Advanced Ultrasonic Alternatives for Inspecting Coarse Grained Stainless Steel Components

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ULTRASONIC INSPECTION

UT has become a very effective inspection tool for a variety of things including:

- ✓ Thickness Points (TMLs) for establishing corrosion rates.
- ✓ Code Inspection for New Weld Integrity (In-Lieu of Radiography)
- ✓ In-Service Crack Sizing and Detection
- ✓ Non-Intrusive Alternatives
- ✓ Supporting RBI Needs or Fitness-for-Service (FFS) evaluations

Bottom Line:

Ultrasonics are an integral part of our programs. These inspections are being used to allow for longer run times, extended life, and fewer internal inspections.

ULTRASONIC TECHNIQUES

Available Tools in the box vary by application:

- ✓ Standard 0 degree
- ✓ Shear Wave
- ✓ High Angle Longitudinal Waves
- ✓ Time of Flight Diffraction
- ✓ Phased Array
  - ✓ Sectorial
  - ✓ Linear
  - ✓ Dual Matrix
  - ✓ TFM
  - ✓ Full Matrix Capture
  - ✓ Adaptive Focusing

All great advancements and tools to help us verify integrity, reduce risk, and increase profitability.

ULTRASONIC VARIABLES

Variables that can affect the effectiveness of an inspection include:

- ✓ Velocity
- ✓ Material Type
- ✓ Age
- ✓ Thickness
- ✓ Heat Treatment
- ✓ Temperature
- ✓ Acoustic Impedance
- ✓ Wave Modes
- ✓ Plate Differences
- ✓ Grain Structure

Some of these are controllable and verifiable, but which ones?
And is this being done on all inspections?

CODE

Some variables that the code addresses are:

- ✓ Calibration Block Material
  - ✓ Acoustically similar
  - ✓ Same product form, and/or equivalent P Number
- ✓ Heat Treatment
  - ✓ Minimum tempering by material spec for type, grade, and PWHT if there are welds involved
- ✓ Surface Finish
  - ✓ Shall be representative
- ✓ Austenitic Materials
  - ✓ Those that exhibit coarse grained or directionally-orientated grain structure that can cause reflection and refraction at grain boundaries as well as velocity changes within the grains……

STAINLESS STEEL APPLICATION

Customer request inspection in-service cracking of typical 304SS Material.
Typical approach would be:

- ✓ Calibration Block Material
  - ✓ Acoustically similar
  - ✓ Range of Diameters

- ✓ Calibration Flaw Sizes
  - ✓ EDM Notches, and SDH’s
- ✓ Reference Blocks
  - ✓ 304 SS Naviships/IIW

- ✓ Probe/Frequency Selections
- ✓ Procedural Development/Scan Plans
- ✓ IF coarse grained – weld mockups according to T150

STAINLESS STEEL APPLICATION

And as a last resort…….

- ✓ Request "cut out sample" of problem areas

VERIFICATION

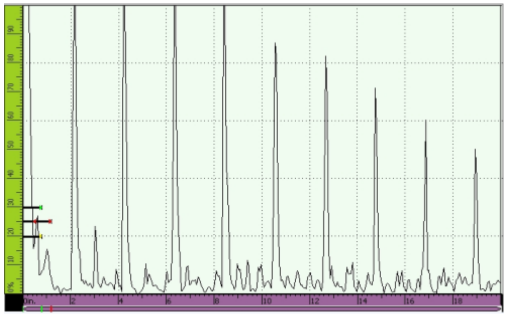
Sample piece was provided with damage.

Inspection began with the normal process

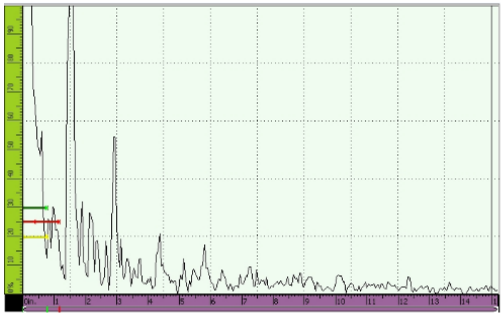
Longitudinal (0 degree) Wave

- ✓ Lower Frequency,
- ✓ Larger Aperture (diameter)

Sampling of similar thickness/material calibration block revealed:



Actual piece revealed this:



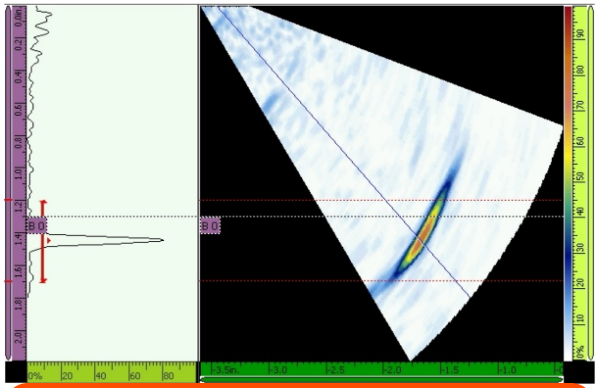
VERIFICATION

Sample piece was provided with damage.
Inspection began with the normal process.

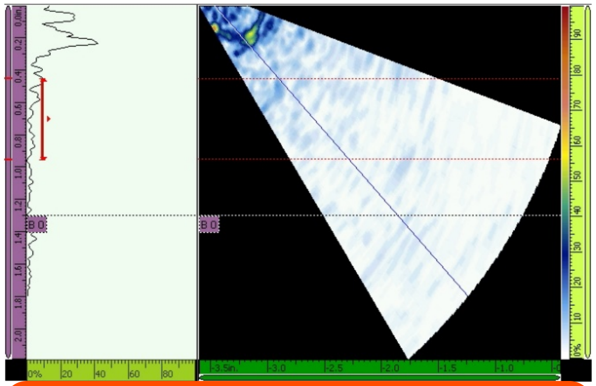
Shear Wave

- ✓ Lower Frequency,
- ✓ Larger Aperture (diameter)

Quick Screening with Shear wave results revealed the following:



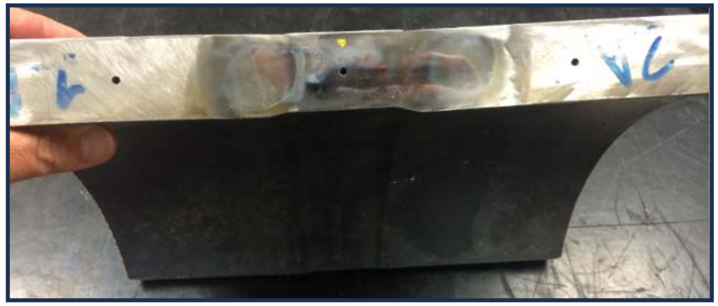
Reflection from Corner of Calibration block



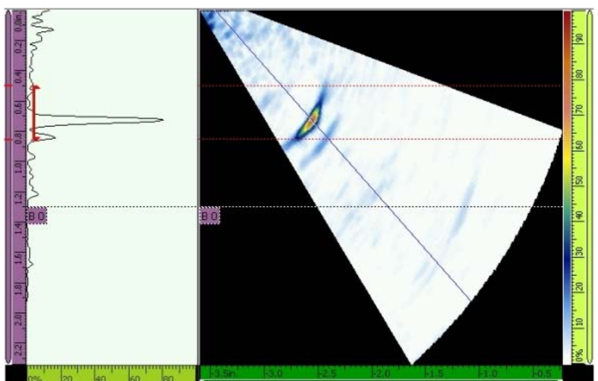
Reflection from Corner of Sample

VERIFICATION

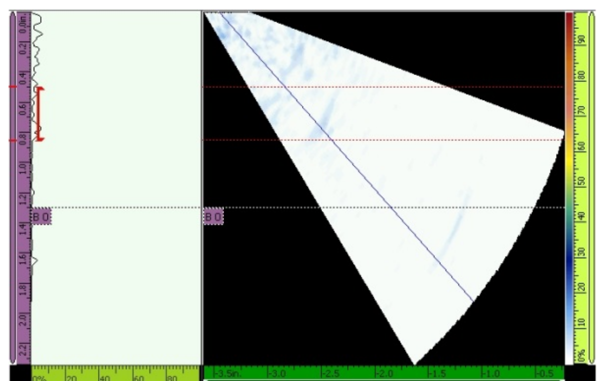
Taking one step further, SDHs were introduced into the sample piece.



