Waste Package Closure System NDE – Phase Array UT

Tim McJunkin
Idaho National Laboratory
Industrial Technologies
Timothy.McJunkin@inl.gov
208 526 7895

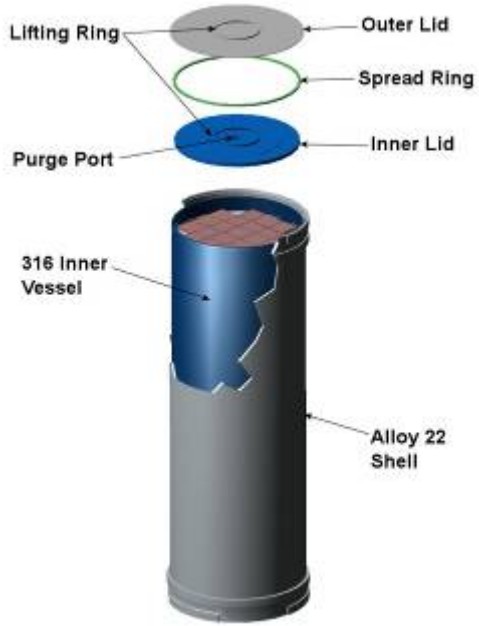
Dennis Kunerth
Michael Clark
Colleen Shelton-Davis

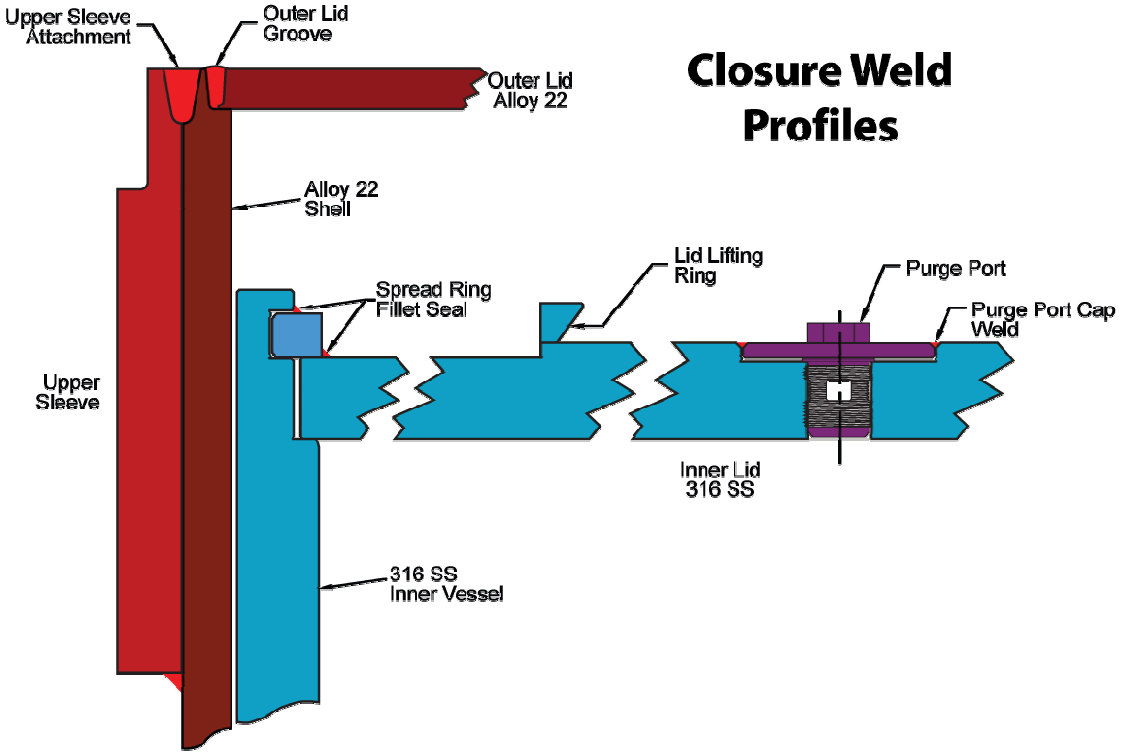
Idaho National Laboratory

Idaho National Laboratory

Completed Demonstration System 3/2009

Yucca Mountain Waste Package Design





Project Description

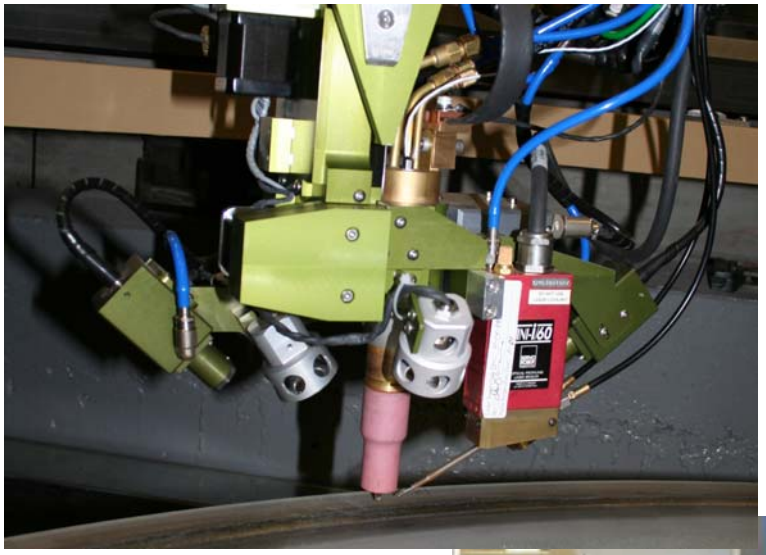
- Idaho National Laboratory has developed a full scale automated, remote, closure system for spent nuclear fuel and high level waste containers.
- Work was initially for the standard canister for the National Spent Nuclear Fuel program, which will contain Department of Energy owned spent nuclear fuel.
- The technology was expanded to include closure of the Yucca Mountain repository waste package design. A demonstration with a full diameter waste package mockup was successfully completed in March of this year.

Closure Systems

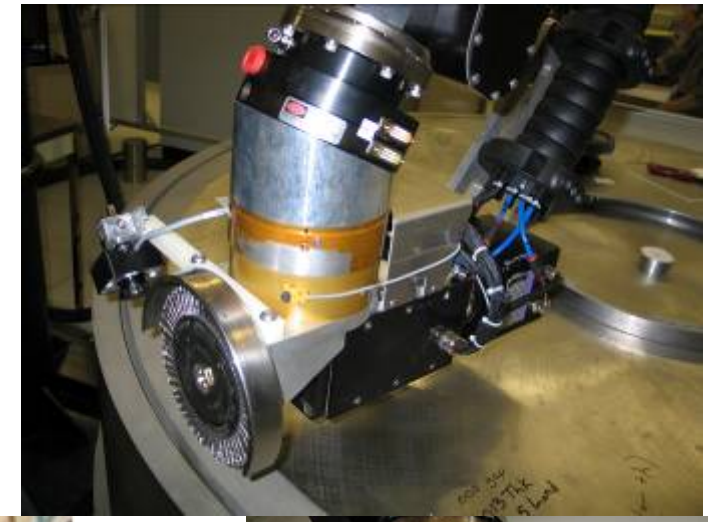
- **Development of the following processes were included in the closure system:**
  - **Welding**
  - **Nondestructive examination (visual, leak detection, eddy current, ultrasonic)**
  - **Brushing and grinding**
  - **Evacuation and backfill with helium**
  - **Stress mitigation**
  - **Material handling**
  - **Control and data management**
    - **For more information see reference below.**

C. V. Shelton-Davis‡ and T. R. McJunkin, "Remote Closure Operations," in Nuclear Energy Institute Dry Storage Information Forum, Bonita Springs, Florida, May 2009. http://www.nei.org/newsandevents/conferencesandmeetings/dsif/archives/.

