Performance Demonstration Update – New Phased Array Procedures

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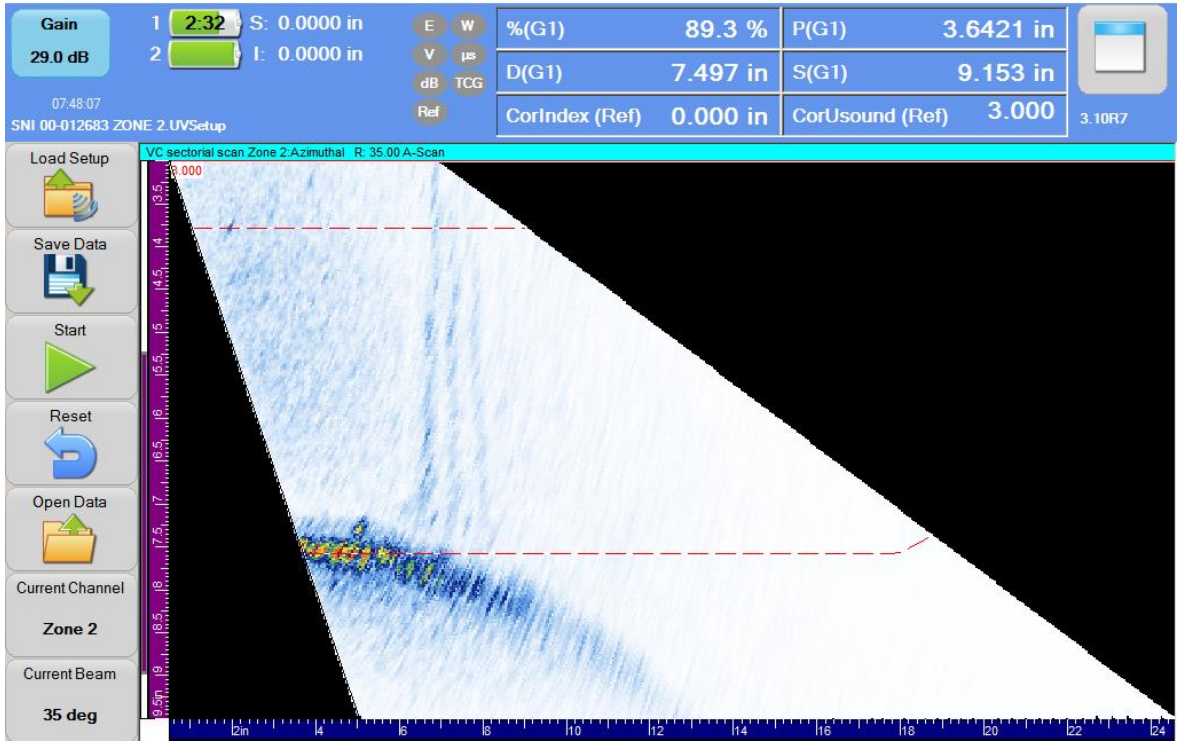
Use of New PDI-UT-14 Manual Phased Array UT Procedure for RPV Welds

PDI-UT-14 Manual PA RPV Procedure – Recent OE

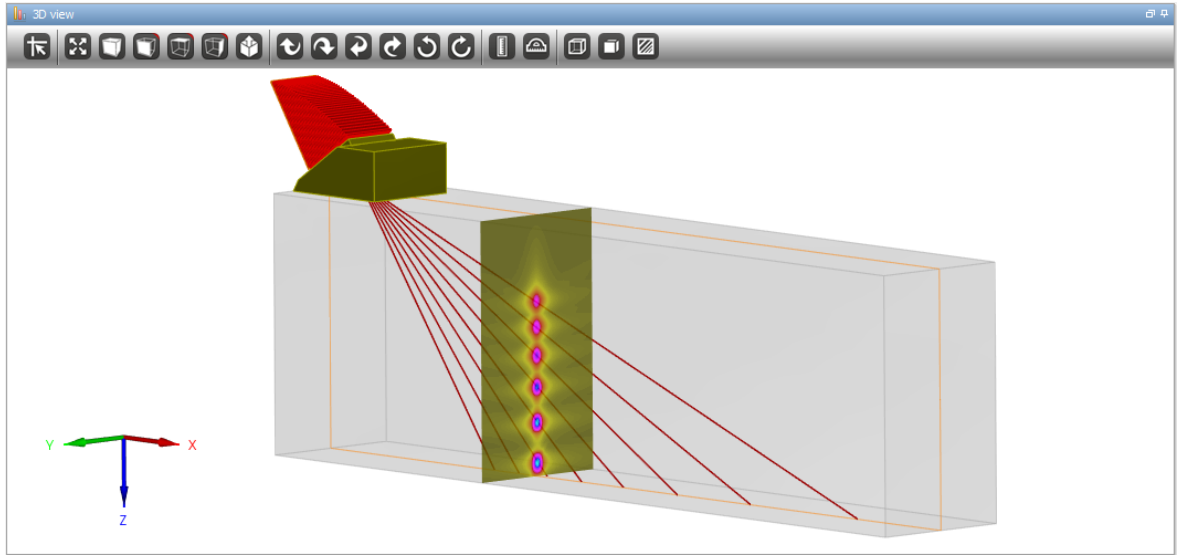
- Stacked indications detected during the PDI-UT-6 conventional flaw detection scans of a nozzle-to-shell RPV weld at a BWR
- Separating indications from one another and the inside surface was not possible when using the PDI-UT-7 conventional UT sizing scans were challenged
- Probes and wedges for the new manual phased array PDI-UT-14 examination procedure for detection and sizing of flaws within nuclear pressure vessel welds were sent to the site
  - Onsite examiners had qualified to this procedure just a couple of weeks prior to the refueling outage
- Phased array UT scans revealed a large excavation weld repair area containing embedded weld fabrication reflectors along the fusion line
  - -6db focal spots are ~24% to ~40% of the PDI-UT-6 detection probe focal spot
  - -6dB focal spots are ~21% to ~35% of the PDI-UT-7 sizing probe focal spot

