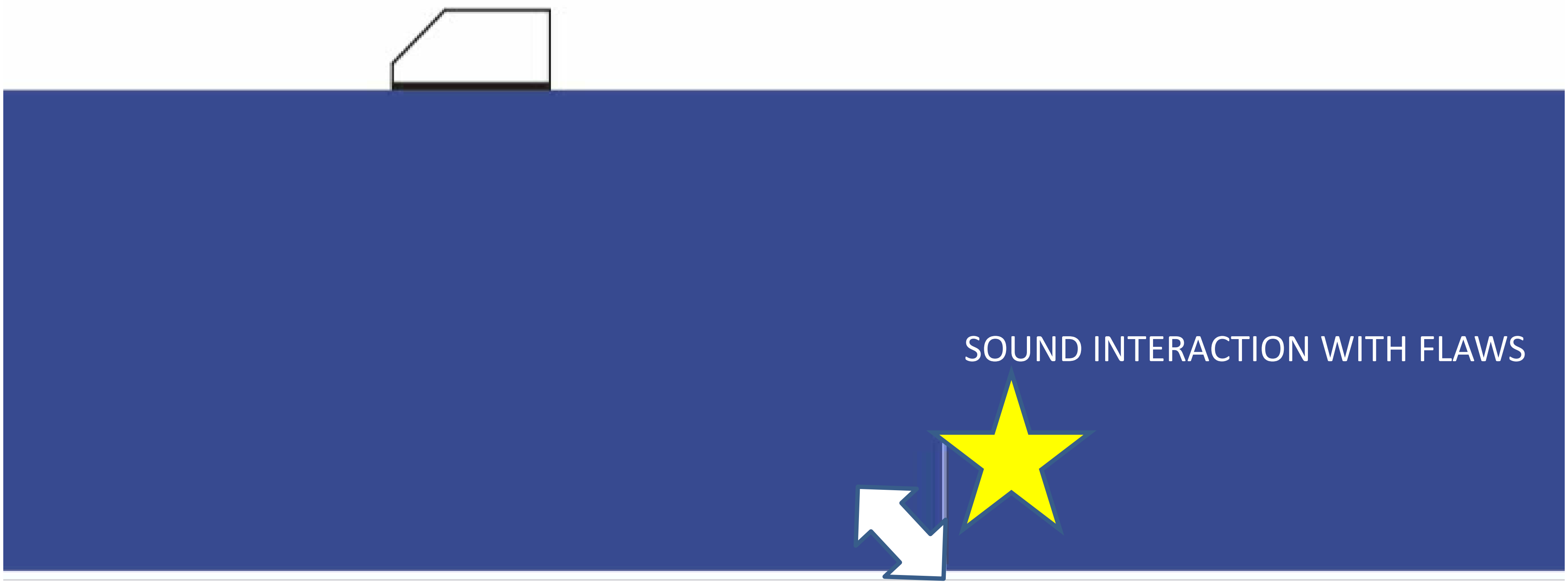
NDT&E Methods: UT Flaw Detection & Evaluation

NDT&E Methods: UT

6.	NDT&E: Introduction to Methods
6.1.	Ultrasonic Testing: Basics of Elasto-Dynamics
6.2.	Ultrasonic Testing: Ultrasound Generation
6.3.	The Pulse-Echo Method
6.4.	Flaw Detection and Evaluation
6.5.	UT-Systems: Transducer, Instrument, Manipulator
6.6.	Current Developments
6.7.	Case Studies by Movies

NDT&E Methods: UT

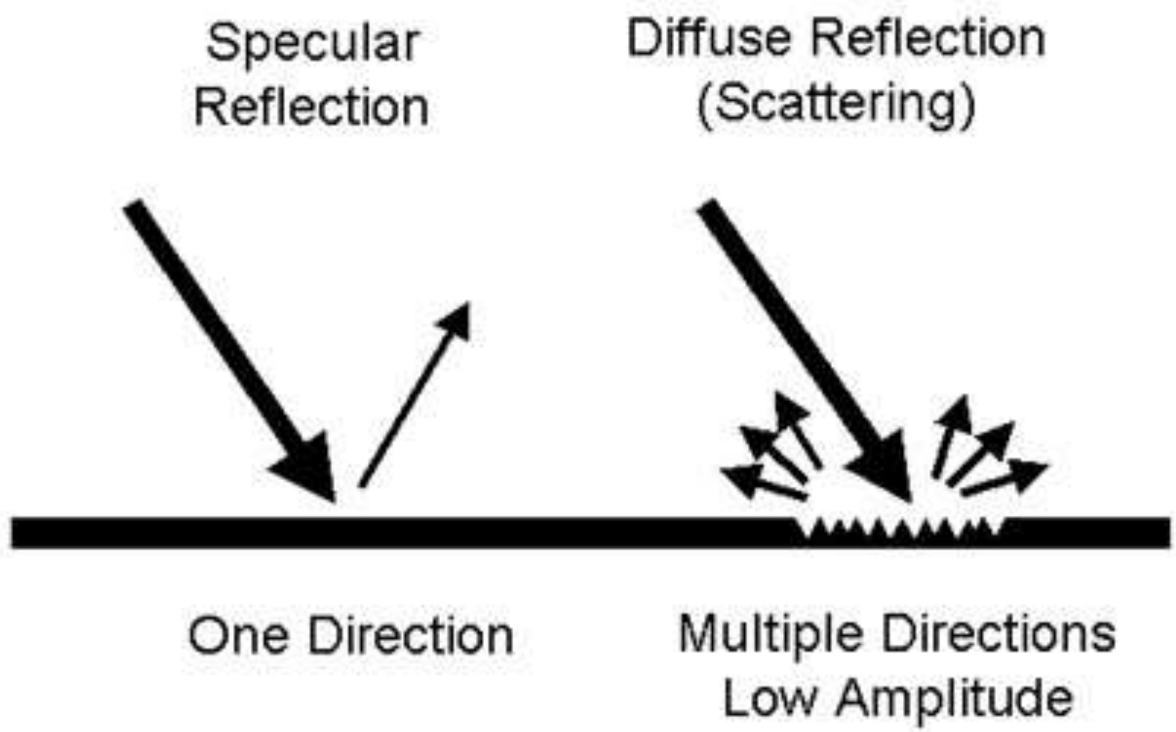
The Pulse-Echo Method



NDT&E Methods: UT Flaw Detection & Evaluation

CONCEPT & TERMS

UT detects and evaluates specular reflections:

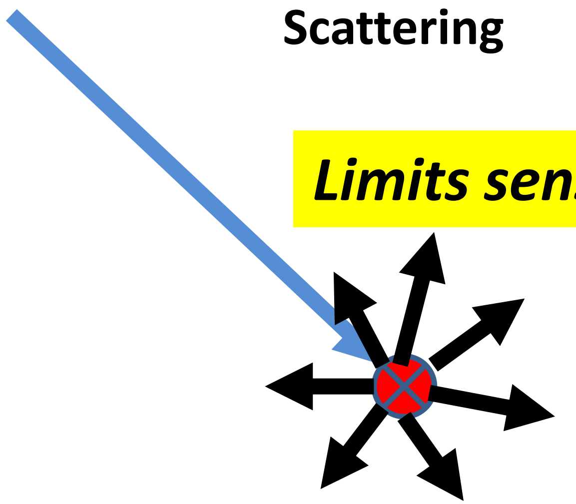


NDT&E Methods: UT Flaw Detection & Evaluation

CONCEPT & TERMS

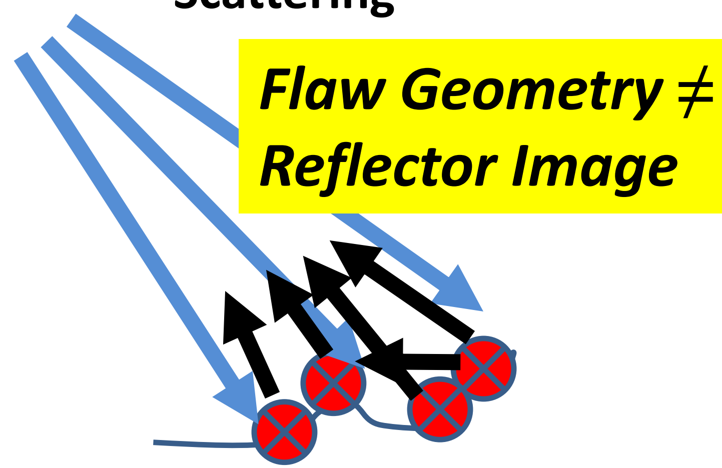
UT detects scattering and compound reflectors:

Stochastic & Rayleigh Scattering



Multiple Directions
Low Amplitude
(Echo Grass)

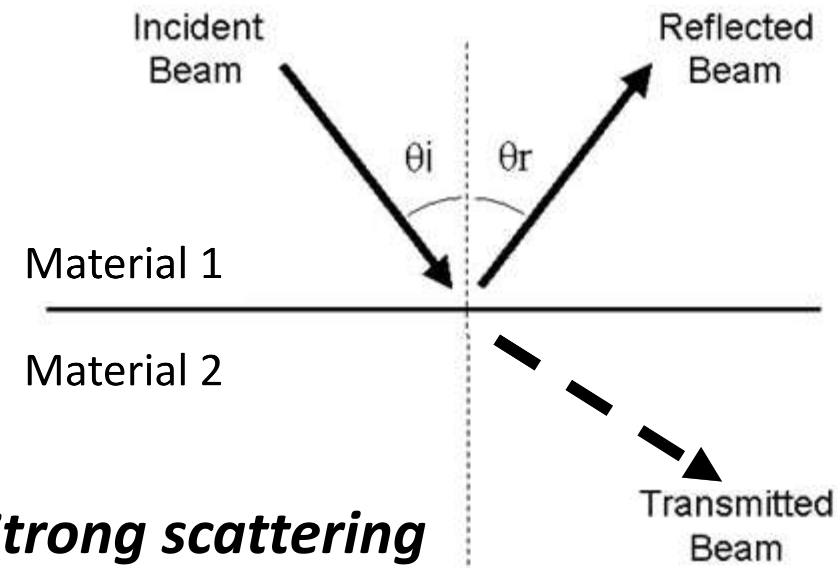
Compound Scattering



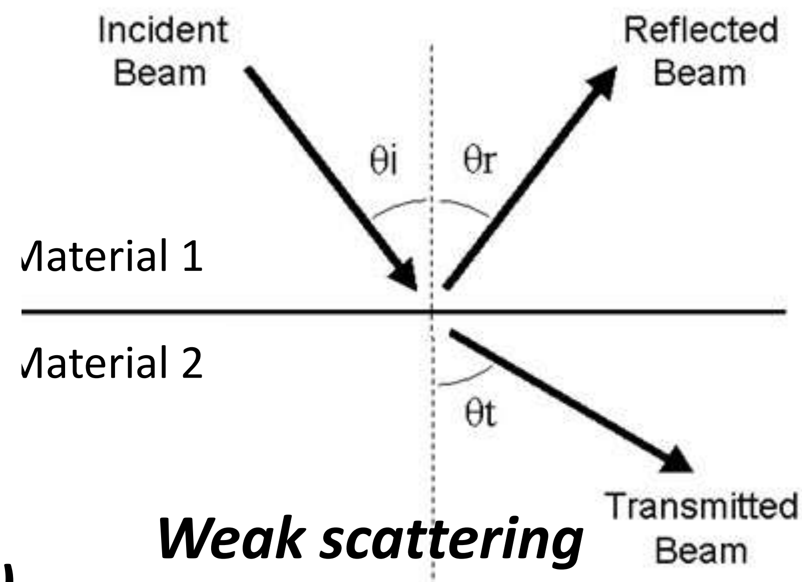
Interfering Signals & Artifacts
(Compound Echo)