Welding/Seemtracking/VT



Brushing/Repair



UT/Surface(ET)

Repair Groove Exam

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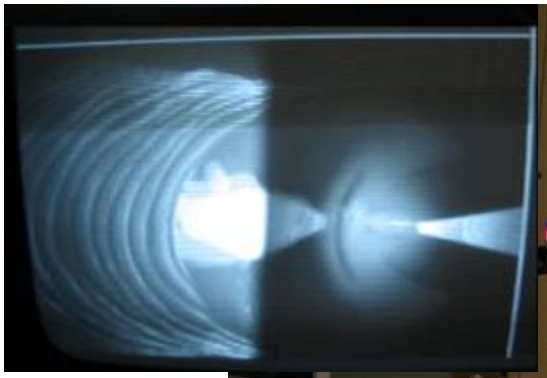
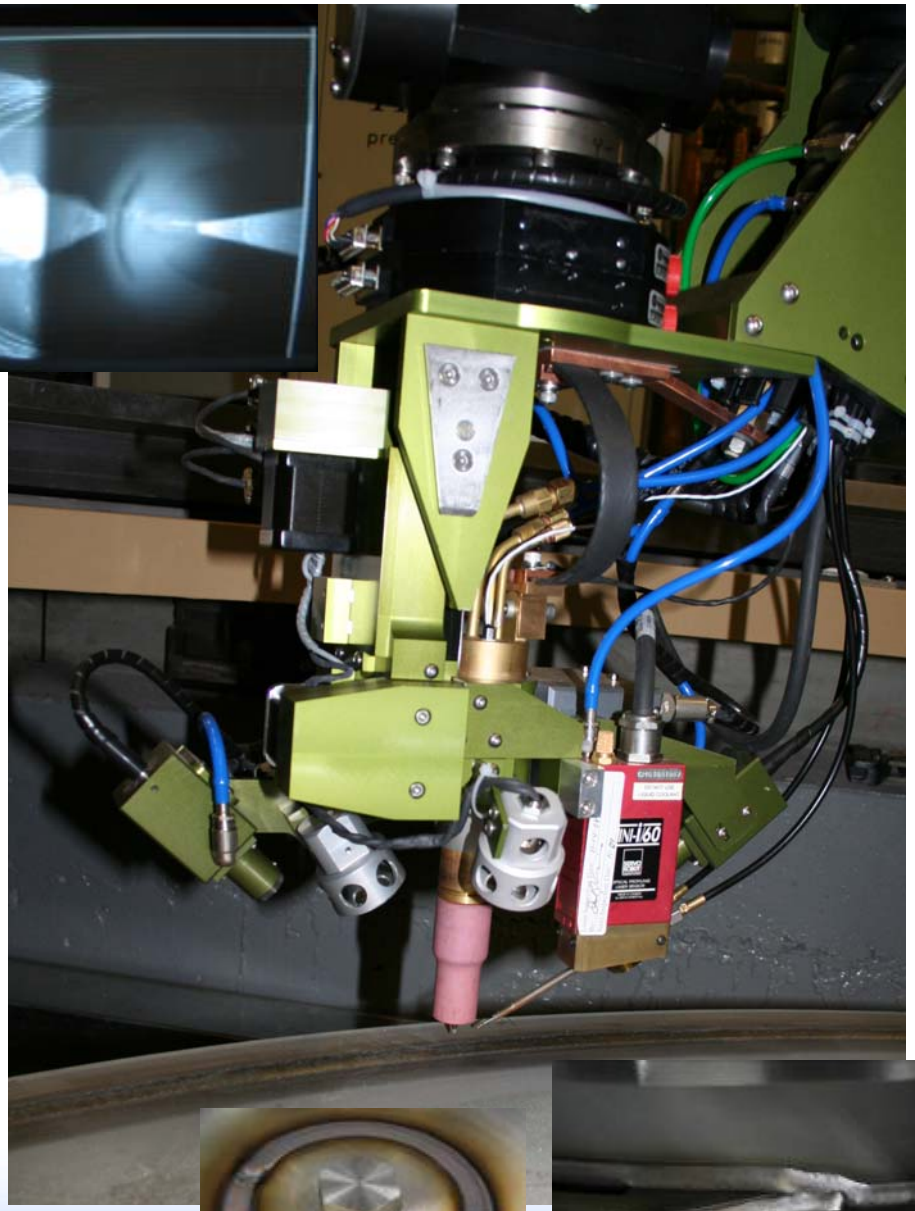
Four Tools

Welding

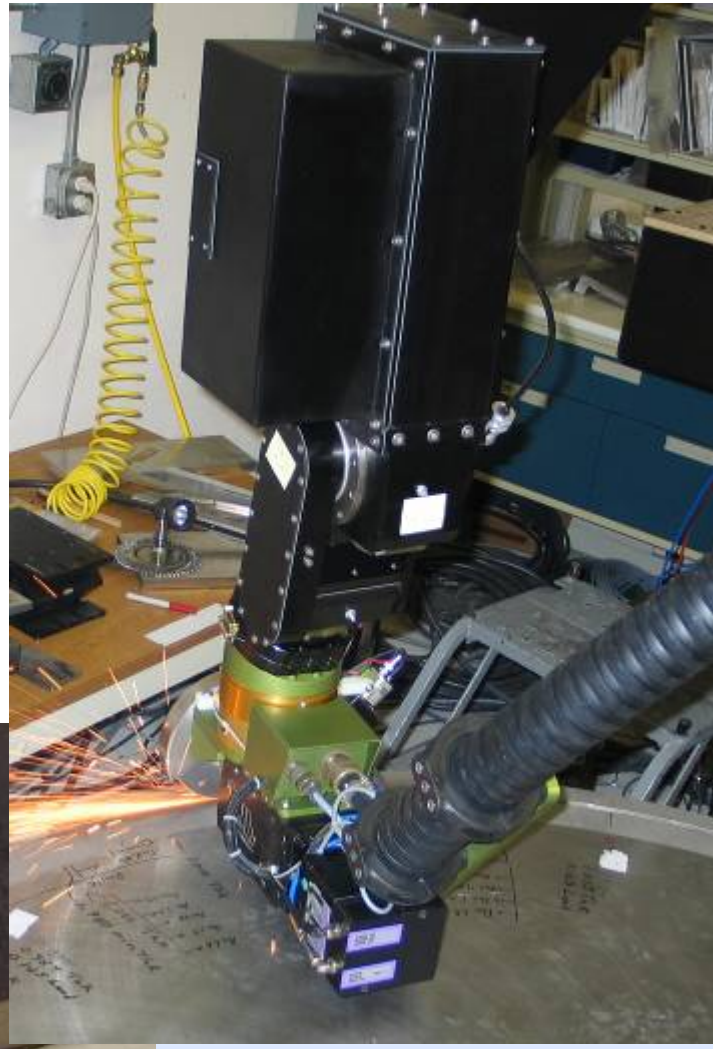
Welding Cold Wire GTAW
-Arc Viewing Cameras
-Seam Tracking
- Weld Voltage/Current
-Additional axes (AVC/Oscilation)
-Air cooled 400A torch
-Remotely Adjustable gas cup
-Remote wire trimmer
-Remote Tungsten Changer





Brushing and Repair Grinds

- Switch brush/grinding wheel remotely
- Grind a repair cavity that is both weldable and inspectable.
- Material of the components.