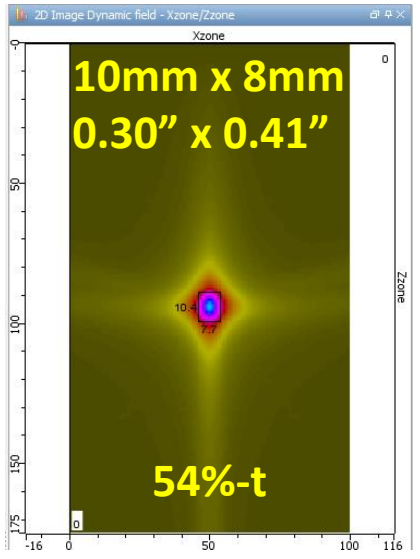
Manual phased array examination of the Midland Unit #2 reactor vessel closure head–to–flange weld at Framatome

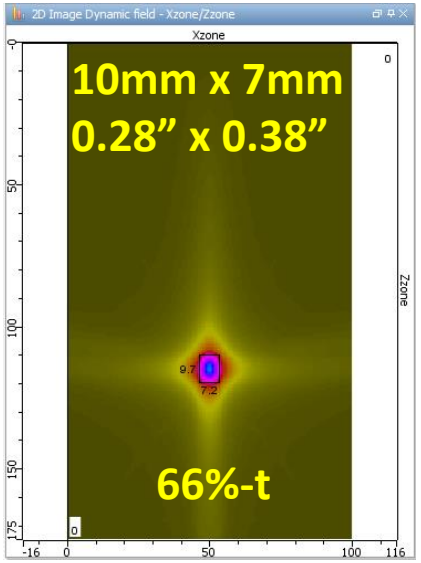


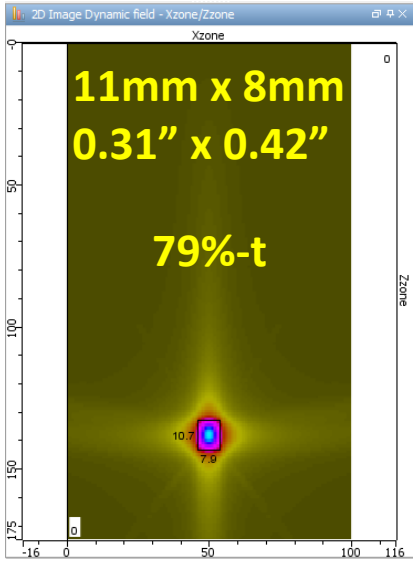
Height Versus Length Focal Spots (New PDI-UT-14)

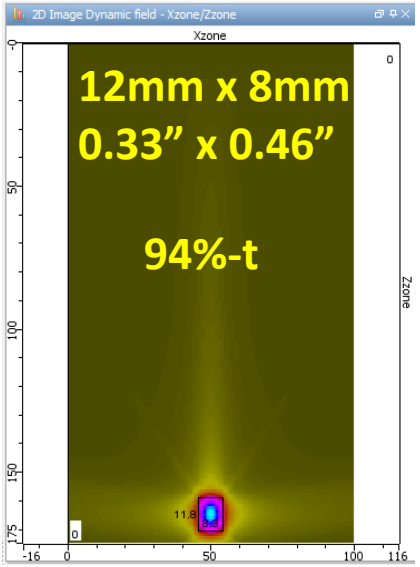
- New manual phased array procedure for detection, length sizing, and through-wall sizing in nuclear pressure vessels
  - Focal spots essentially the same for the inner 50%-t
    - RPV thickness within focal range of search unit
  - 94%-t focal spot still provides separation from inside surface