CONCEPT & TERMS

There are strong & weak scattering interfaces depending on the impedance ratio:



Strong scattering
(no or low intensity transmission)



Weak scattering
(low intensity reflection)

CONCEPT & TERMS

We call interfaces with impedance change:

Material Inhomogeneity

Inhomogeneity is characterized by a local change of material properties.
Homogeneous material is uniform without irregularities

Material Discontinuity

- Surface
- Volume

Discontinuity is defined as an interruption of the typical material structure,
(a lack of homogeneity in its mechanical, metallurgical, or physical characteristics).
A discontinuity could be the result of a defect, but isn't necessarily a defect
Material Inhomogeneity

CONCEPT & TERMS

We call interfaces with impedance change:

Material Imperfection/Irregularity

- Macro (lamination)
- Micro (small inclusions)

Imperfections/irregularities are characterized by a non-perfect material quality as specified. It does not relate to the usability of the material.

Material Flaw

A flaw is a feature that mars the designed quality of the material. It may but must not hurt or damage the intended use of material.

Material Defect

A defect is a flaw that by nature or accumulated effect (for example, total crack length) renders a part or product unable to meet minimum applicable acceptance standards or specifications. A defect results in rejection of the part or product and may cause failure when part is in operation or use.

CONCEPT & TERMS

We call interfaces with impedance change:

Typical Material Flaws

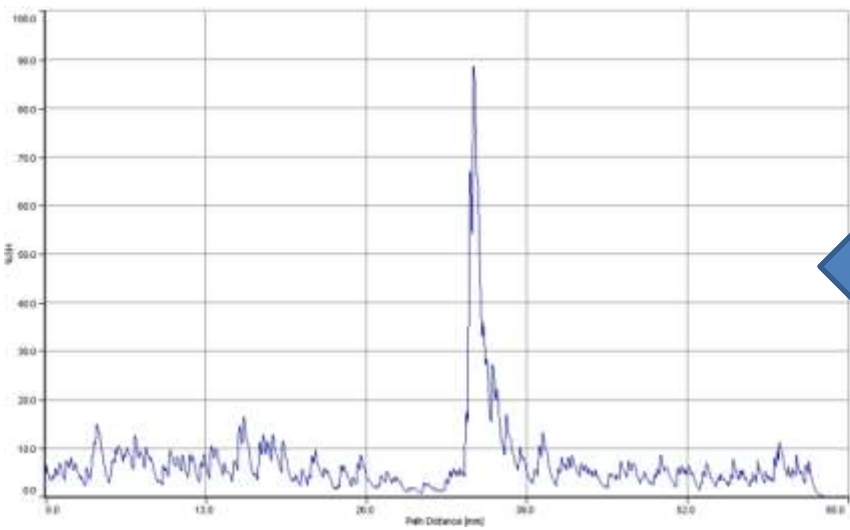
Inclusion	Undercut
Pore	Delamination
Void	Blister
Crack*	Dent
Lack of Bonding	Pit

There are many more flaws, depending on material, joining/production technologies and load conditions when in use.

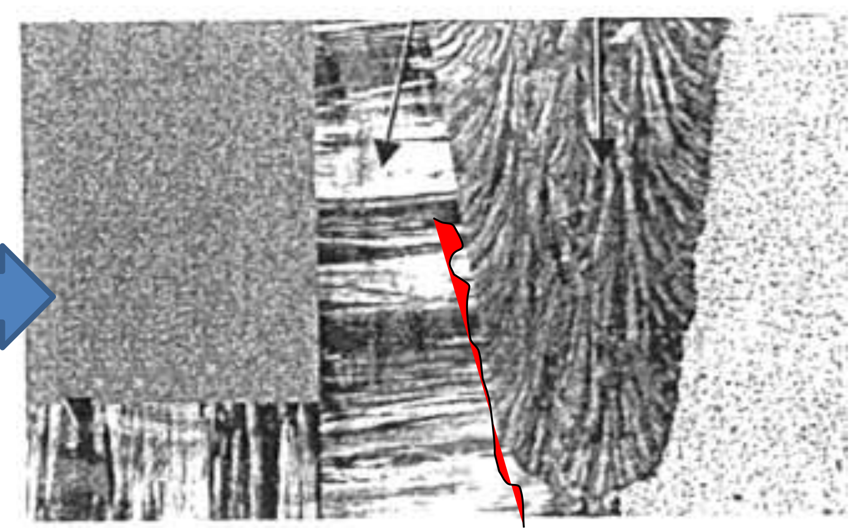
* A crack is evaluated a defect in most cases due to its stress concentration effect

NDT&E Methods: UT Flaw Detection & Evaluation

Ultrasonic Flaw Indication



Macrosection of a Cracked Weld

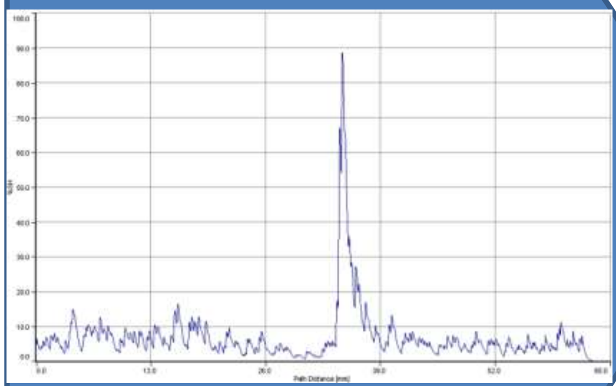


Correlation Problem

NDT&E Methods: UT Flaw Detection & Evaluation

OBJECTIVE

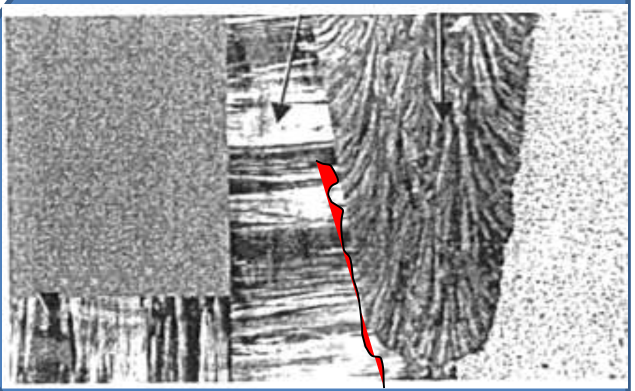
QUANTITATIVE ULTRASONIC TESTING



THE WORLD IS 3-D
THE DETAILS ARE TINY

QUT

HIGH RESOLUTION
HIGH CONTRAST



Dissimilar Weld

FAST SCANNING & REAL TIME FLAW EVALUATION

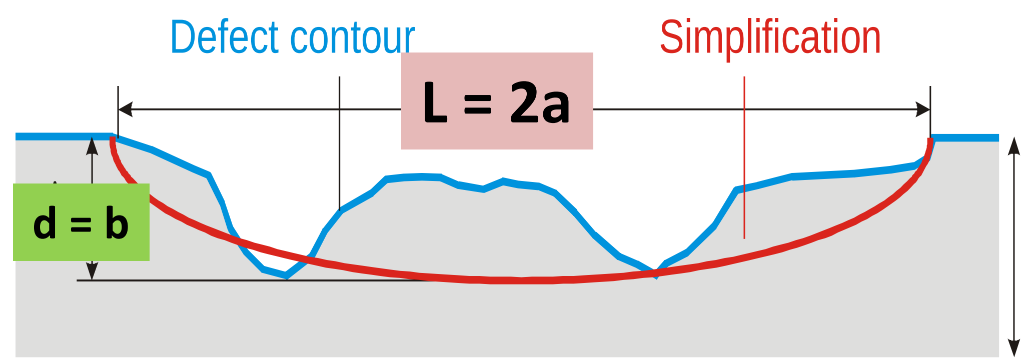
NDT&E Methods: UT Flaw Detection & Evaluation

45°/4 MHz A-scan
ID Crack Signal

STATE OF ENGINEERING

STATE OF PHYSICS

FRACTURE MECHANIC
MODEL CRACK



NDT&E Methods: UT Flaw Detection & Evaluation

Two Successive Steps

DETECTION	EVALUATION
Probability of Detection	***Flaw Type***
Reproducibility	***Dimensions***
Completeness	***Risk Assessment***

DETECTION

Remind the Basics:

We use high-frequency ultrasonic pulses – very much directed
(Standard frequencies for most of the steel part inspections: 1MHz to 5MHz)

The received pulse is a specular reflection of discontinuities of mm – dimensions
(or a compound diffuse reflector or a systematic appearance of low amplitude echo signals)

The transmitted pulse strikes the surface of discontinuity perpendicularly
(or we have to use "pitch and catch" transducers:
the discontinuity mirrors the pulse back to the receiving transducer)

Required Minimal Sensitivity for Flaw Signal Detection

DETECTION

Calibration:

We have to calibrate the inspection instrument for:

- **Correct positioning of detected discontinuity**
- **Sensitivity for flaw detection**

NDT&E Methods: UT Flaw Detection & Evaluation

DETECTION

Calibration:

We have to calibrate the inspection instrument for:

- **Correct positioning of detected discontinuity**

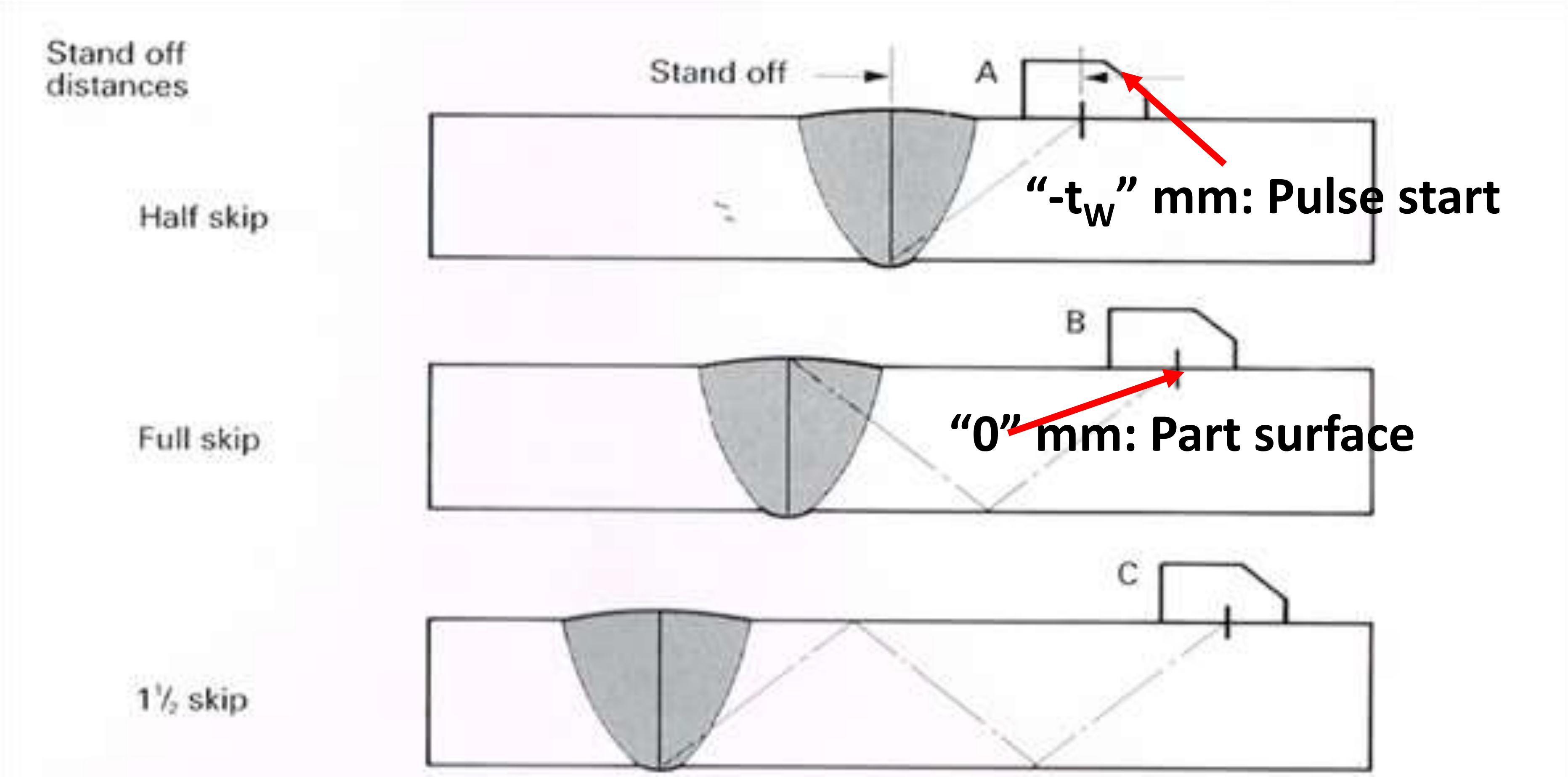
Sound Velocity

Angle of Incidence

Wedge: Surface position of measured amplitude-time signal

NDT&E Methods: Detection

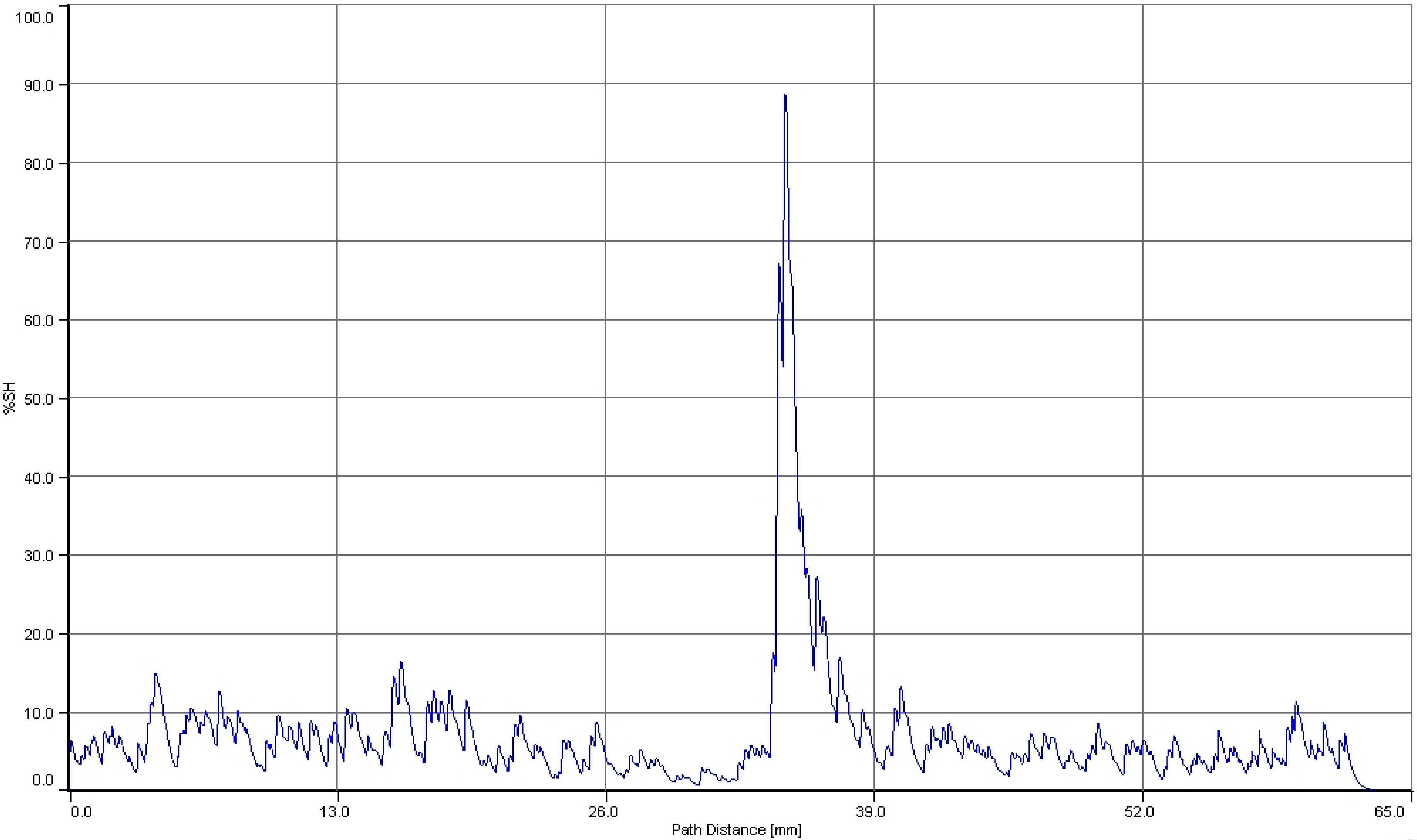
➢ **Correct positioning of detected discontinuity**



Schematic of "Skip Distances"

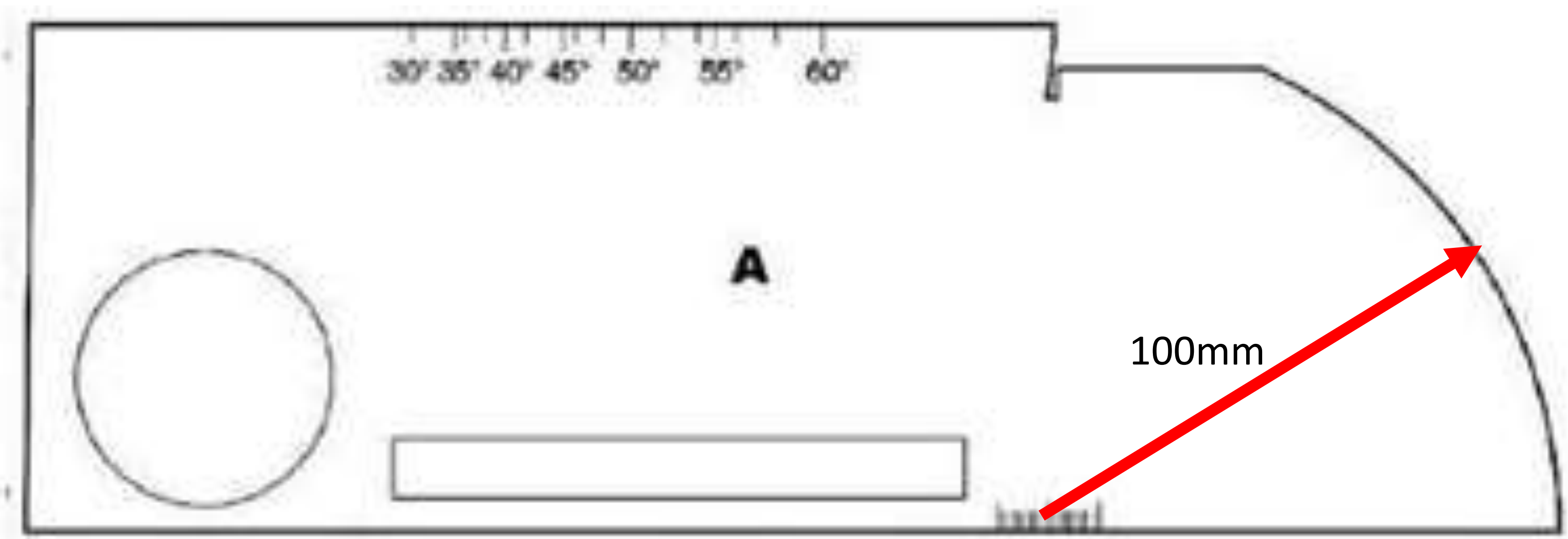
NDT&E Methods: Detection

For Discussion:



NDT&E Methods: Detection

Calibration Standard Blocks

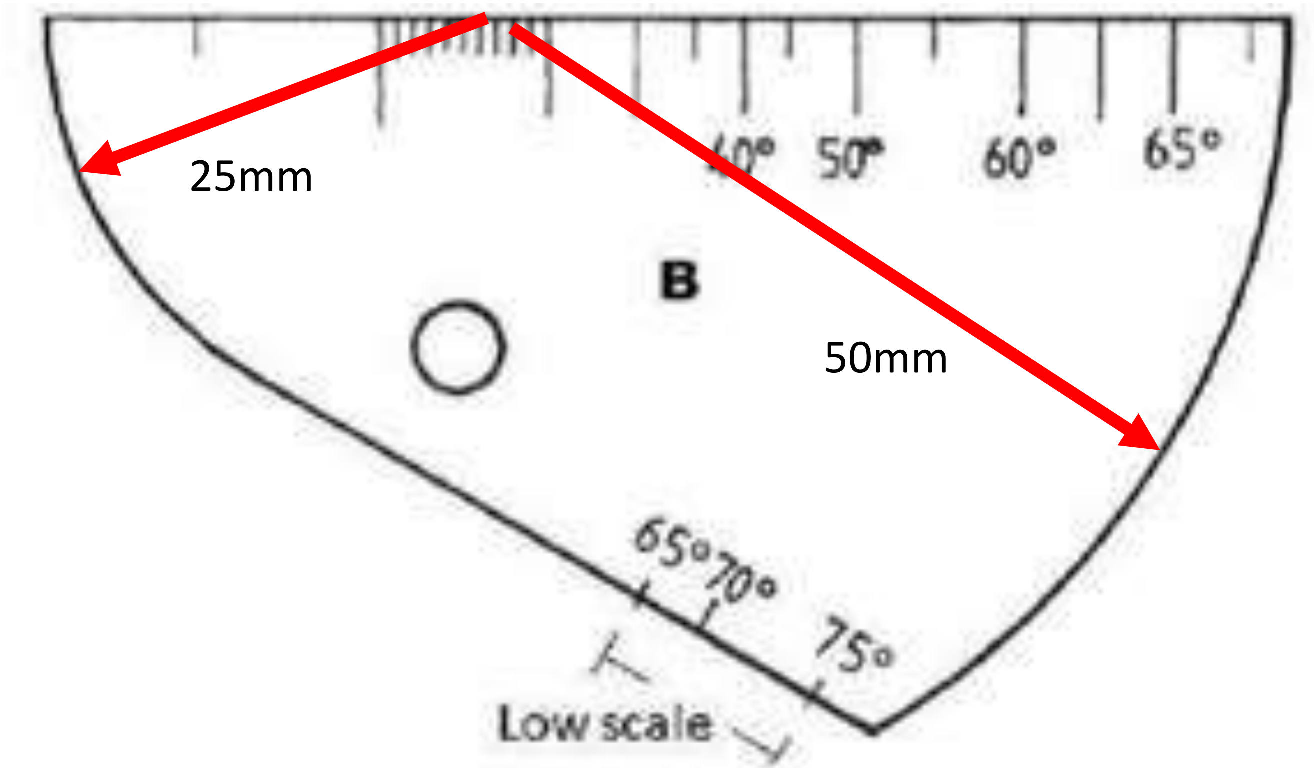


ISO 2400 Number 1 block

The standard Nr.1 block is 300mm long and 25 or 50mm thickness with a 100mm radius machined on one end.
The test block also contains two drilled holes, 50 and 1.5mm in diameter and a flat bottomed machined notch

NDT&E Methods: Detection

Calibration Standard Blocks



The ISO 7963 Number 2 block

Calibration:

We have to calibrate the inspection instrument for:

- **Appropriate sensitivity for flaw detection**

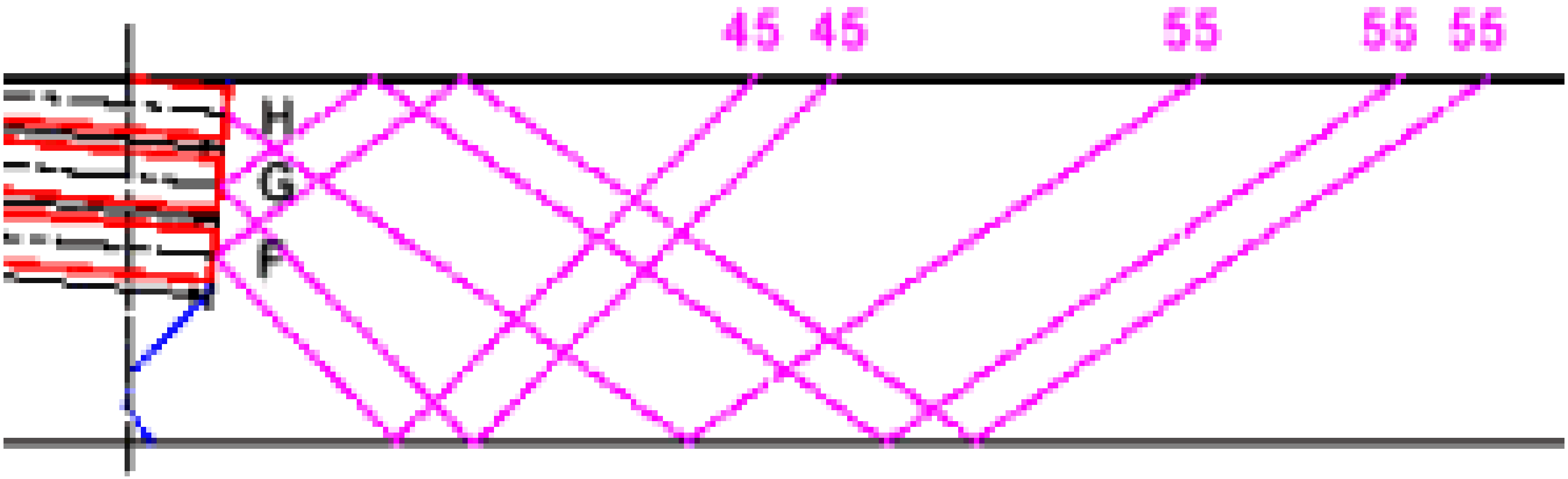
KEY: Reference Reflector

- **Notch**
- **Flat Bottom Hole FBH (Disk)**
- **Side Drilled Hole SDH (Cylinder)**
- **Spherical Void SPH (Sphere)**

- **Back-Wall (AVG)**

NDT&E Methods: UT Flaw Detection

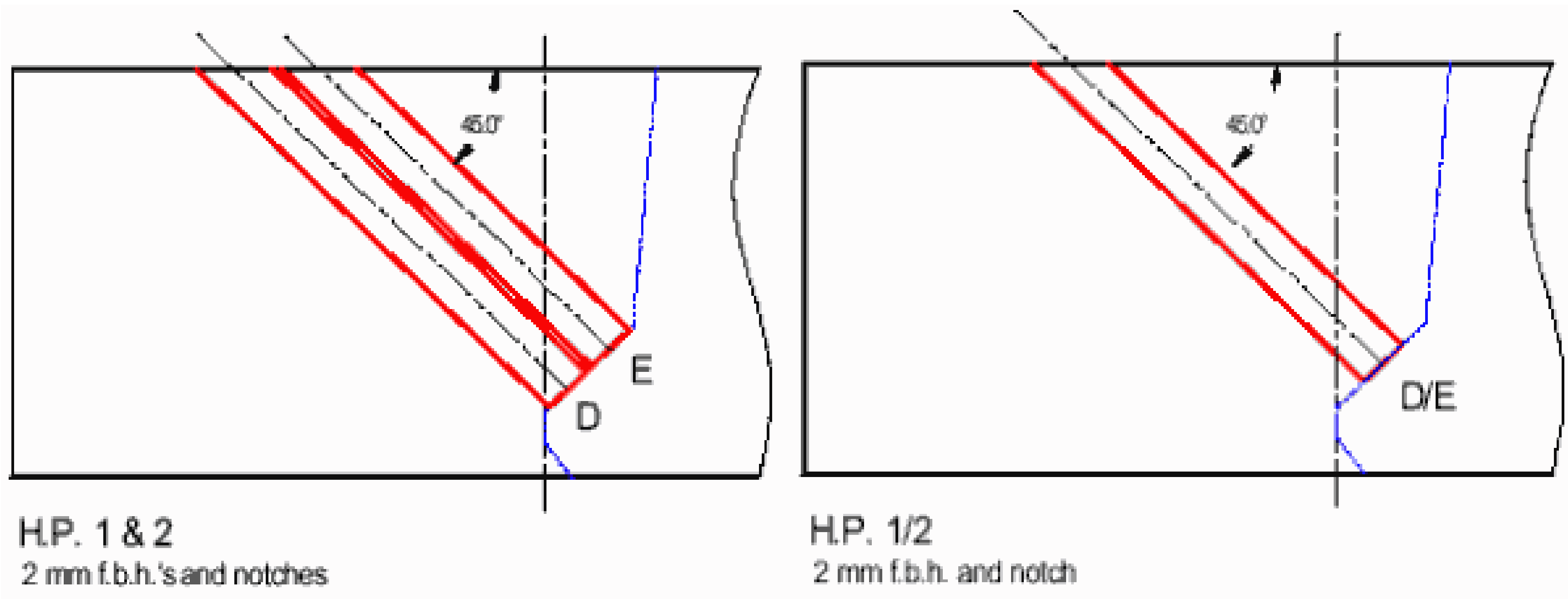
Calibration:



Flat Bottom Holes (FBH) Reference for Weld Inspection

NDT&E Methods: UT Flaw Detection

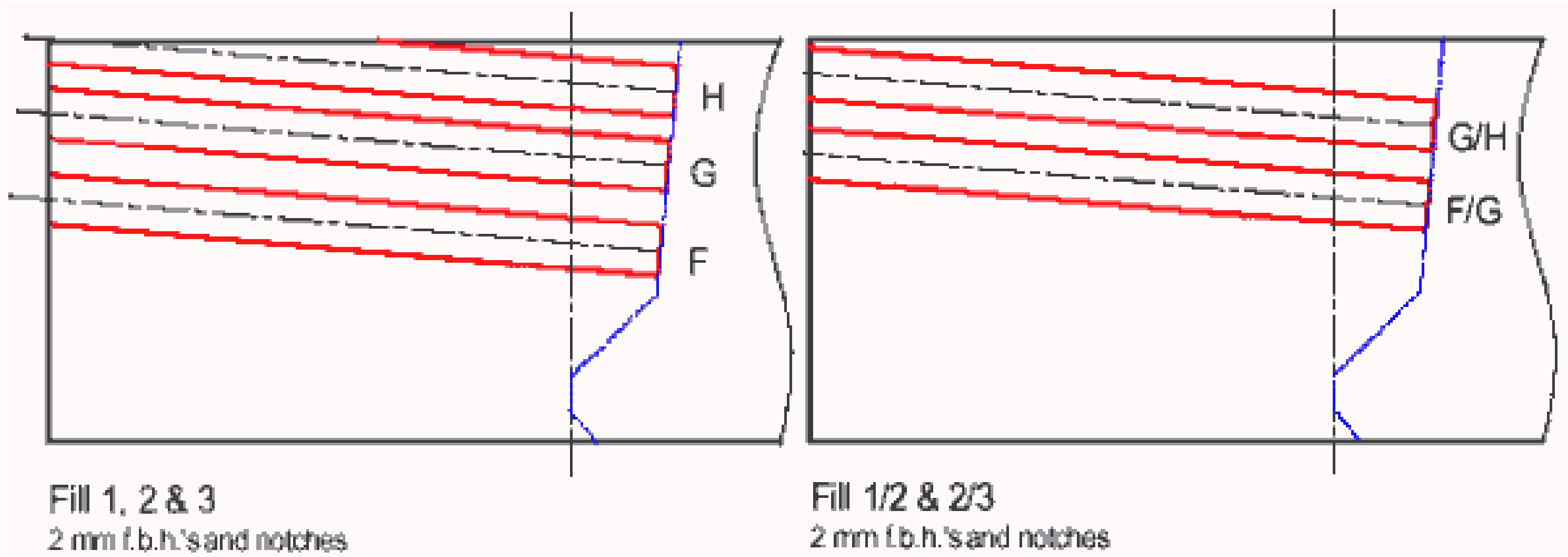
Calibration:



Flat Bottom Holes (FBH) Reference for Weld Inspection

NDT&E Methods: UT Flaw Detection

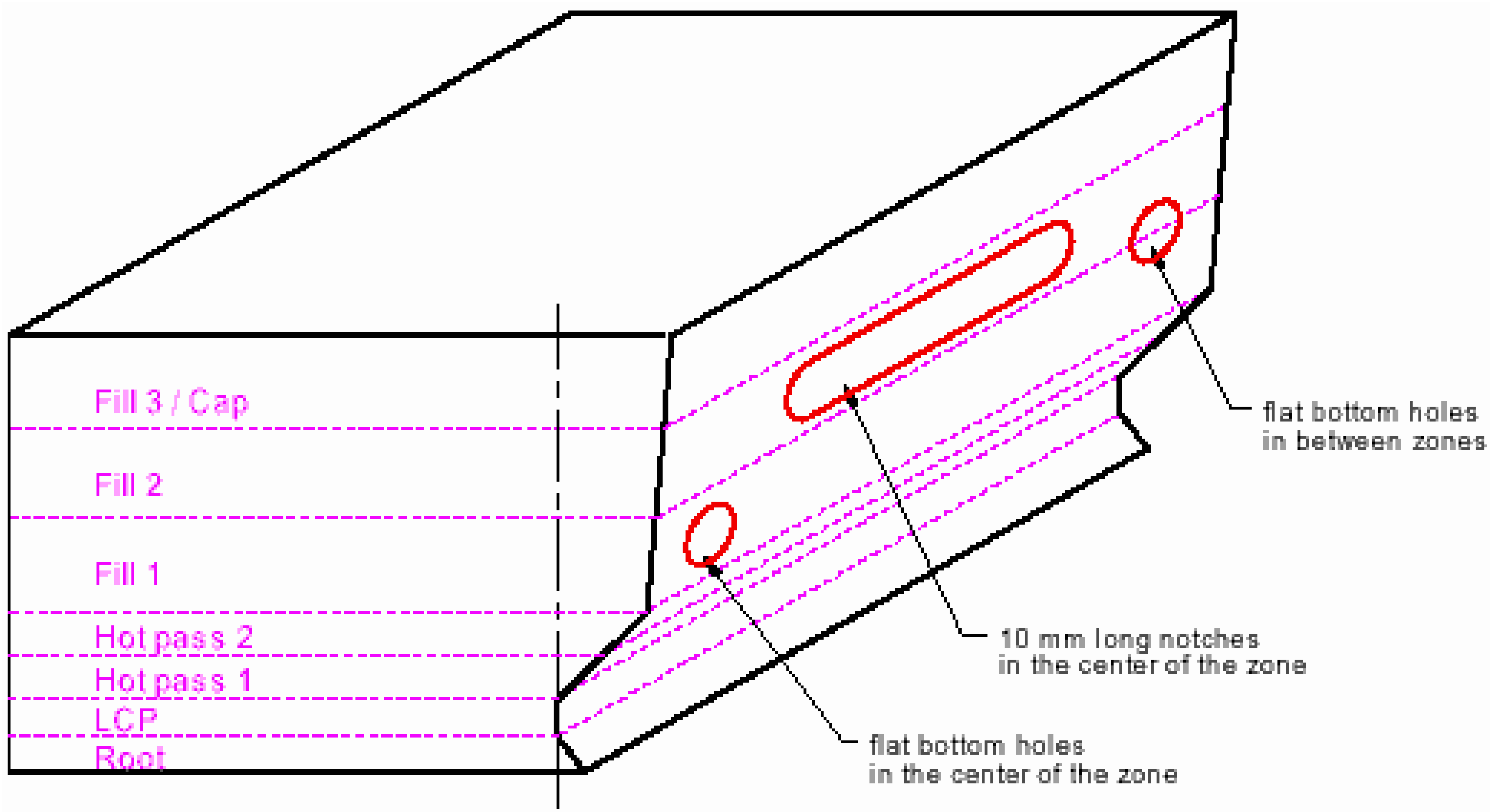
Calibration:



Flat Bottom Holes (FBH) Reference for Weld Inspection

NDT&E Methods: UT Flaw Detection

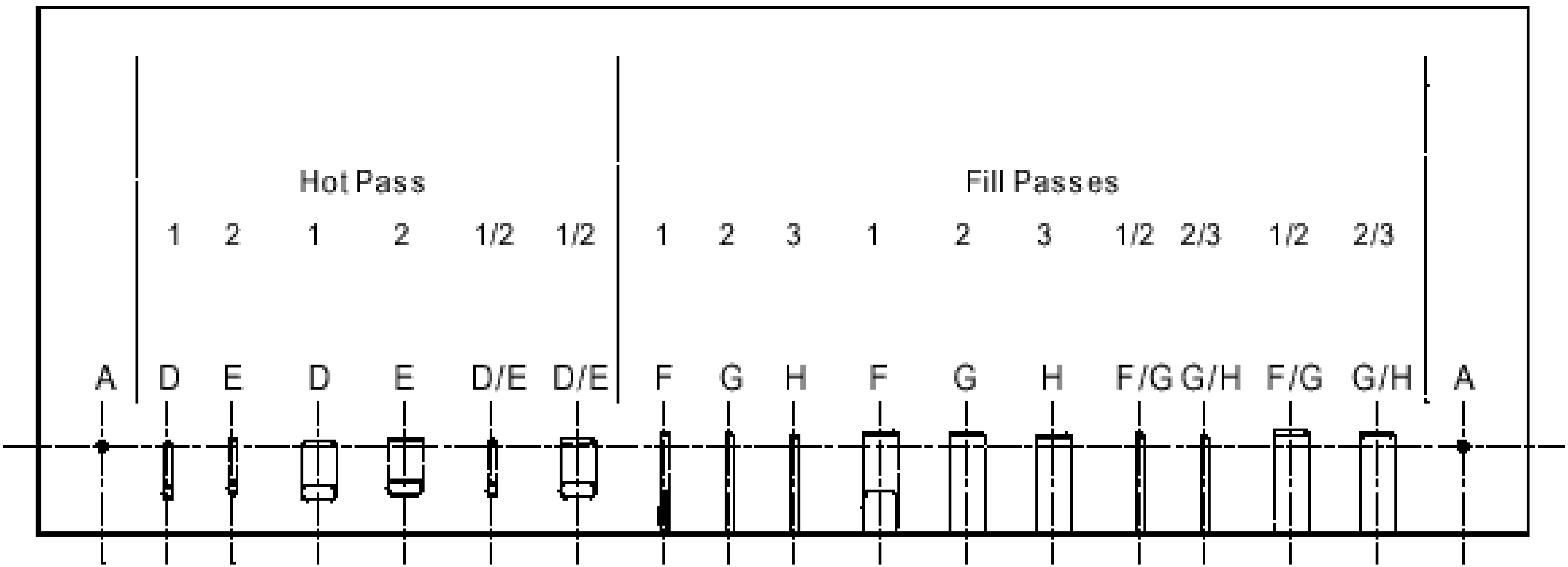
Calibration:



Flat Bottom Holes (FBH) Reference for Weld Inspection

NDT&E Methods: UT Flaw Detection

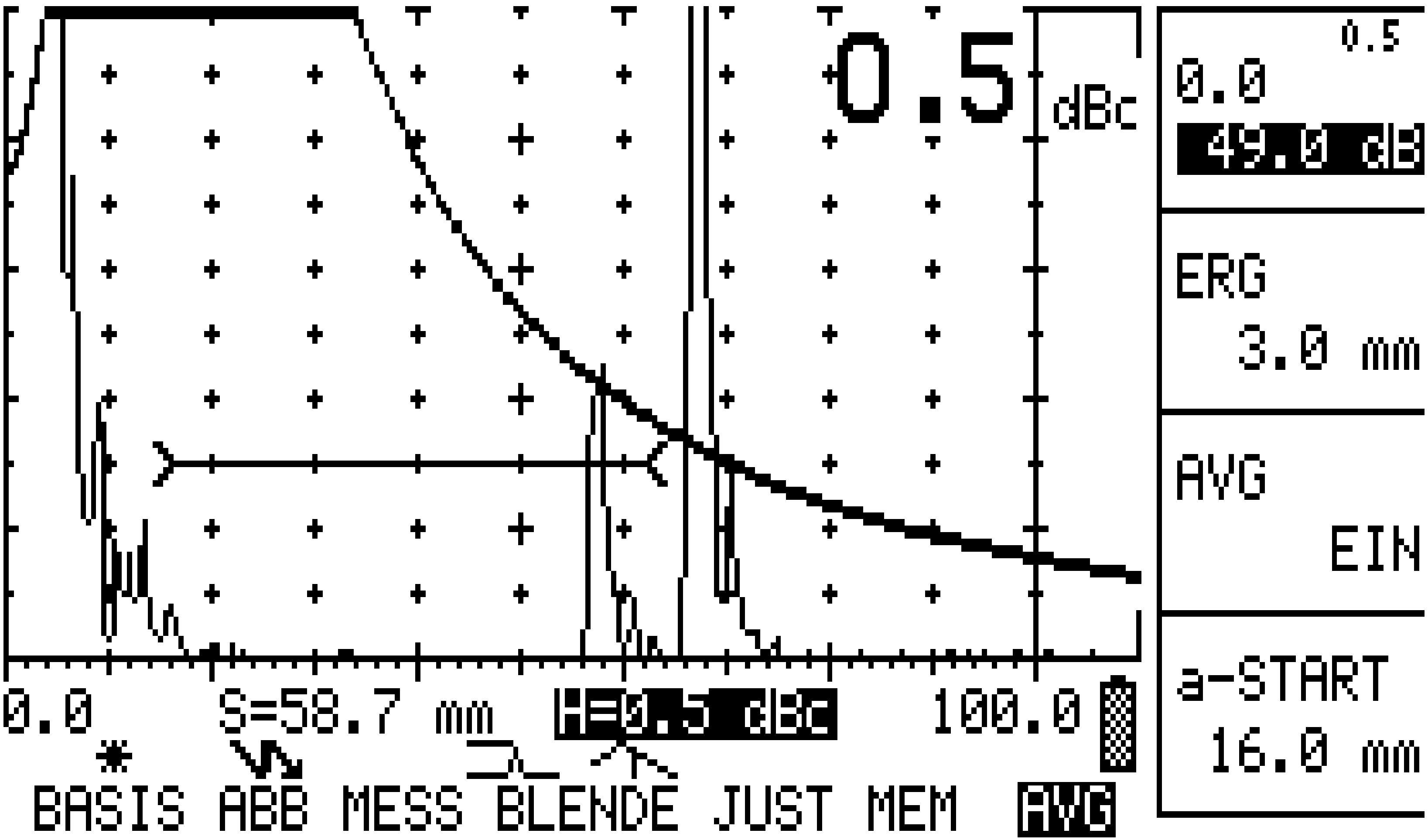
Calibration:



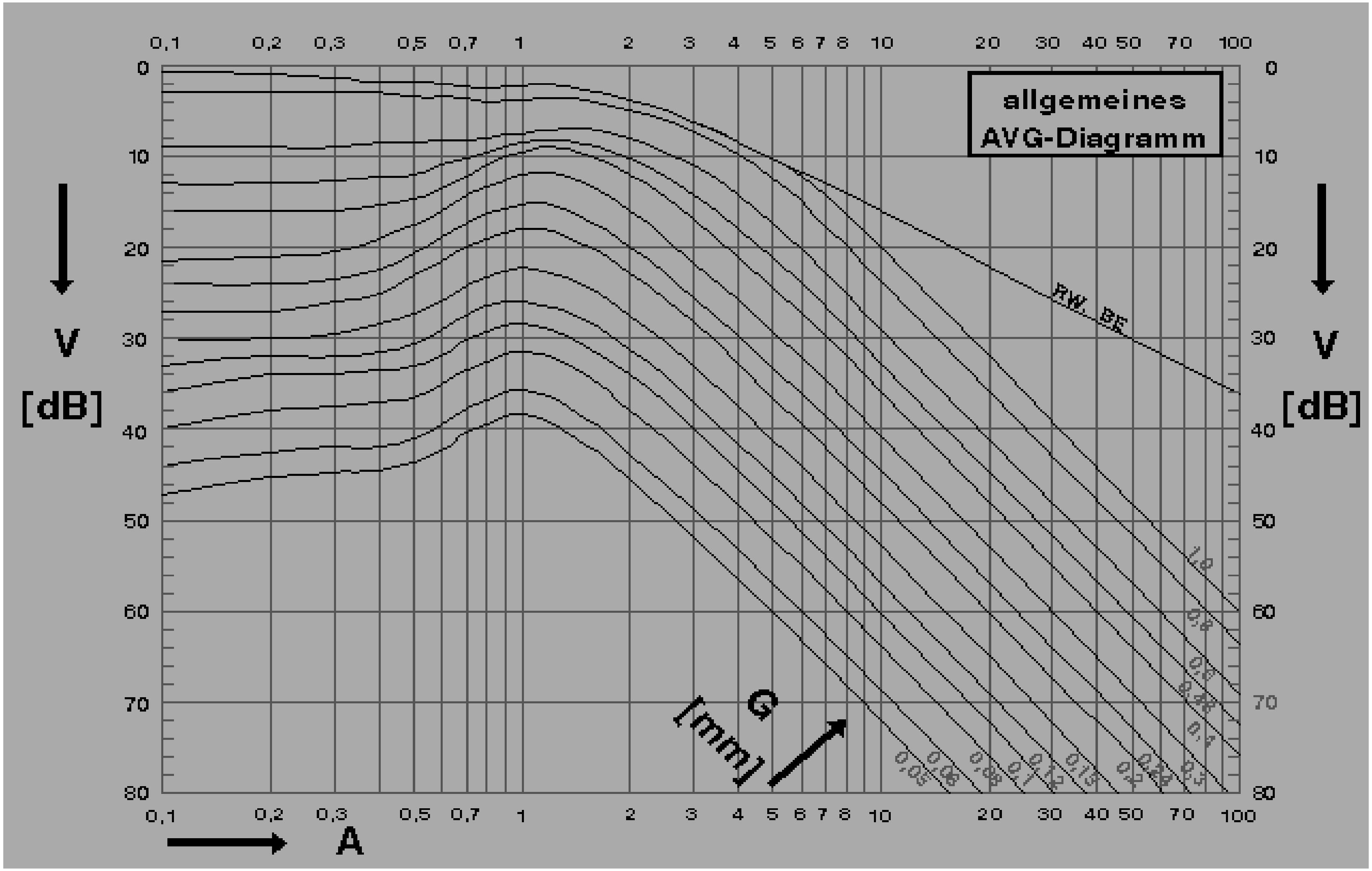
Flat Bottom Holes (FBH) Reference for Weld Inspection