Eddy Current Inspection

- Array probe provides:
  - simplified mechanical scanning system
  - increased inspection rates
  - reduced probe wear
- Surface inspection concurrent with UT in lieu of dye penetrant
- Repair Groove.

Eddy Current Array Surface Inspection

Array Elements
- Individual coils
- Electronically controlled
- Work individually or grouped

Advantages
- *Simplified mechanical scanning system*
- Increased inspection rates
- Reduced probe wear

Seamtracking Visual Inspection

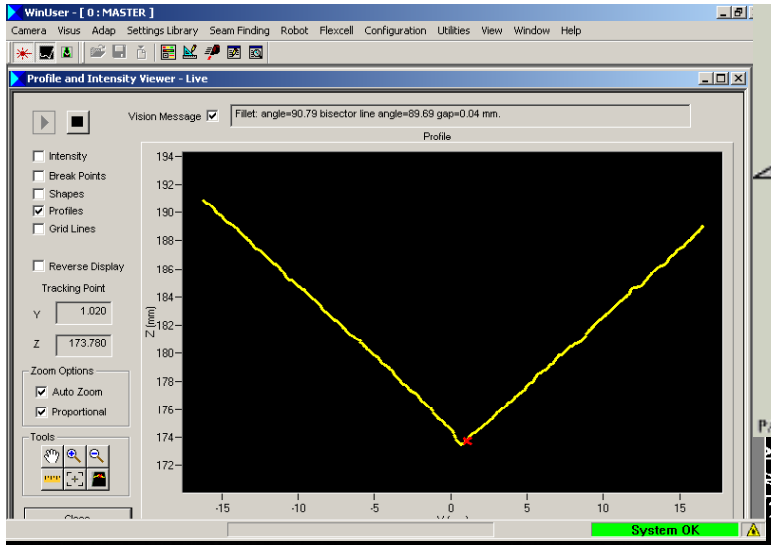
Laser Profiling System

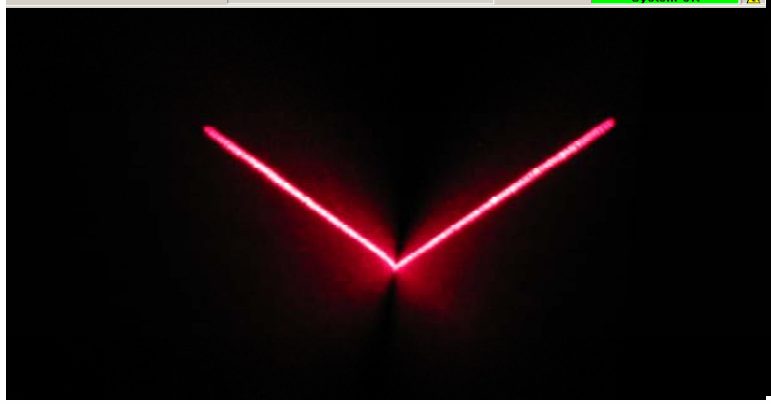
-Provide detailed trajectory corrections

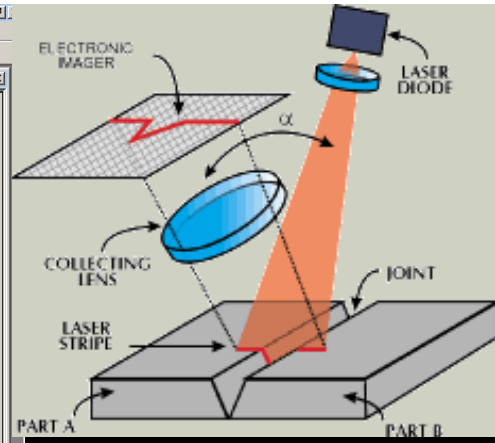
-Used to Detect Visible Surface Flaws for Quick Repair

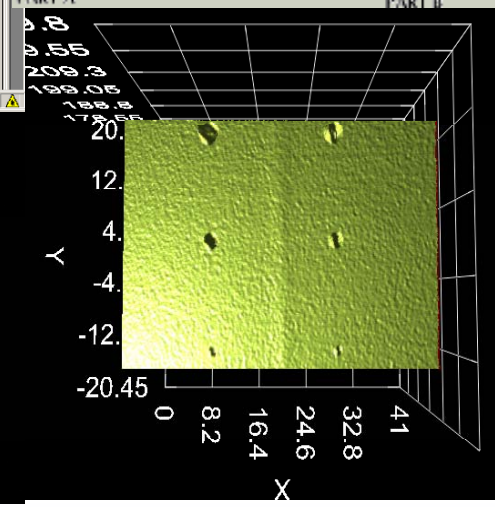
- Measures Weld Profile

- Verifies Workmanship is Adequate to Perform Eddy Current and Ultrasonic Inspections