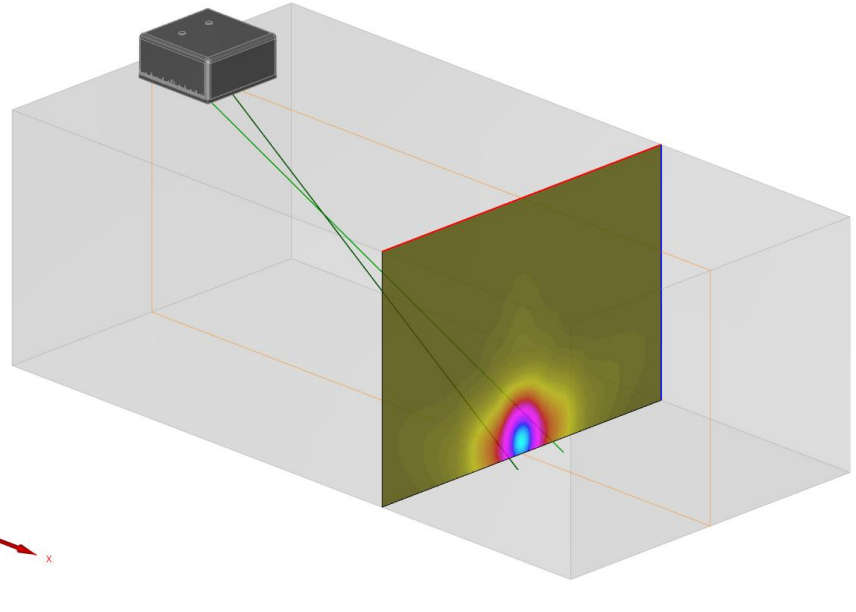


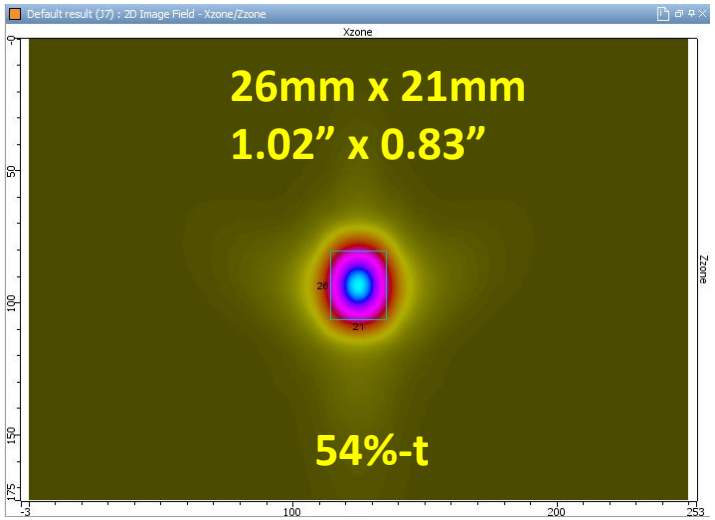


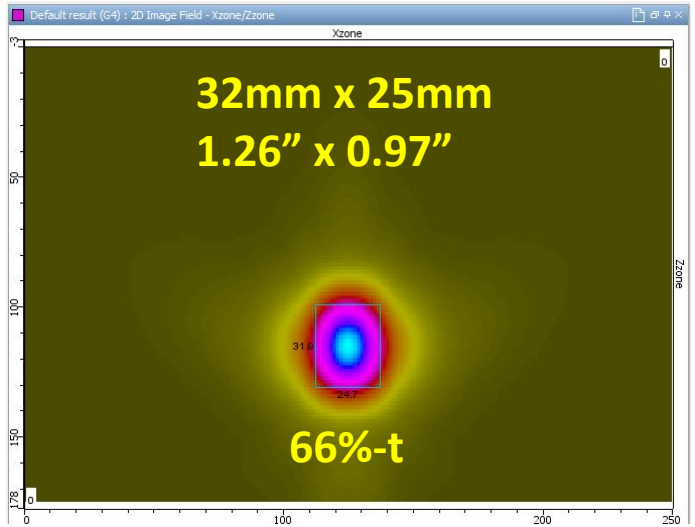


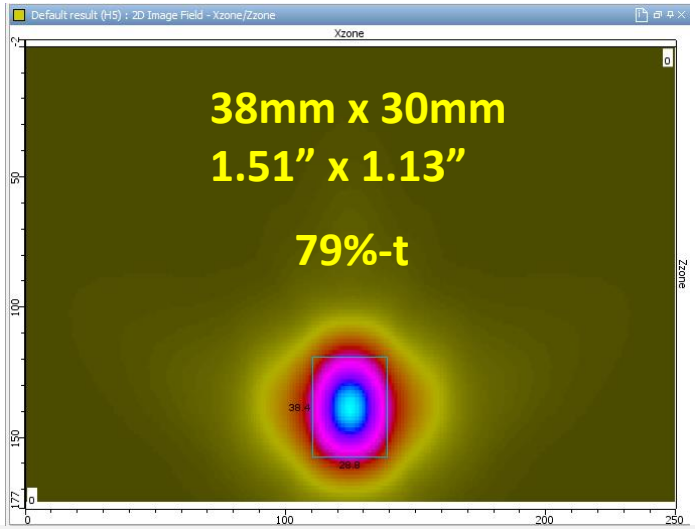
Height Versus Length Focal Spots (Old PDI-UT-6)