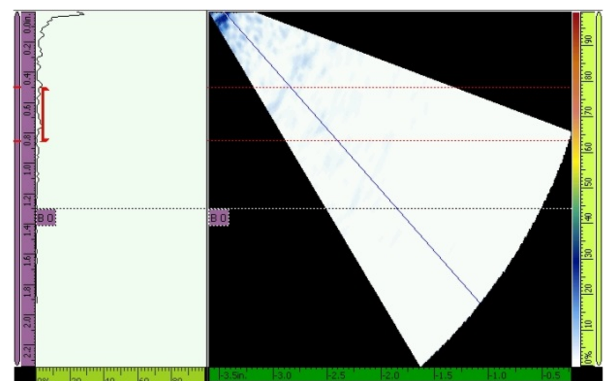
Quick Screening of the holes with Shearwave revealed the following:



Reflection from SDH
Calibration block



Reflection from SDH
Base material (Sample)



Reflection from SDH
In weld (Sample)

GRAIN SIZE DISCREPANCY

Typical 304SS Grain Size

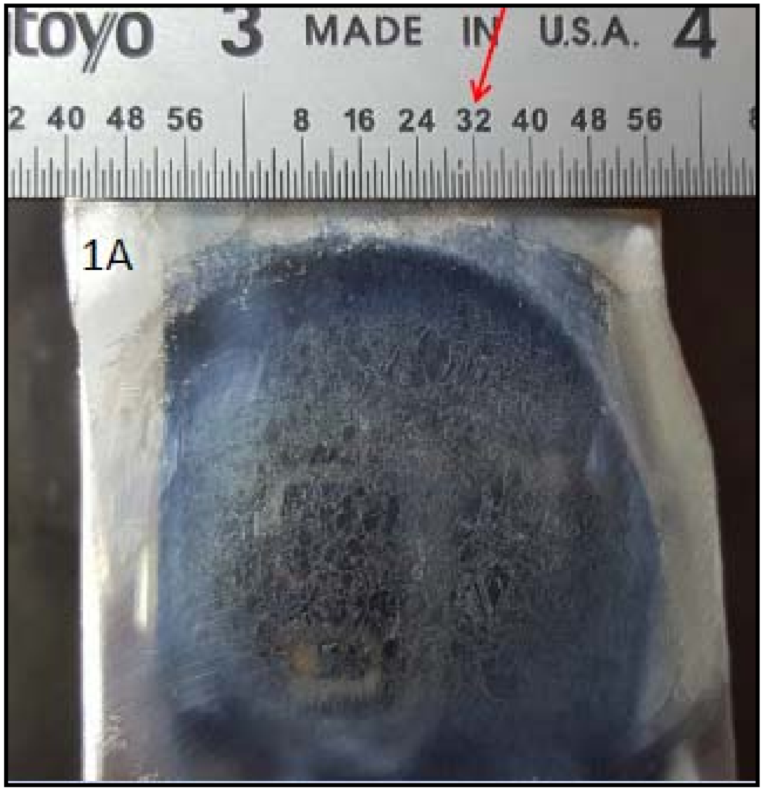
Typical 304SS Grain Size

Microstructural Analysis revealed that grain sizes were off the microscopic grain chart in ASTM E112.

It is believed that this was due to extreme temperatures (2000 -2200 F°).

GRAIN SIZE VISIBLE

Grain Size is actually visible to the NAKED EYE!



SELECTION

- ✓ Due to previous steps, it was clear that a different selection of probes was necessary.
- ✓ Shear waves were not offering a good solution to the problem.
- ✓ Next step was to evaluate DMA (Dual Matrix Array) probes with varying frequencies/sizes to compare effectiveness and come up with an inspection plan. These probes operate by producing longitudinal waves, but in a T/R Mode.

Benefits of these types probes are typically:

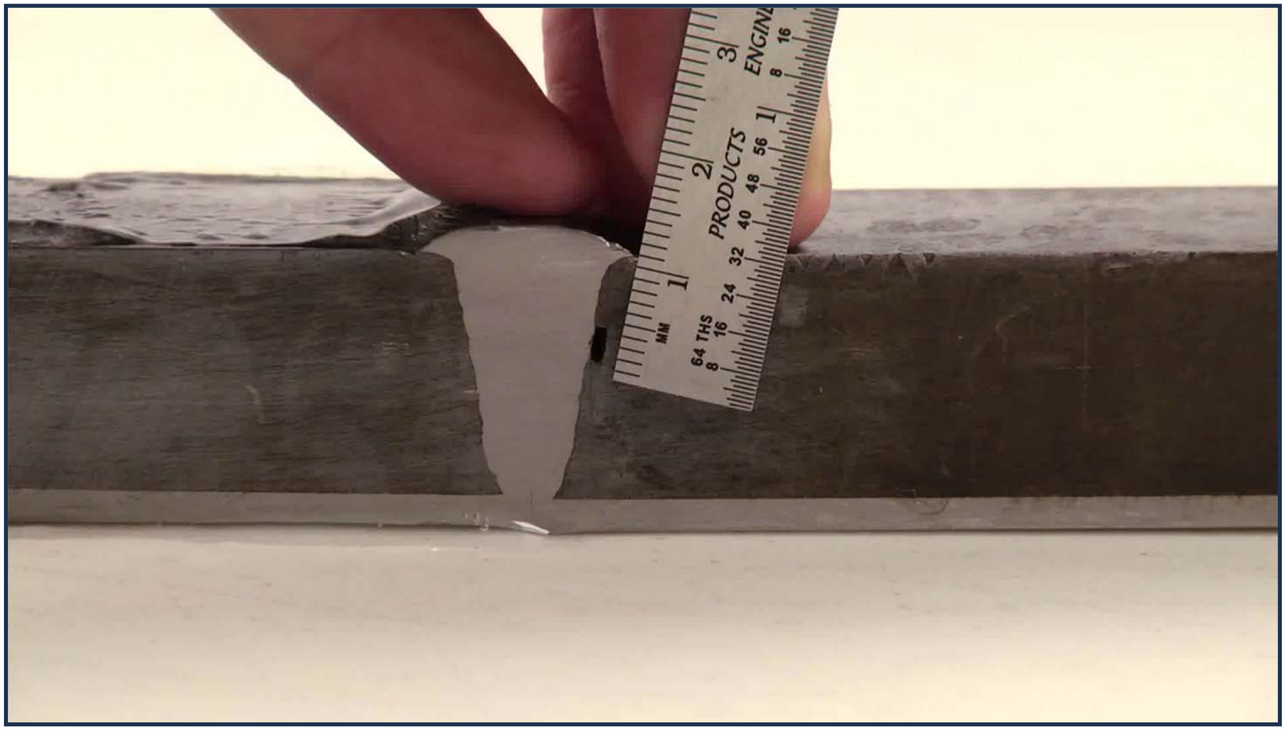
- ✓ Ability to penetrate coarse grain structures
- ✓ Higher signal to noise ratio
- ✓ Near Surface Resolution

Potential Drawbacks:

- ✓ 1st Leg information only
- ✓ Mode converted signals can be difficult to interpret
- ✓ Oversizing/Distortion due to low frequency and large aperture size.