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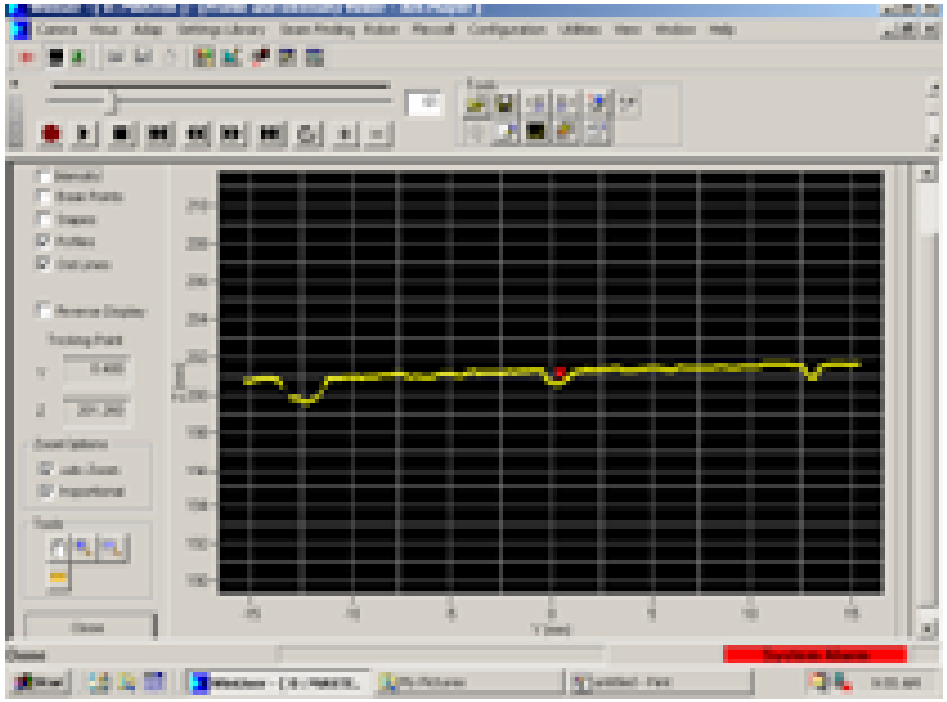
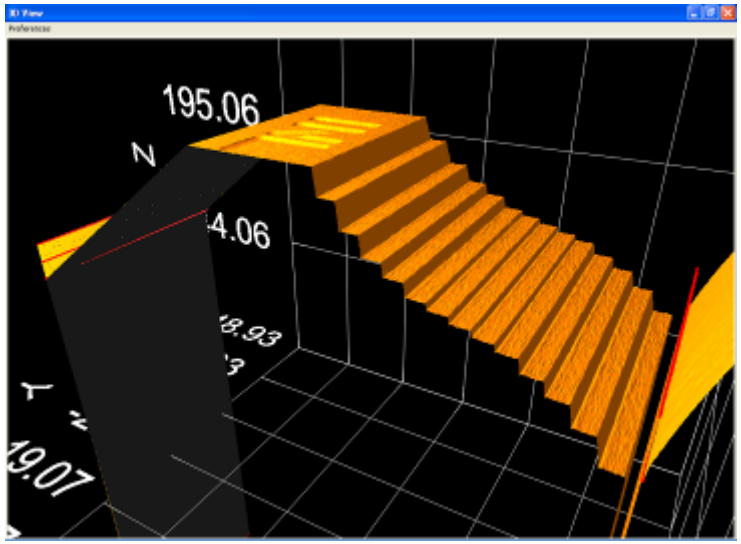
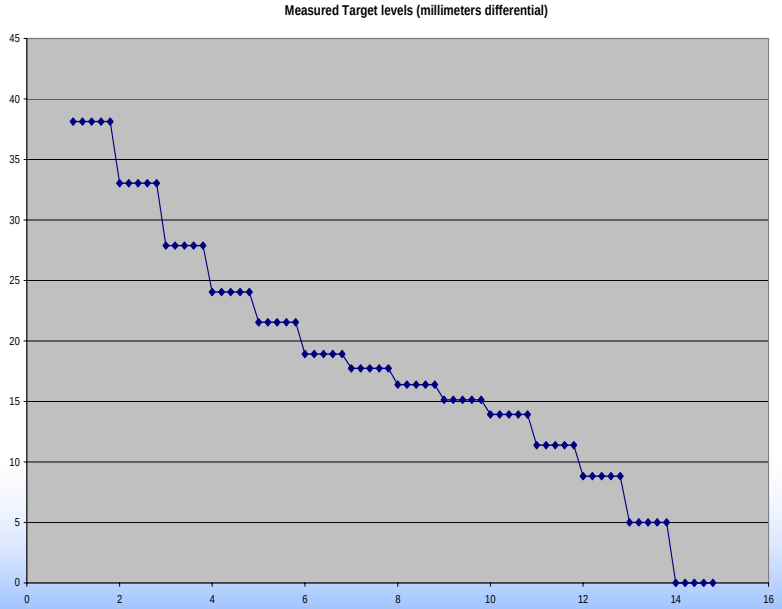
Dimensional Measurements







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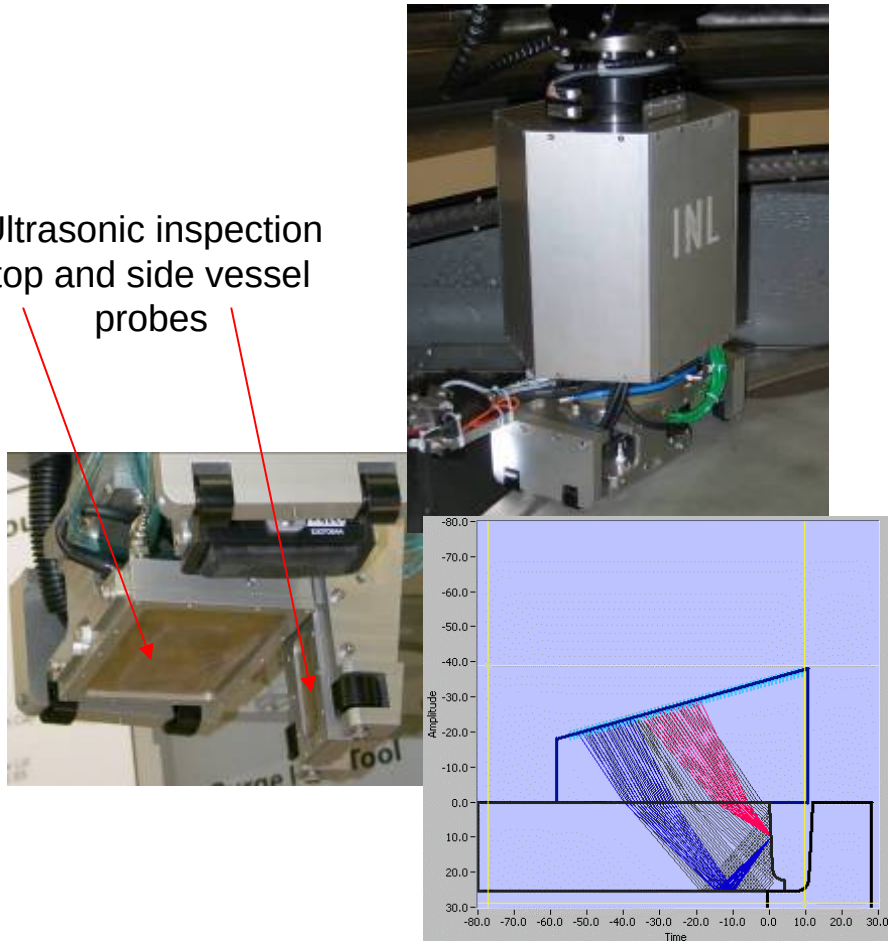
Surface/Volumetric Inspection

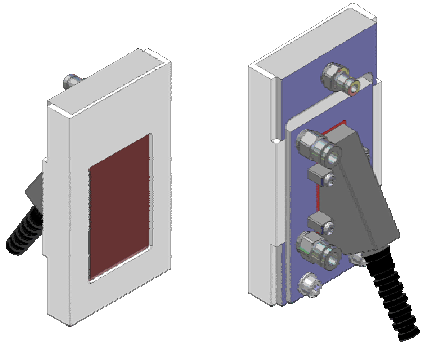
Volumetric

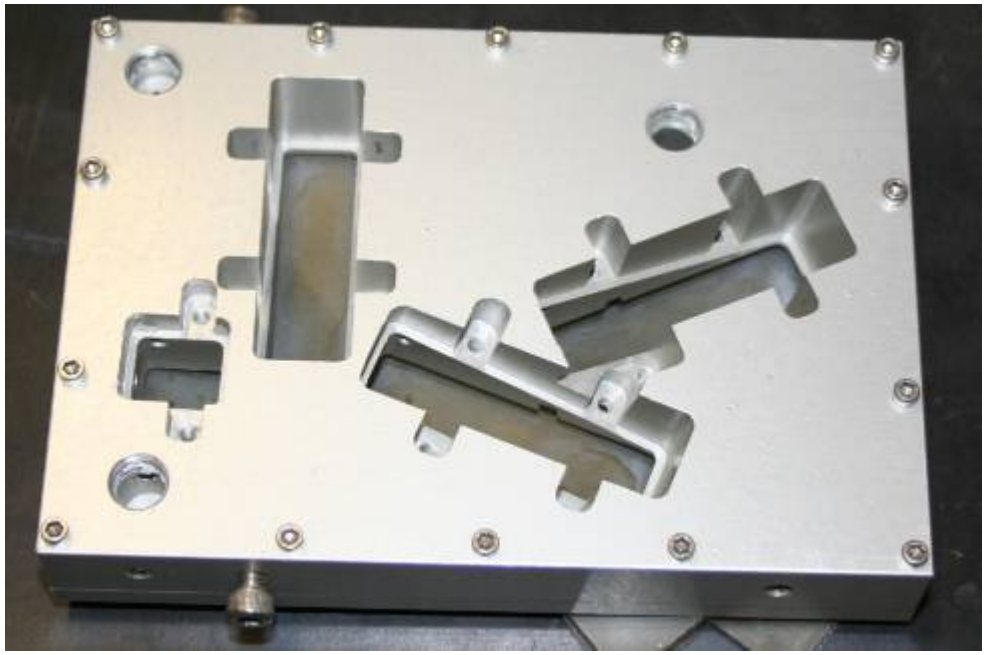


- **Phased array:**
  - **provides ability to electronically aim, steer, focus, and scan**
  - **is smaller, lighter, easier to deploy remotely**
  - **increases inspection rates**
- **Full volumetric inspection for 1/16 inch flaws**
- **Probe design custom for application. Examination from many directions.**