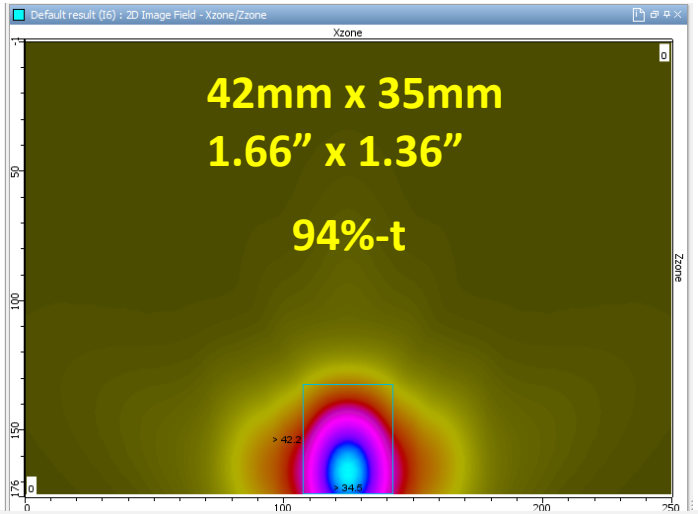
- Previous conventional UT procedure for flaw detection in RPV welds
  - Focal spots increase in size as RPV thickness is beyond focal range of search unit