NDT&E Methods: UT Flaw Detection

DISTANCE CORRECTION



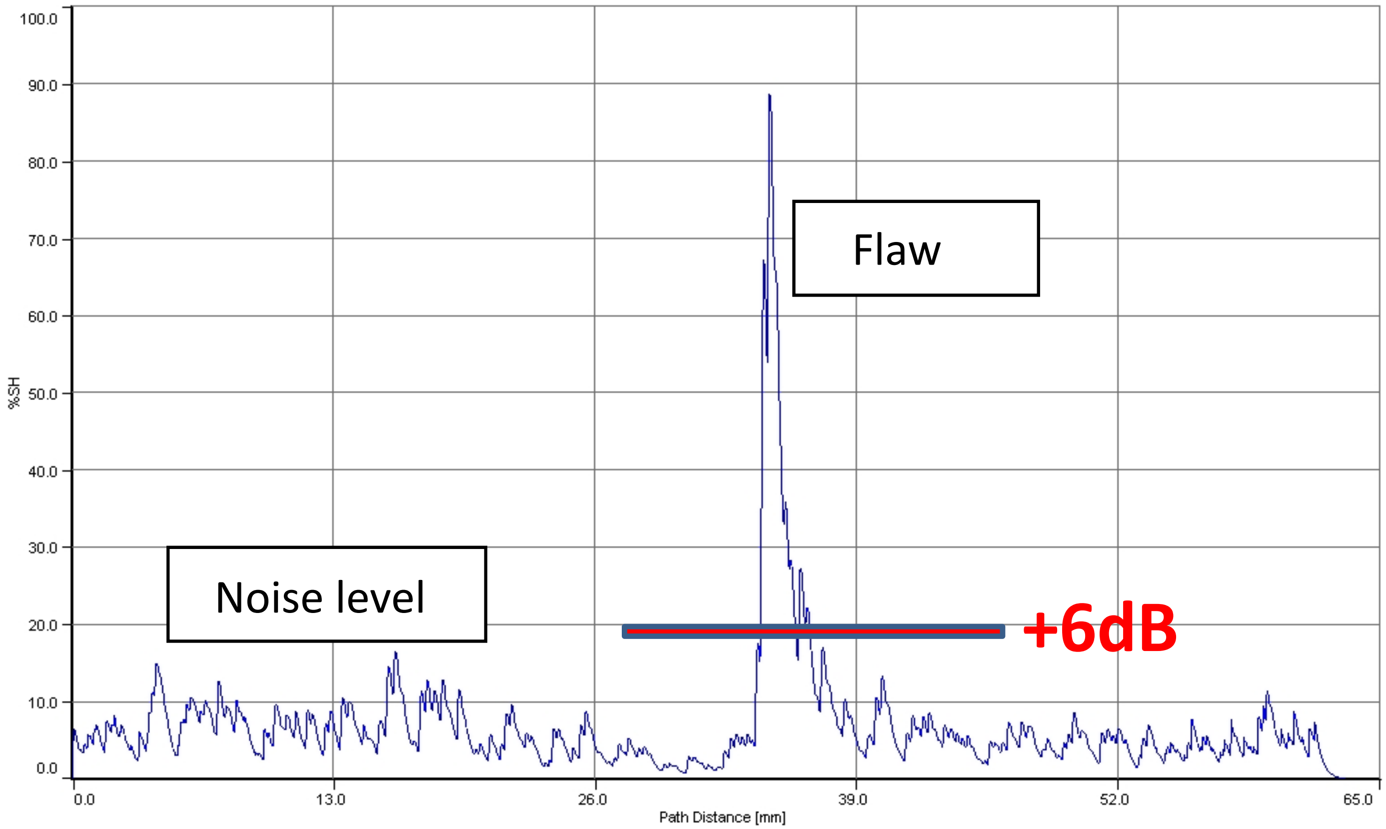
NDT&E Methods: UT Flaw Detection



"AVG" (Distance-Gain-Size) Diagram

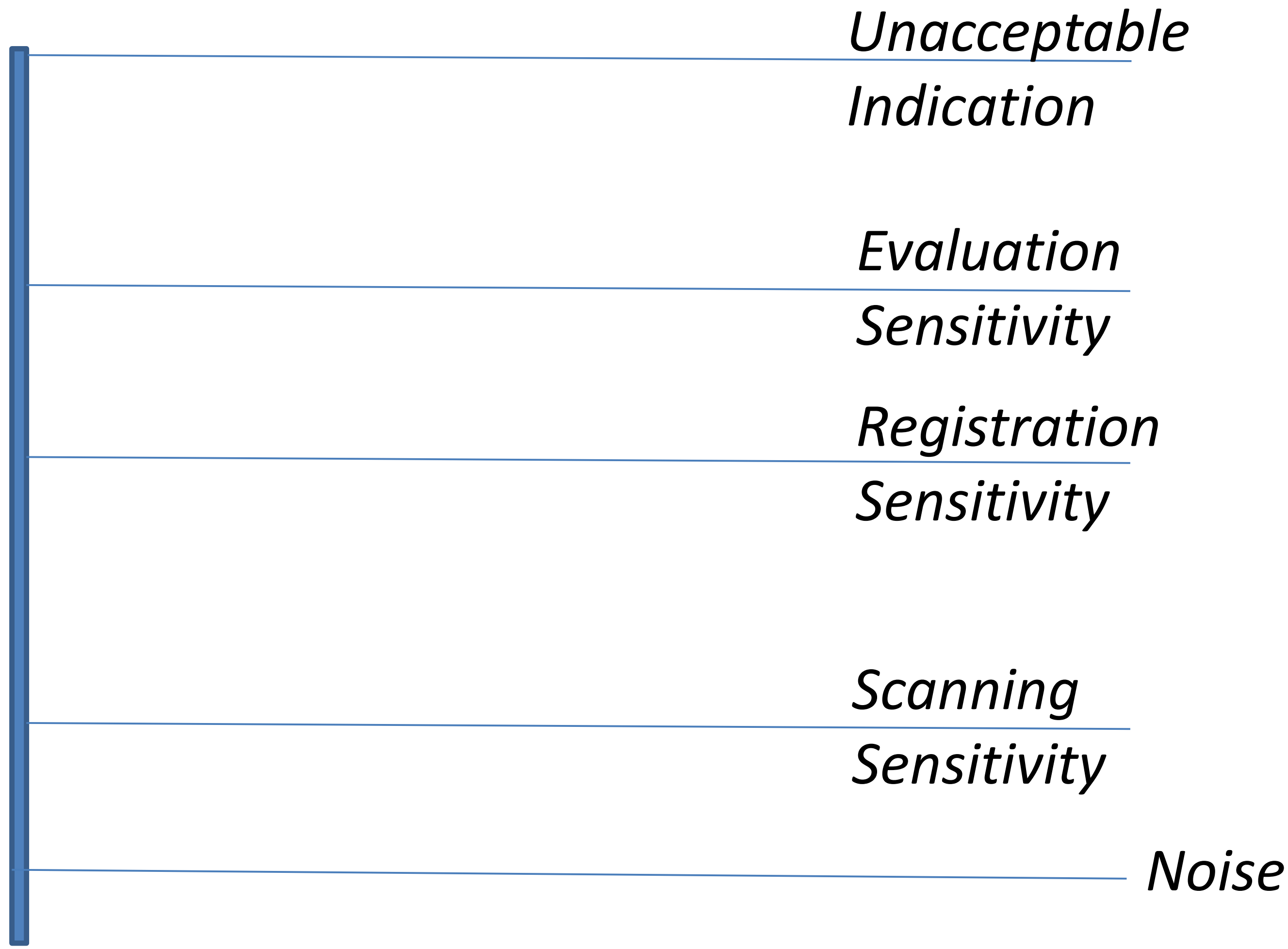
Back-Wall can serve as reference; valid for rather resonant transducers only

NDT&E Methods: UT Flaw Detection & Evaluation



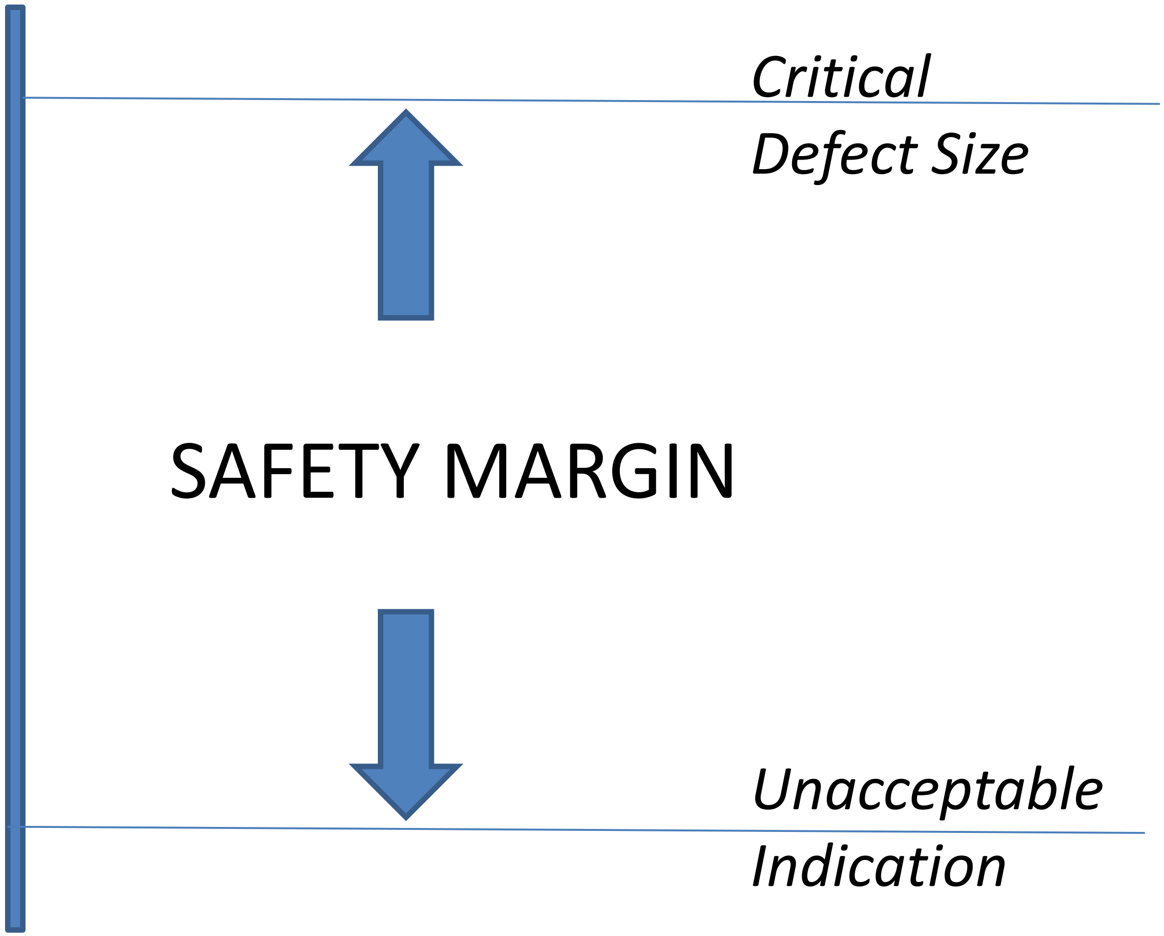
Required Minimal Sensitivity for Flaw Signal Detection