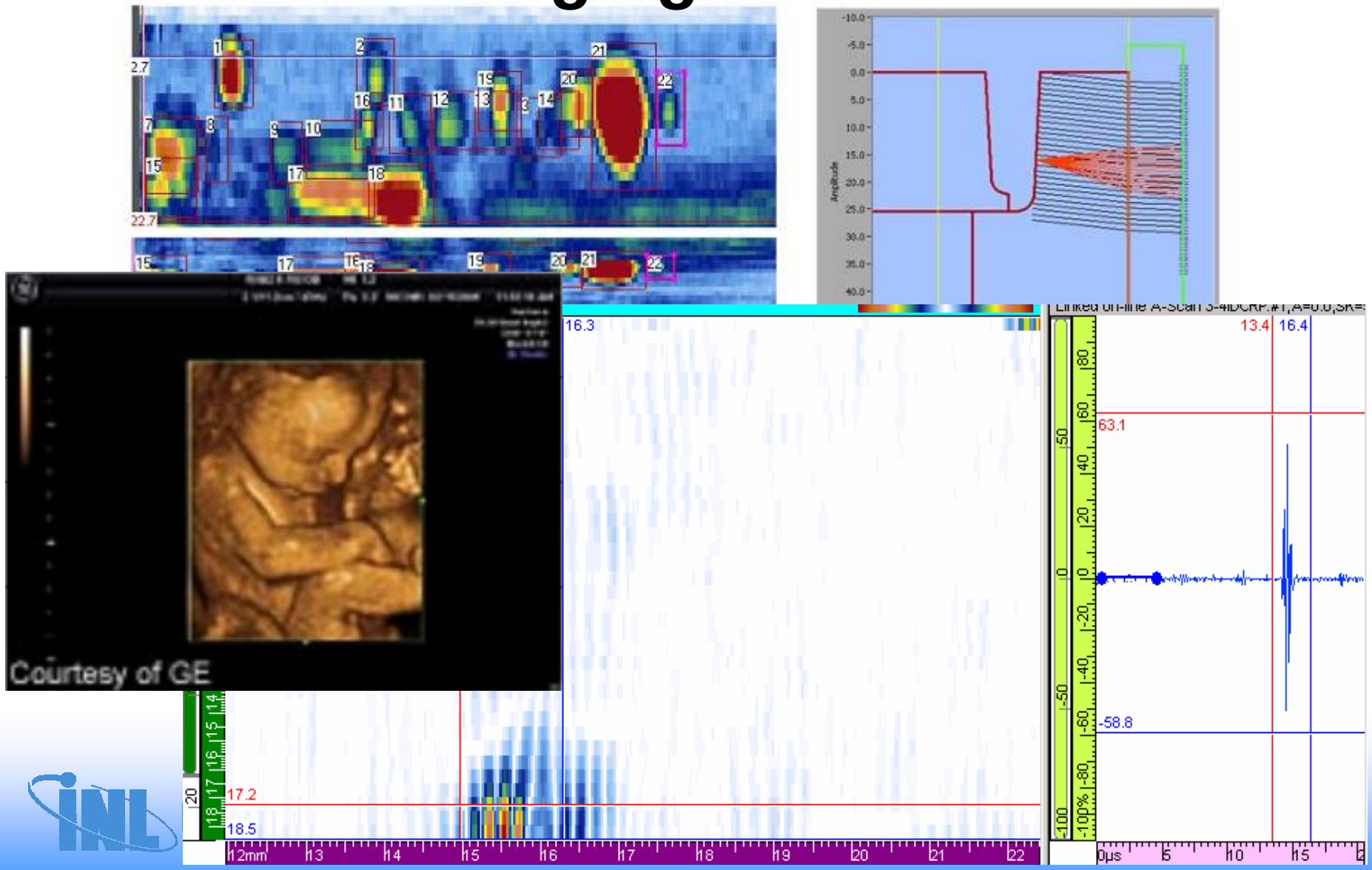
Ultrasonic Probes

- **Multiple Transducers for complete coverage**
- **Angle Beam, Straight Beam, Transverse Planar.**
- **Water as couplant, cycled through probe to keep transducers cool.**
- **Minimum water on the waste package was a customer set goal.**