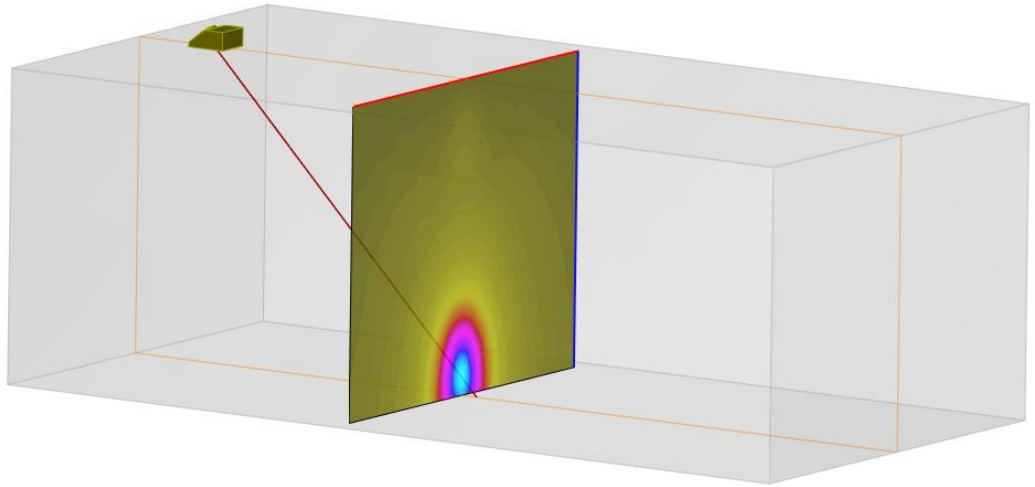


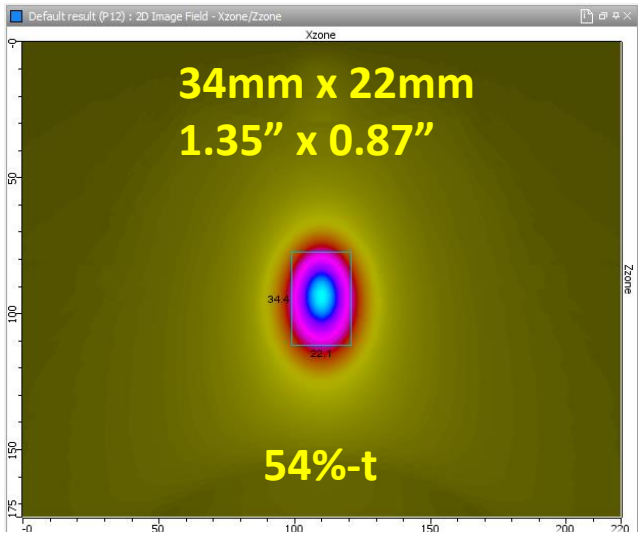


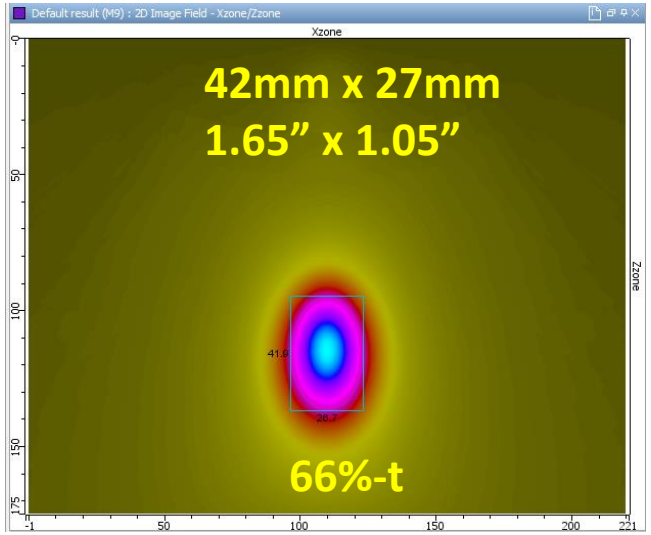


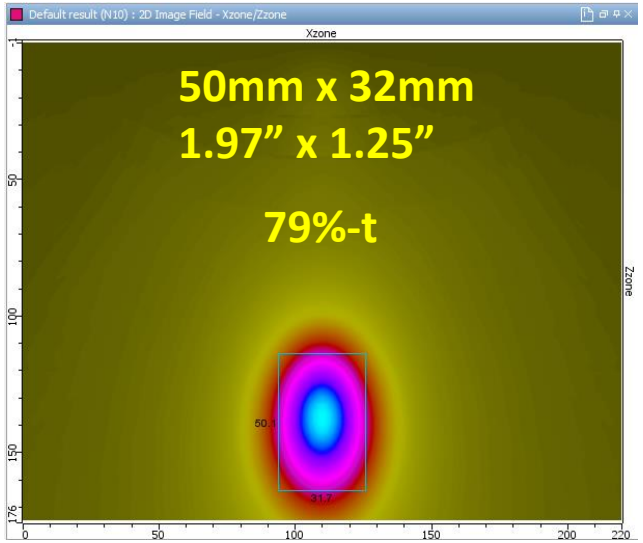
Height Versus Length Focal Spots (Old PDI-UT-7)

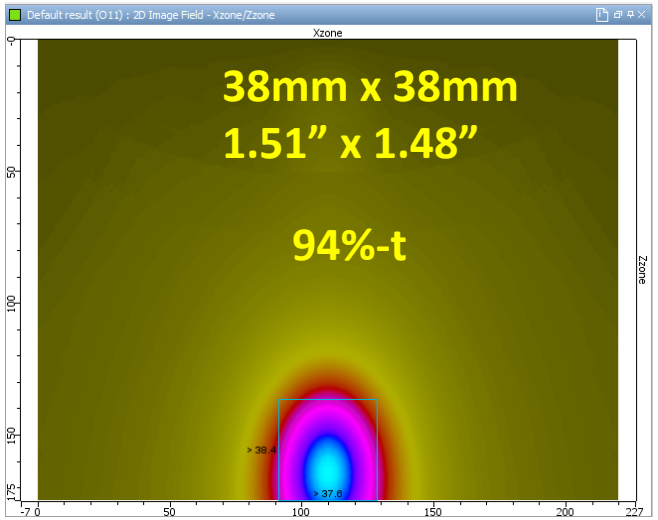
- Previous conventional UT procedure for flaw length sizing and depth sizing in RPV welds
  - Focal spots increase in size as RPV thickness is beyond focal range of search unit