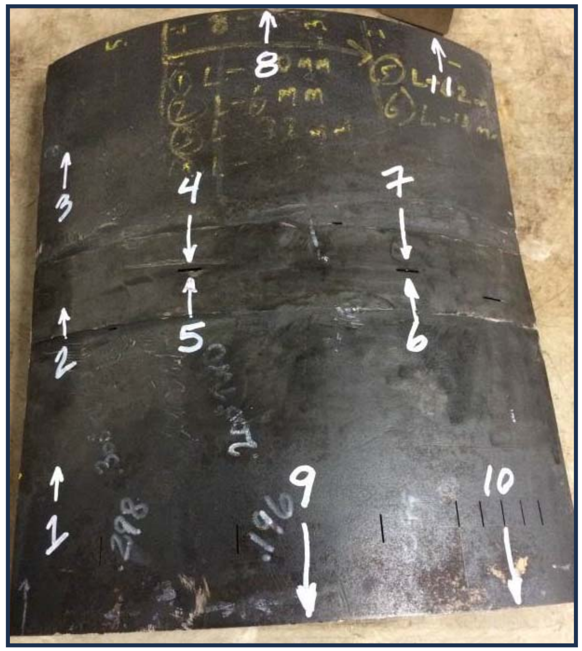
DIFFERENCE BETWEEN

DMA's versus Shear wave on large coarse grain materials

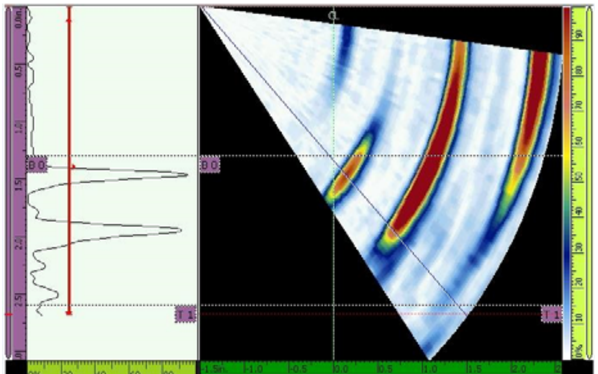


SENSITIVITY COMPARISON IMAGES

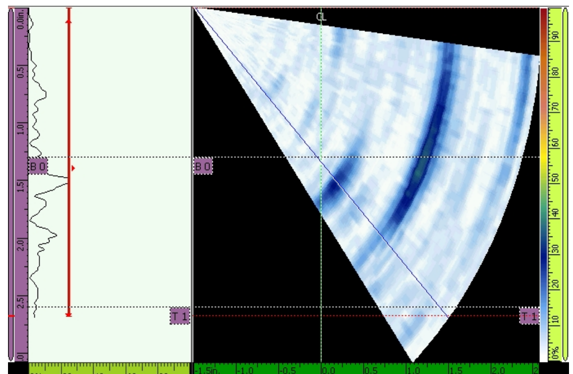
To better understand probe performance on different sections of the block, we gathered data and comparison of each, some from corners, SDHs, and OD notches.



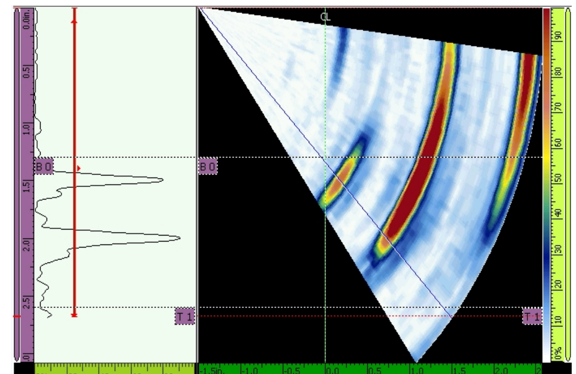
SENSITIVITY COMPARISON IMAGES (CORNER)