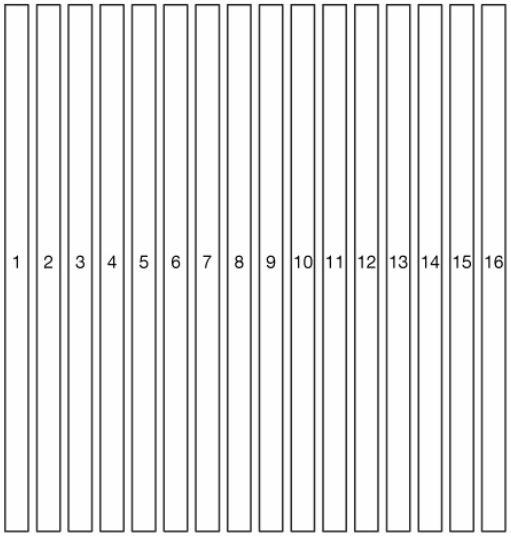




Ultrasonic Imaging



Phase Array Ultrasonic

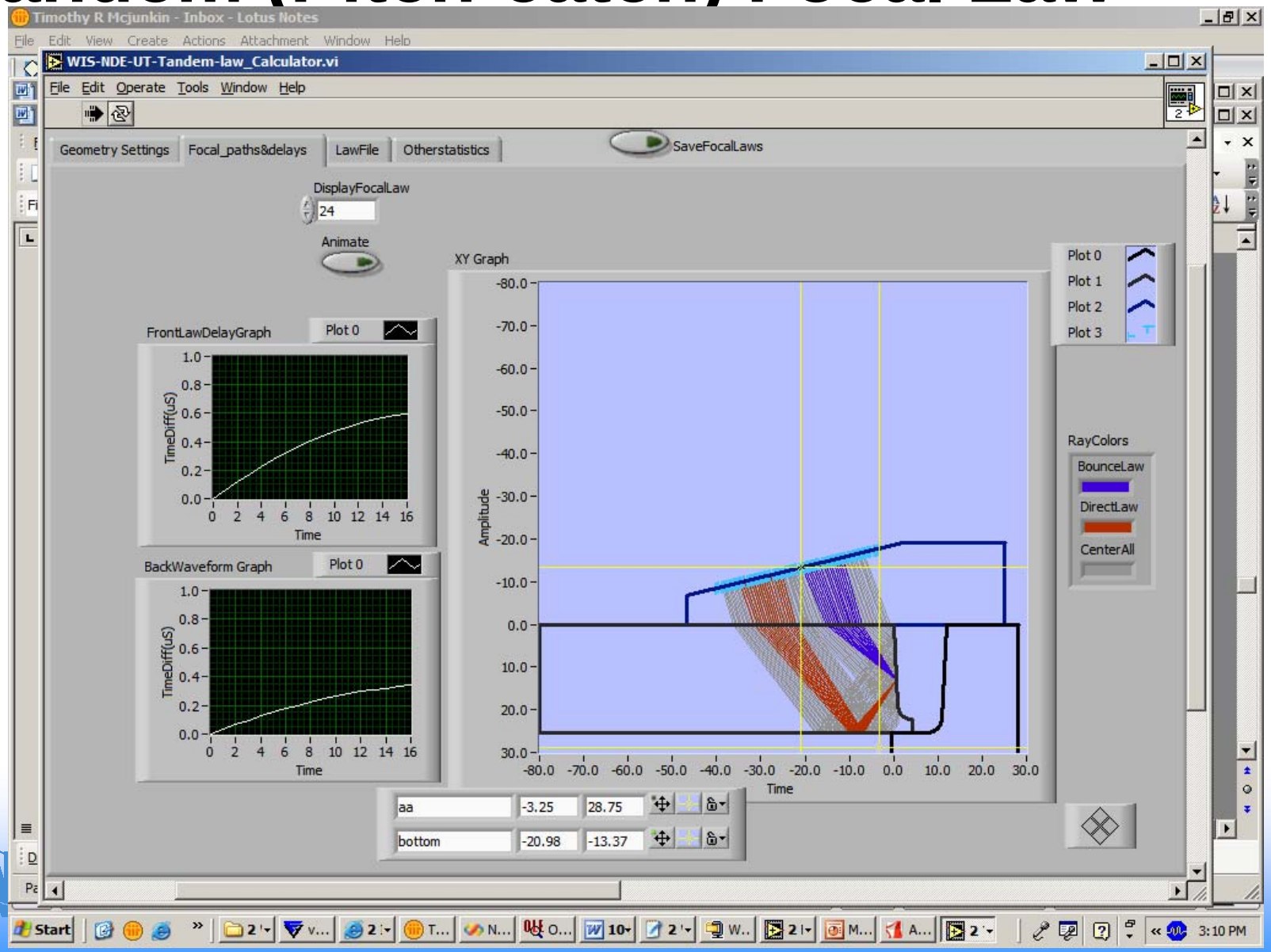


- **Use a bunch of small elements with a separate pulser and receiver on each.**
- **Control timing of pulses to a group of elements to produce constructive interference at the desired focal point.**
- **Linear array focuses in one direction**

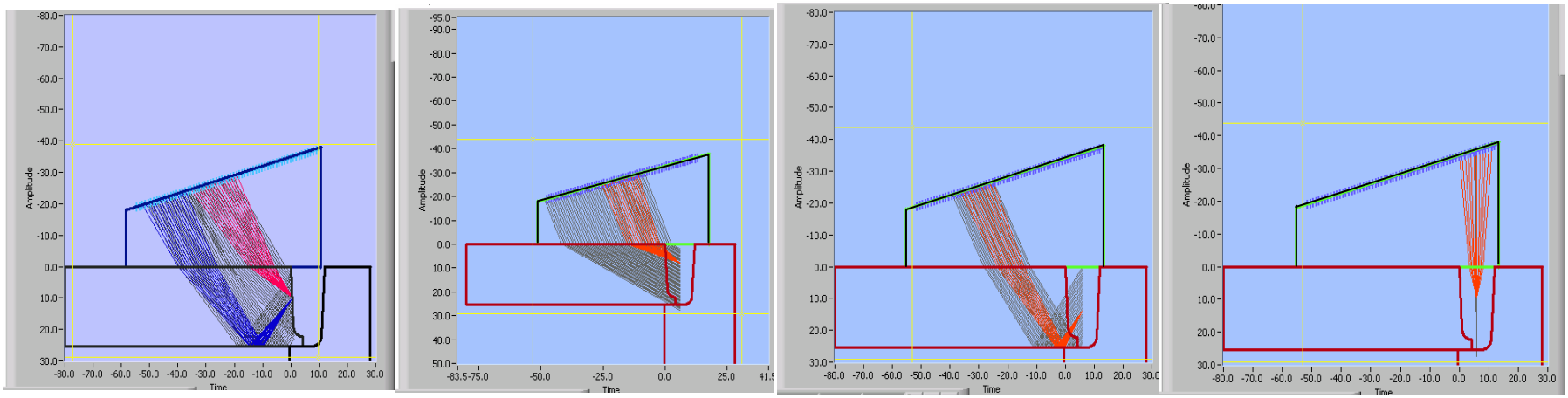
Capabilities

- Effectively “focus” at different sound paths
- Use a long linear array to perform a scan. Electronically raster in one direction, simplifying the scan mechanics.
- Produces various angles. Sector scans.
- Tandem scans without mechanical complexity or interference.
- Do a bunch of these in the same scan/same probe.