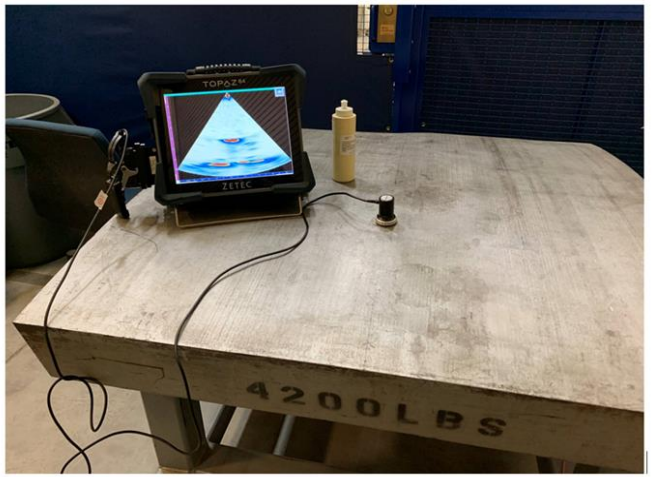


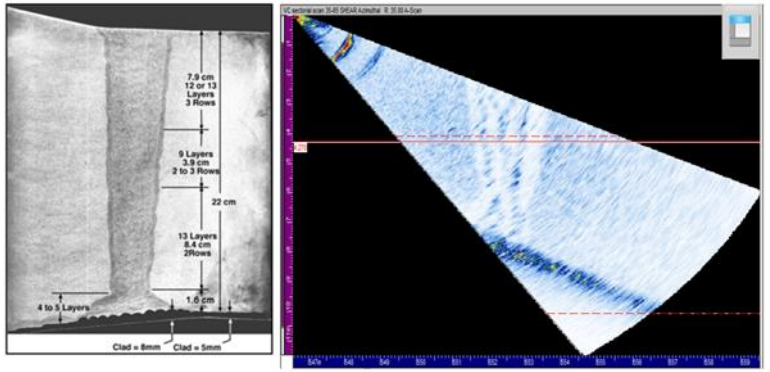
Current Status of PDI-UT-14

- Inspection vendors interested in personnel qualifications using new RPV remains
- Procedure has been used with great results for welds in which inspection challenges are present
  - Procedure has been used successfully when fabrication flaws are present
- Procedure offers a wider range of examination angles for claiming inspection coverage
  - Reduces scan time
  - Reduces the amount of RPV insulation which must be removed prior to UT
- Procedure eliminated amplitude-based threshold for recording indications
  - Indications are recorded if they image measurable through-wall extent
  - Reduces scan time spent on the RPV

Continuing Work on PDI-UT-14

- Procedure is available for Licensee and inspection vendor personnel qualifications
- Currently evaluating the included supplemental guidance for using a phased array 0° probe to provide additional response characterization
  - Current guidance based on UT beam simulations, now exercising this guidance on flawed RPV mockups
- 2025 BWRVIP NDE Project: Create guidance for interrogating regions surrounding internal RPV attachment welds for cracking which propagate into the low-alloy RPV material
  - Recently obtained canceled RPV sections containing welded attachments
- EPRI NDE Program Project: Expand UT Simulator to PDI-UT-14
  - Allows for examiner practice and/or training without hands-on time on actual specimens at EPRI





Update on New Manual Phased Array UT Procedure For the Examination of DM Welds

Background Information

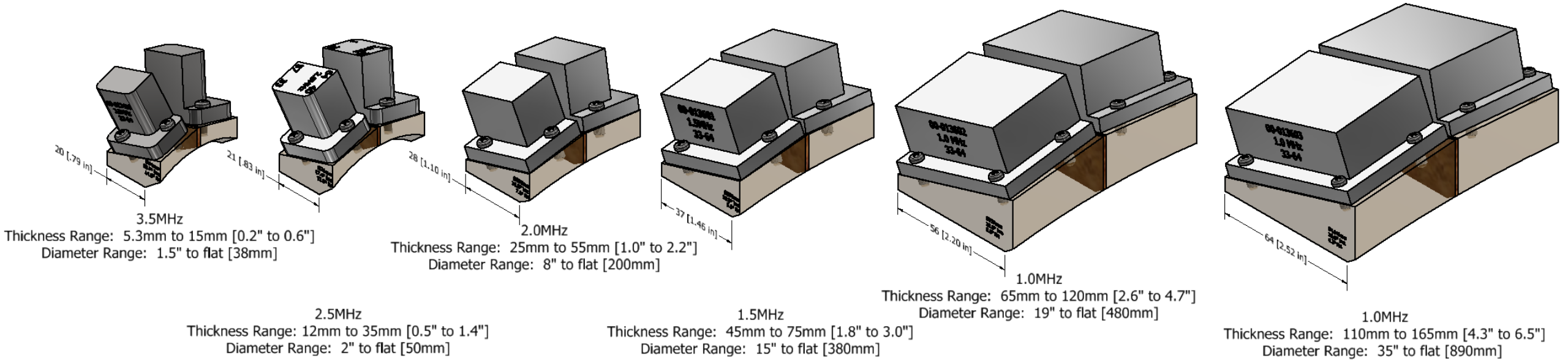
- The EPRI NDE Program is developing a new manual phased array procedure for the examination of DMWs
  - Will be an Appendix VIII-qualified “industry procedure” available to all EPRI NDE Program members
    - Qualified for detection, length sizing, and depth sizing
- Existing industry procedure is ~15 years old; 15 years of technology advancements and OE have identified areas for improvement
  - Areas seen needing improvement are:
    - Reduce the contact area of the wedge
    - Reduce time/dose spent performing exams
    - Use current technology to increase inspection coverage
    - Make it easier to use/deploy
  - The existing procedure will remain available for use, EPRI will likely cease all further development to instead focus on the new procedure

Improvements

- Several probe and wedge configurations
  - Probe size and configuration are now optimized for specific weld configurations to increase coverage and probe contact
  - Eliminate the need to perform separate scans using shear wave focal laws
- Probes and wedges optimized, designed, and ordered for a wide range of configurations
  - Thickness range: 0.2” to 6.5” [5.3mm to 165mm]
  - Diameter range: 1.5” to 52” [38mm to 1320mm]
  - Qualified equipment should cover nearly all DMW configurations across the fleet, and attempt to eliminate the need to design and qualify probe/wedge combinations for one-off configurations
- Probes contain captured Phillips® screws with metric threads
  - Captured screws so they stay in probe housing, no more hunting down tiny screws
  - Phillips® screws versus a socket head eliminates the need to find the correct Allen key
  - Metric threads make finding replacement inserts easier for non-U.S. users