NDT&E Methods: UT Flaw Detection & Evaluation



Amplitude Criteria for Flaw Detection, Recording, and Evaluation

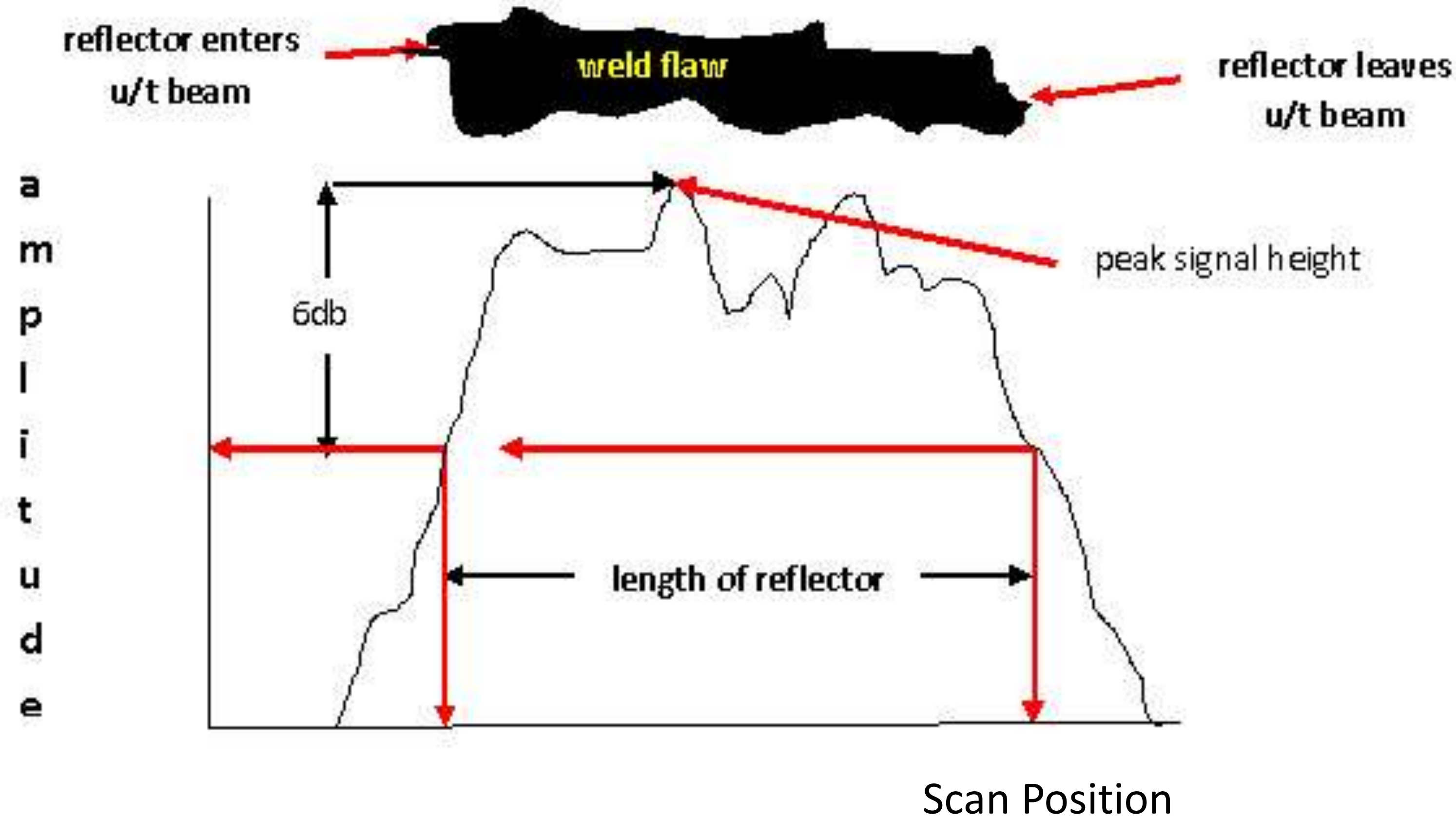
NDT&E Methods: UT Flaw Detection & Evaluation



Amplitude Criteria for Flaw Detection, Recording, and Evaluation

NDT&E Methods: UT Flaw Registration

6 dB Drop Method



Length of Detected Discontinuity

NDT&E Methods: UT Flaw Detection

Probability of Detection

INSPECTION PROCEDURE

- Material
- Geometry
- Access
- Safety Classification
- Flaw Catalog
- Flaw Classes

- Inspection Volume
- Frequency of Inspection
- Manual/Automated (Human Factor)
- Transducers
- Sensitivity Settings

Required Minimal Sensitivity for Flaw Signal Detection

NDT&E Methods: UT Flaw Evaluation

The detected reflector is characterized by

- ***Its maximum amplitude (in reference to calibration reflector)***
- ***Its length***
- ***Its position***
- ***Its systematic***

Required Minimal Sensitivity for Flaw Signal Detection

Flaw Evaluation & Sizing demands

- ***Case specific procedure***
- ***Expert skills***
- ***3rd party evaluation***

Required Minimal Sensitivity for Flaw Signal Detection

NDT&E Methods: UT Flaw Detection & Evaluation

Sometimes a Problem of Engineering Ethics:

EVALUATION

Risk Assessment

Are you sure about your evaluation?
Often, there is no method on hand that gives you a perfect finding

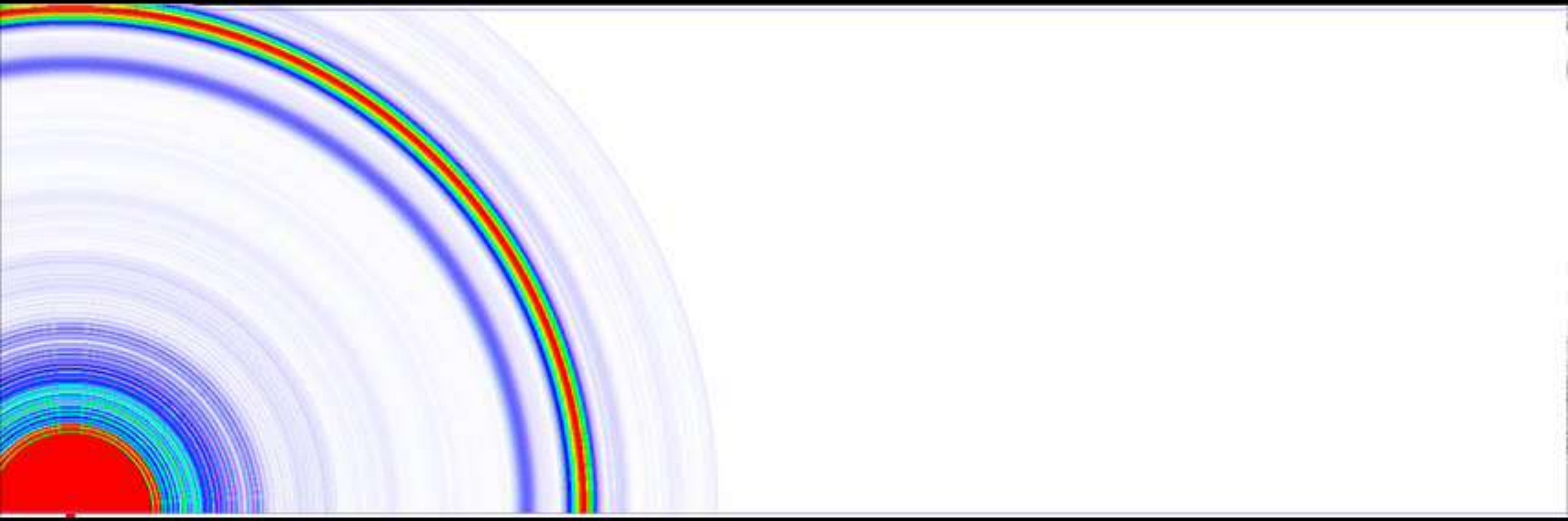
Are you aware of the related risks of failure?

Are there already similar findings and damages?

Use all available information

Do not protect business, care for safety!!!!

A Virtual SAFT Experiment

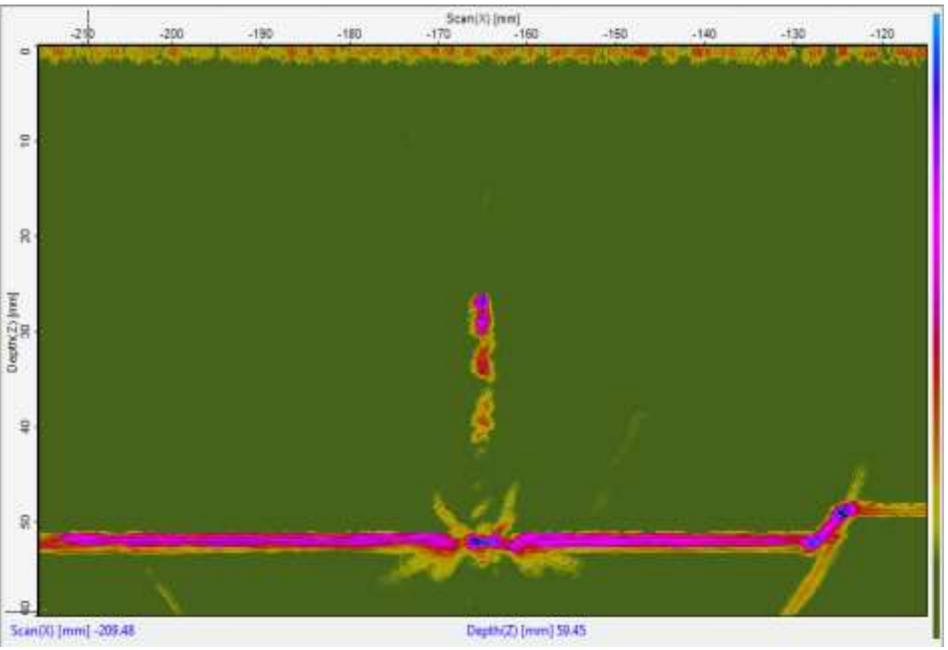


NDT&E Methods: UT Flaw Detection & Evaluation

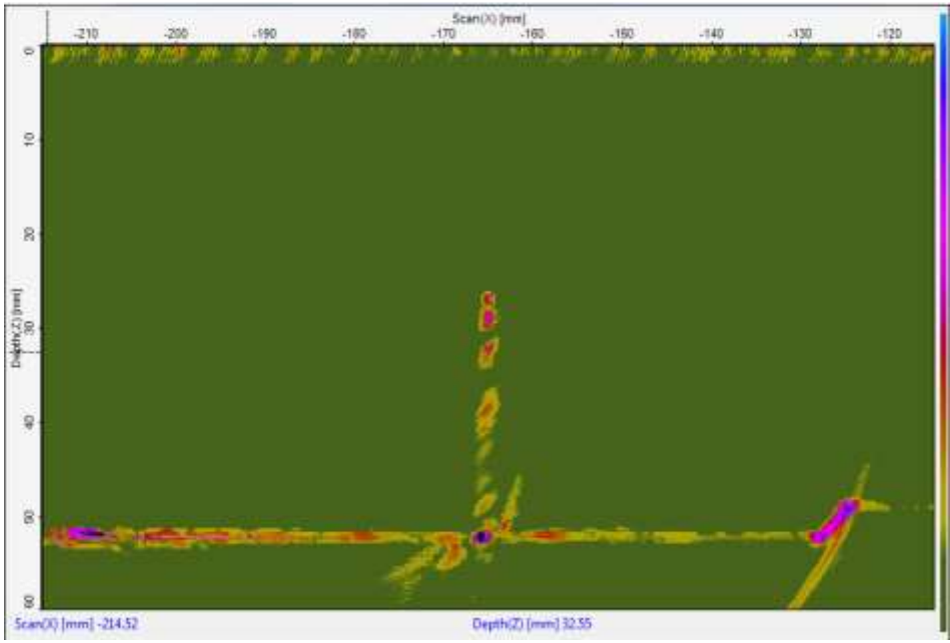
Sparse Migration Array Experiment

8 Elements with skips of 4 wavelengths

NDT&E Methods: UT Flaw Detection & Evaluation



a) Complete Compound Scan



b) Limited Compound Scan

(Transducer: Olympus 60L5; 4 Transmit Elements; L-Mode)

Crack Imaging

Literature

1.