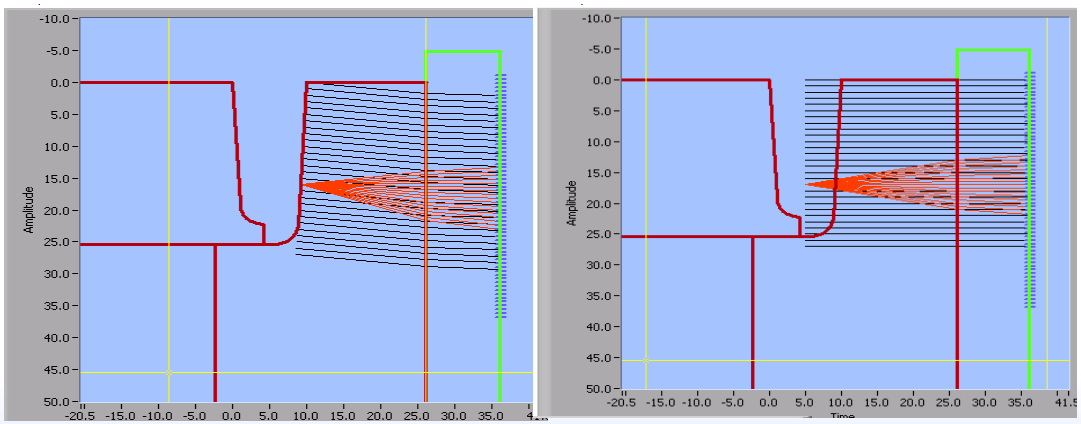
Tandem (Pitch-catch) Focal Law



Example of Focal Law Channels

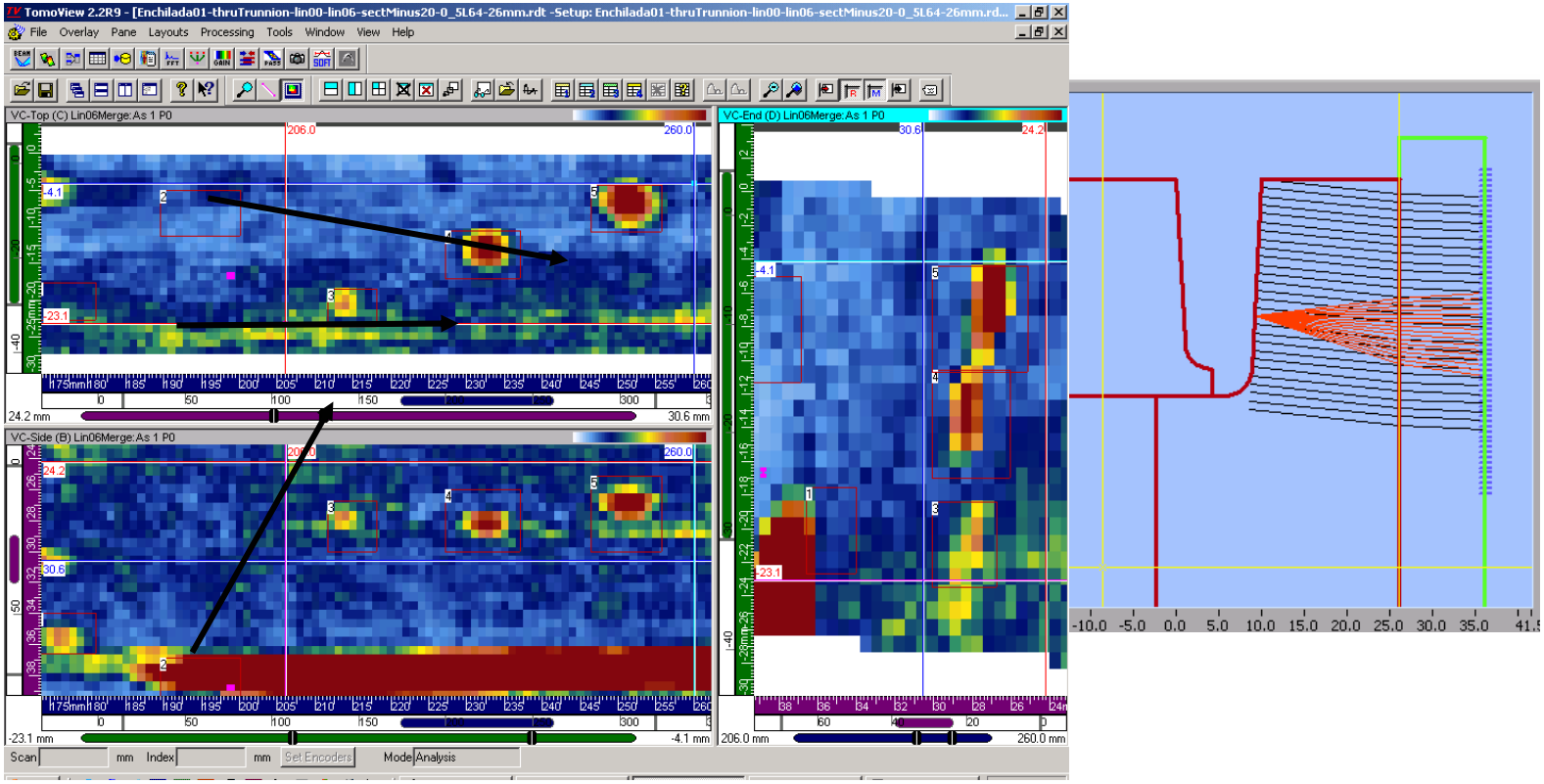


Lid Ultrasonic Probe



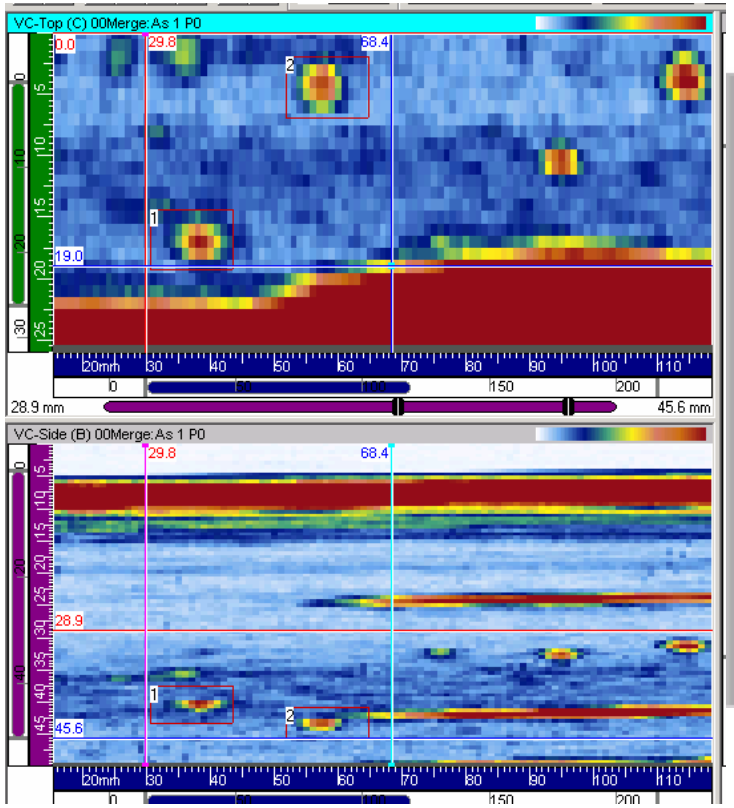
Upper Sleeve Probe

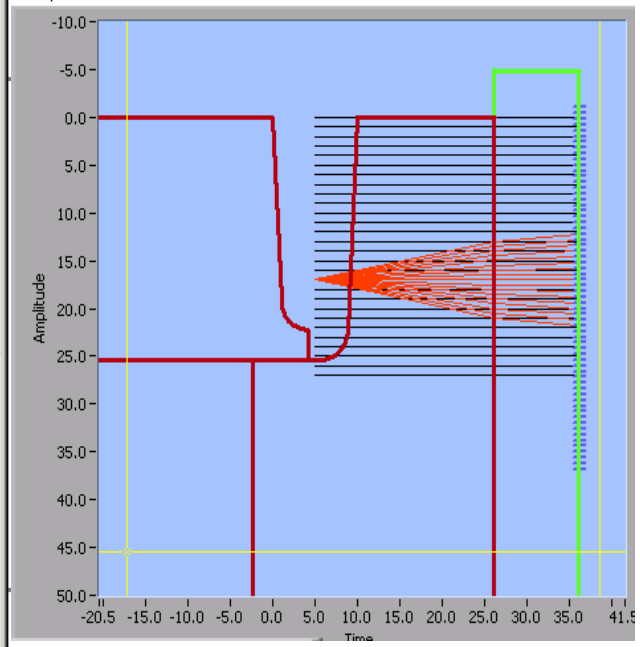
Upper Sleeve Probe Results



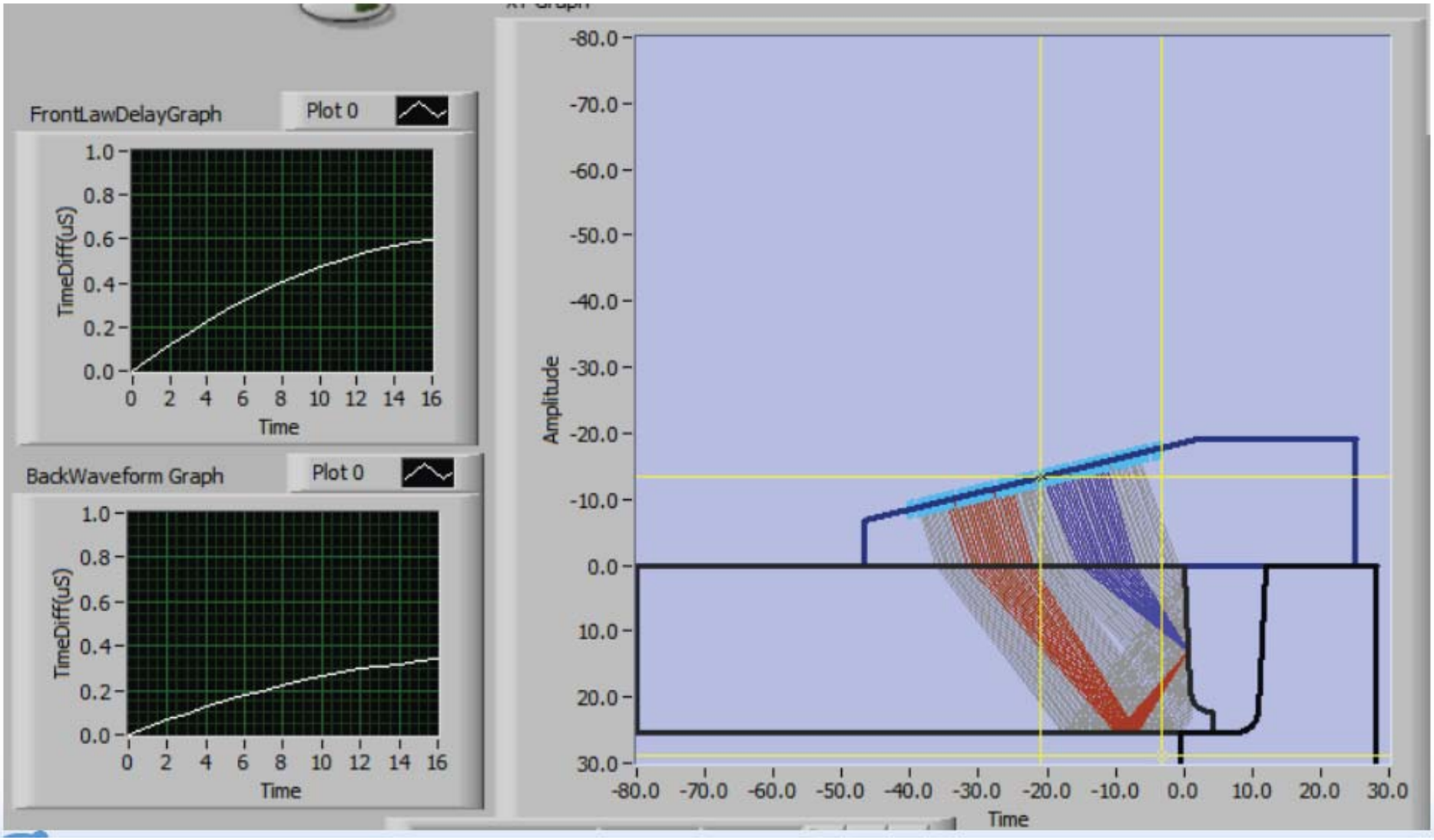