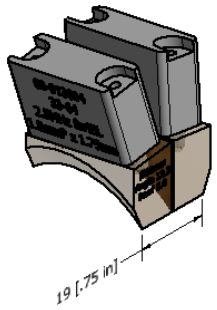
Axial Scan Probes

- Axial scan probes are short and wide
  - Array length/width ratio is optimized for sizing performance and help achieve greater inspection coverage
    - Shortest contact surface is across hoop-shrinkage
- Probe flange and fasteners are along side and front of array
  - Chamfer included on front of wedge to reduce contact area

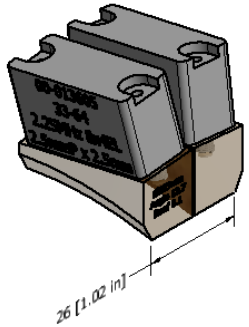


Circumferential Scan Probes

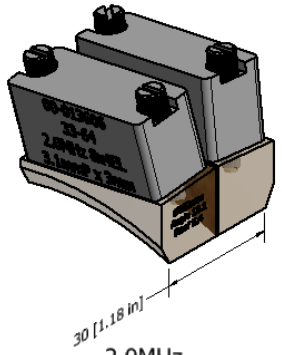
- Circumferential scan probes are long and narrow
  - Shortest distance across hoop-shrinkage to increase probe contact and maximalize inspection coverage when scanning up against obstructions, like nozzles
    - Arrays are one-half as wide as they are long
- Probe flanges and fasteners are along front and back of arrays, minimizing probe width as much as possible
- Wedges are chamfered along the sides to increase inspection coverage when scanning up against an obstruction



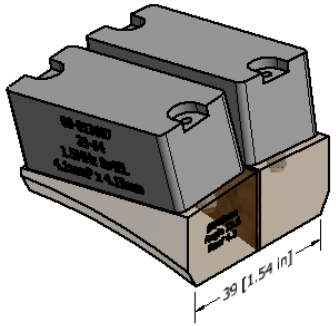
2.5MHz
Thickness Range: 5.3mm to 15mm [0.2" to 0.6"]
Diameter Range: 1.5" to flat [38mm]



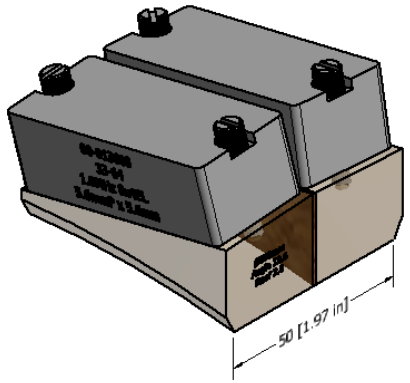
2.25MHz
Thickness Range: 12mm to 26mm [0.5" to 1.0"]
Diameter Range: 6.5" to flat [165mm]



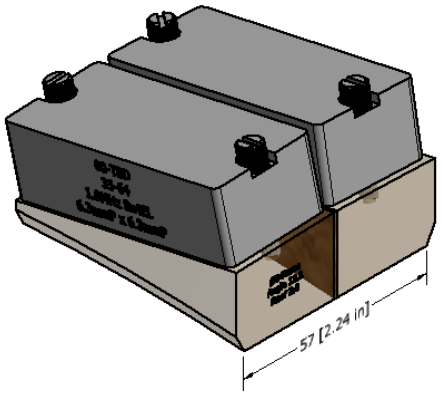
2.0MHz
Thickness Range: 12mm to 35mm [0.5" to 1.4"]
Diameter Range: 4.5" to flat [114mm]



1.5MHz
Thickness Range: 25mm to 55mm [1.0" to 2.2"]
Diameter Range: 4.5" to flat [114mm]



