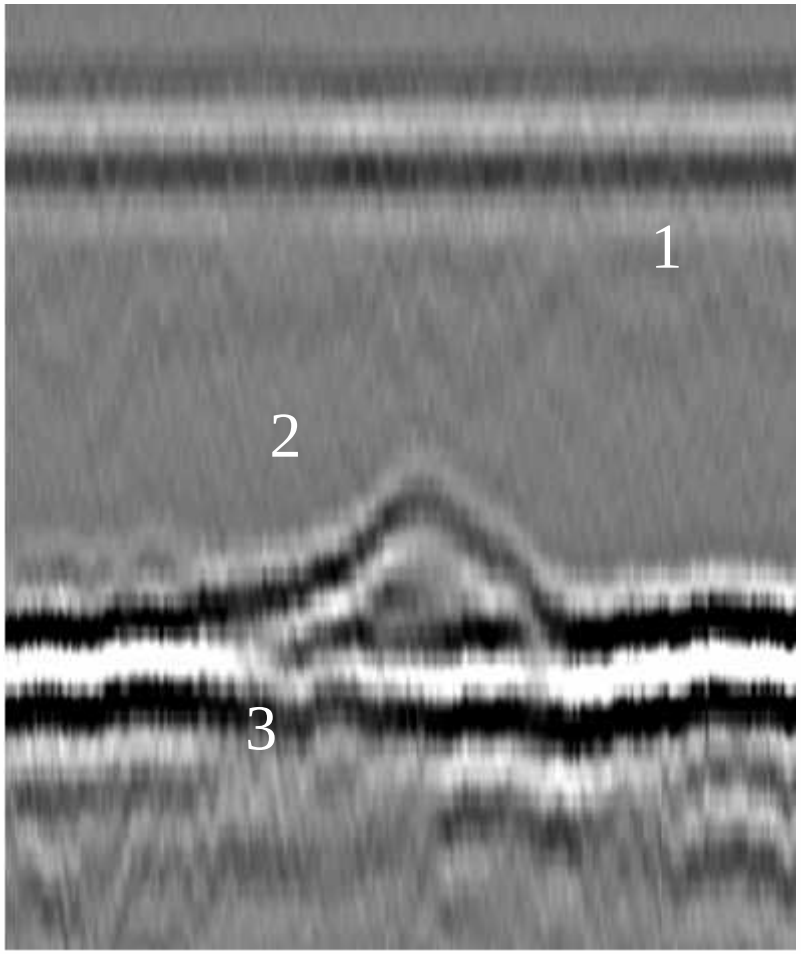




In the LW we can observe the wide beam effect on the crack

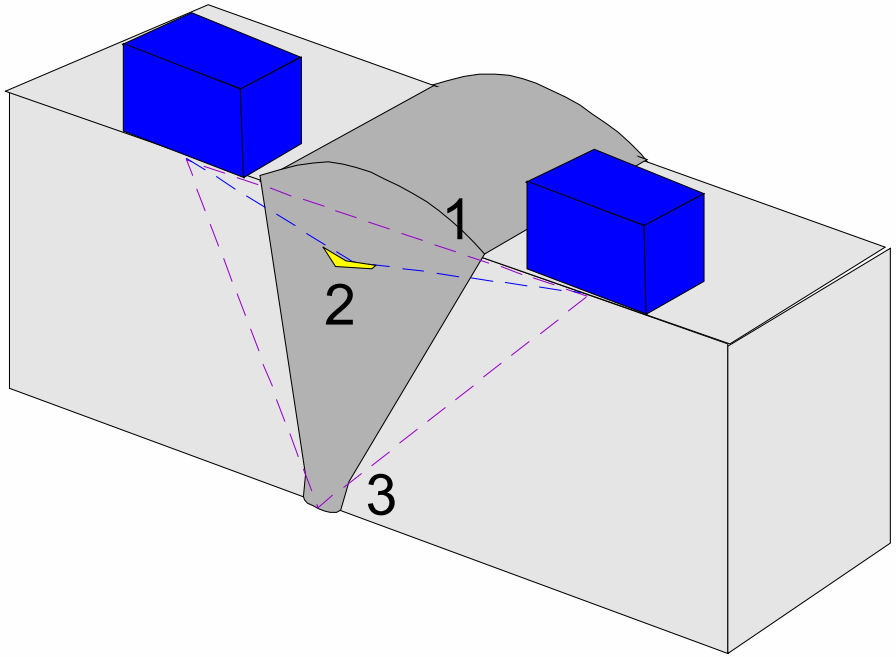
Flaw Characterization - Concave Root

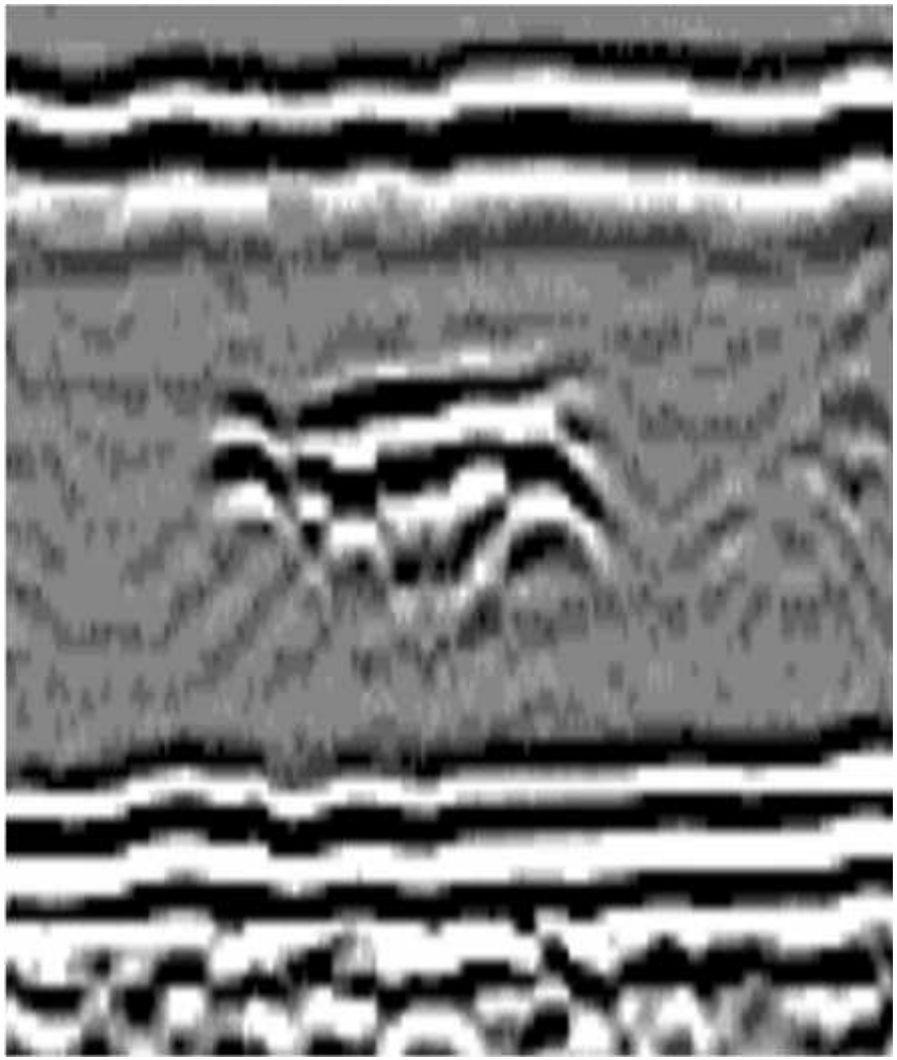




Distortion of back-wall echo

Flaw Characterization Interpass Lack of Fusion





TOFD and PA

- Phased array inspection techniques are often complimented with TOFD.
- TOFD is particularly beneficial for increased length and depth sizing accuracy to compliment amplitude based pulse-echo and phased array inspections.

Analysis – Movie