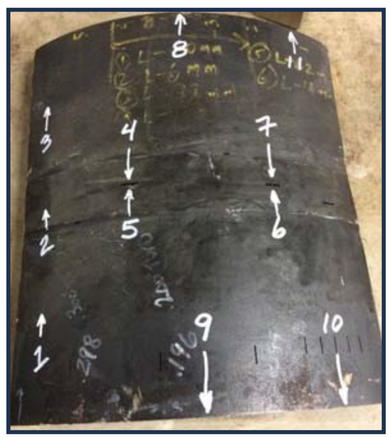
DMA Position 10



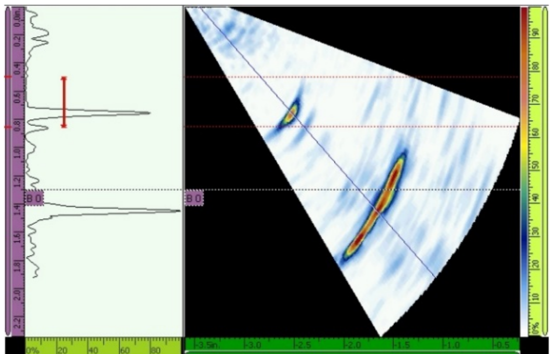
DMA Position 8



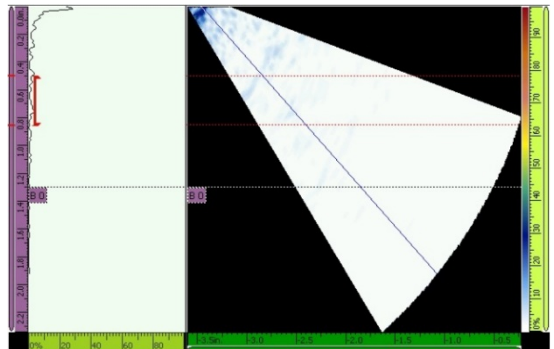
DMA Position 11



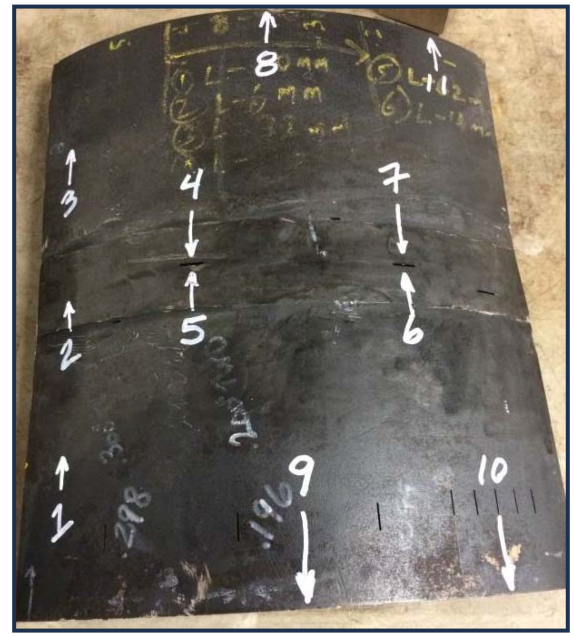
SENSITIVITY COMPARISON IMAGES (SDH)

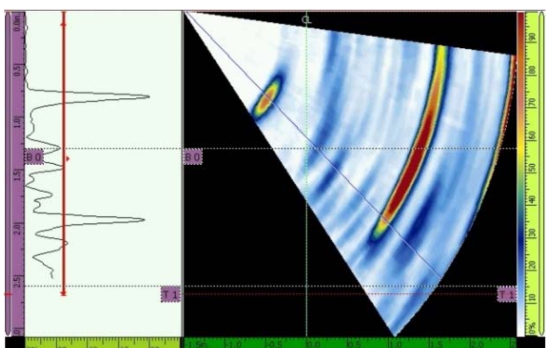


Shear Ref

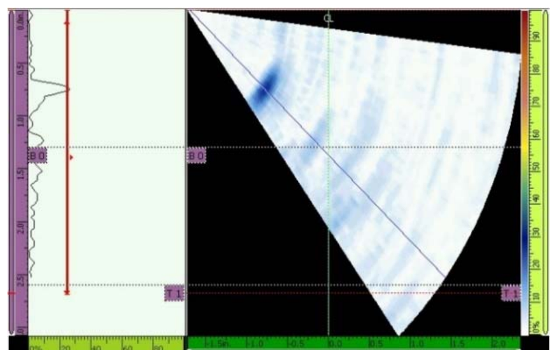


Position 2



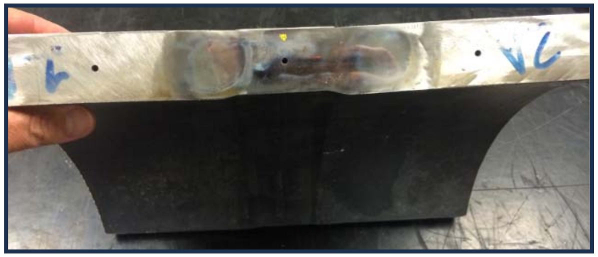


DMA Ref



Position 2

RESULTS



Reference sample=2" T 304 SS, Field Sample=1.5" T 304 SS	Shear wave 2.25Mhz x 1/2" Dia	DMA-1 1.5Mhz x 0.75" x .050"	DMA-2 4Mhz x 0.625" x 0.238"	Pulse Echo PA 2Mhz x 0.75" x 0.80"	0 Degree base material 2Mhz x 1.0" Dia
Commercially produced Reference Weld Sample, 4% Notches/ 0.125"SDH	0	0	0	0	0
Sample Side A SDH (BM)	-5.4 db	-5.9 db	-7.4 db	-4.3 db	-15 db
Sample Side B SDH (BM)	-23 db	-13.3 db	-16.2 db	-20.8 db	-20 db
Weld SDH	-21 db	-9.7 db	-12 db	-18.7 db	-
Sample Corner A (BM)	-11 db	-3.8 db	-6.4 db	-4.8 db	-
Sample Corner B (BM)	-39 db	-14.5 db	-17.7 db	-24.8 db	-

POTENTIAL OUTCOME

We need to open up our thought process and ask ourselves:

- ✓ Have similar inspections been conducted, in which nothing was found?
  - ✓ How do we ensure that nothing means nothing?

- ✓ Have all the proper processes been followed to ensure we didn’t mistake a good inspection for a “bad” one?

TAKEAWAYS

- ✓ Inspection results might not reflect reality
- ✓ Expectations on time to complete inspections need to be understood better
  - ✓ Focus on the result, rather then a result
  - ✓ Don’t forget that results are feeding remaining life calculations or inspection intervals.
- ✓ There are ways to validate materials to raise level of awareness including:
  - ✓ Attenuation
  - ✓ Graininess
  - ✓ Beam Redirection
  - ✓ Velocities

Thank You!

Questions or Comments?