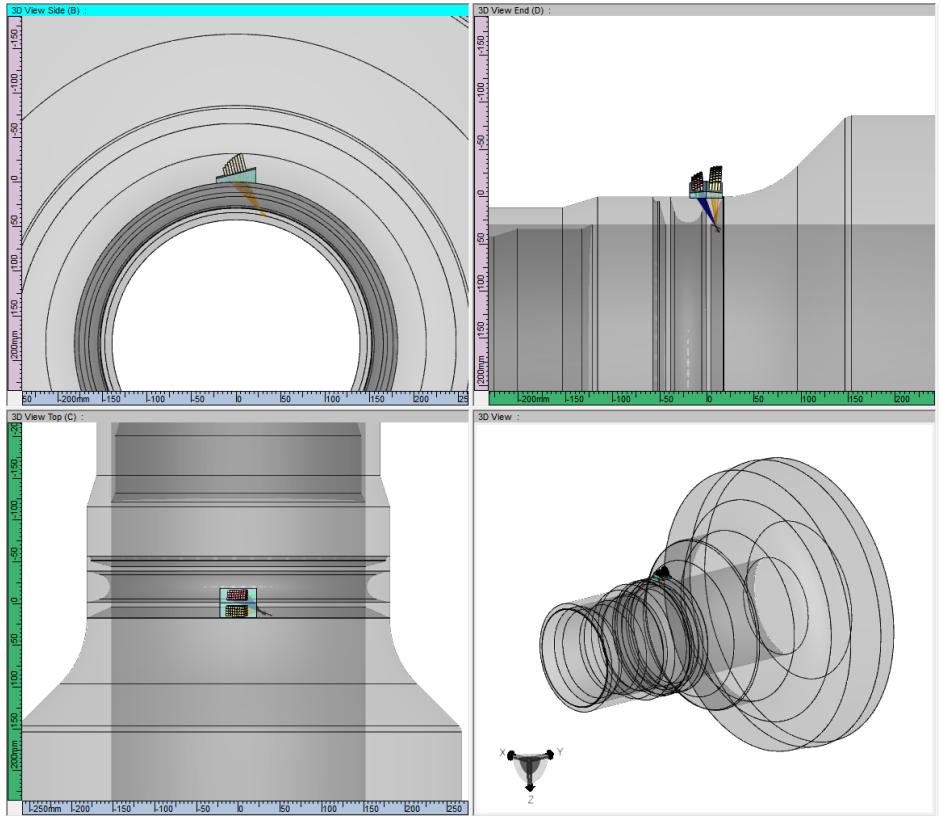
1.0MHz
Thickness Range: 45mm to 120mm [1.8" to 4.7"]
Diameter Range: 15" to flat [380mm]

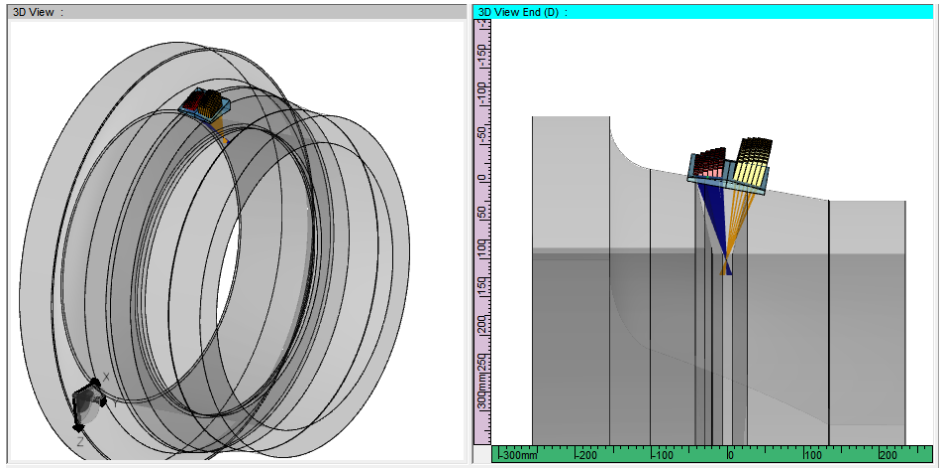


1.0MHz
Thickness Range: 110mm to 165mm [4.3" to 6.5"]
Diameter Range: 27" to flat [685mm]

Improvements

- Probes are 4x8 matrix arrays instead of 1D linear arrays
  - Allows for electronic adjustment of roof angle
    - One wedge per contour with electronic adjustment for thickness
    - Allows for electronic skewing up to ~20° to account for scanning on tapers or increasing inspection coverage
- The need to perform shear wave scans has been eliminated
  - This will reduce time spent at the nozzle





Improvements

- Current procedure draft no longer requires “cal check” after loading new examination set-up
  - If material noise and inside surface responses image on the sector scan as expected, then no need for calibration check
    - This reduces time spent at the nozzle and enhances safety by eliminating the need to bring heavy calibration blocks to each nozzle
- Eliminated amplitude-based recording of indications
  - No longer use a standard reference reflector in ASME Section V basic calibration blocks
  - Procedure images through-wall extent of flaws, so recording threshold may include only indications which contain measurable through-wall extent; there is minimal benefit to manually plot indications after the phased array UT examination
    - This reduces time spent at the nozzle

Current Status

- Qualifying multiple instruments
  - Olympus OmniScan X3 and Zetec Topaz 32 instruments are currently being qualified
- Sensor Networks probes and wedges currently being qualified
  - Alternative search units and wedges from Evident and other manufacturers under consideration
- Qualification sessions are underway to assist with procedure qualification
  - EPRI offering inspection vendors and utilities limited opportunities to no-cost qualification sessions
    - GEH sent 3 examiners, all 3 passed detection and sizing on the first attempt
  - Qualification requirements have been met for detection, length sizing, and depth sizing

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