1/16 in. flat-bottom holes simulating lack of fusion on the trunnion sleeve side of the outer lid weld.

Upper Sleeve Probe Results (contin.)





1/16 in. flat-bottom holes simulating lack of fusion on the lid side of the weld.



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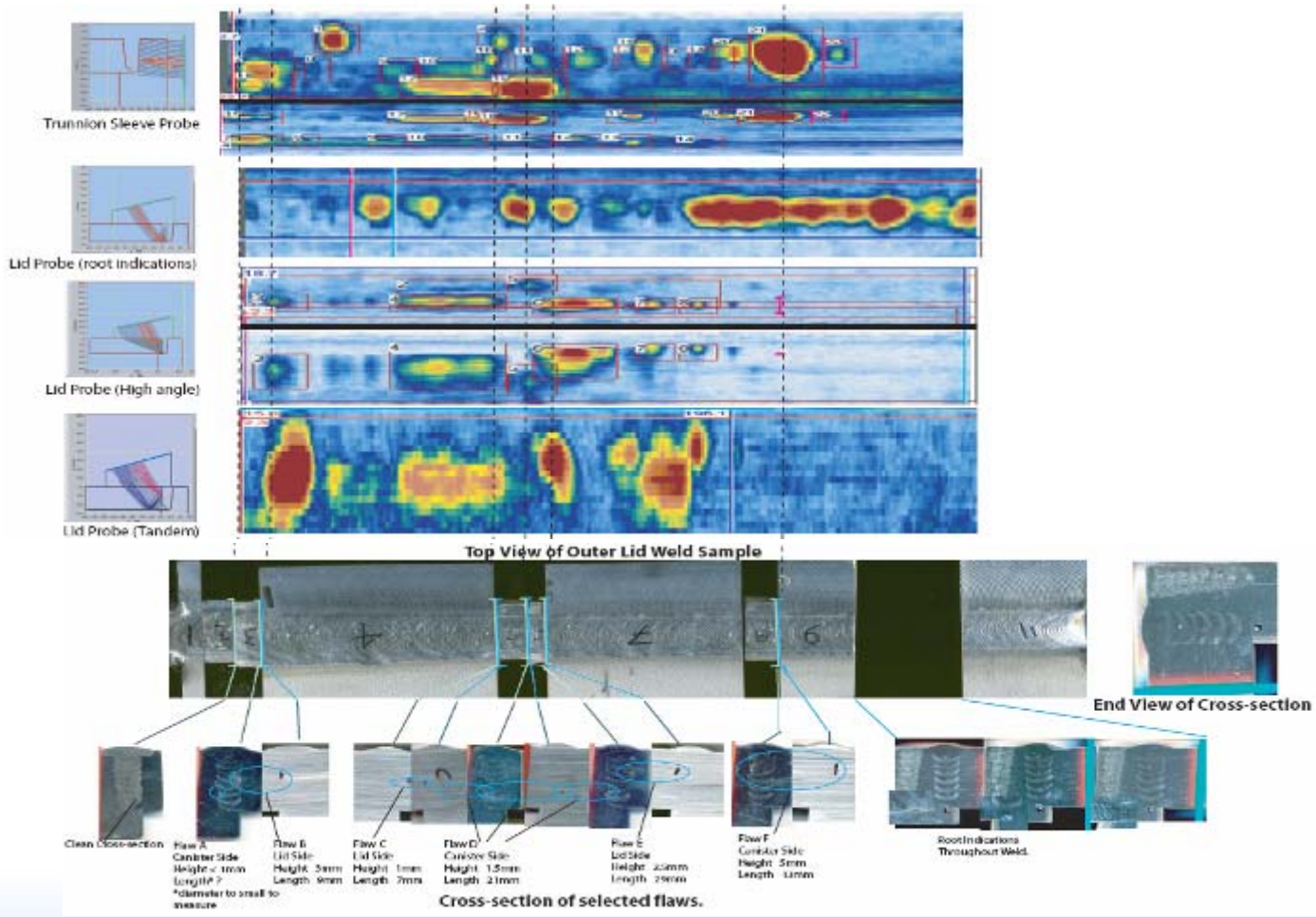
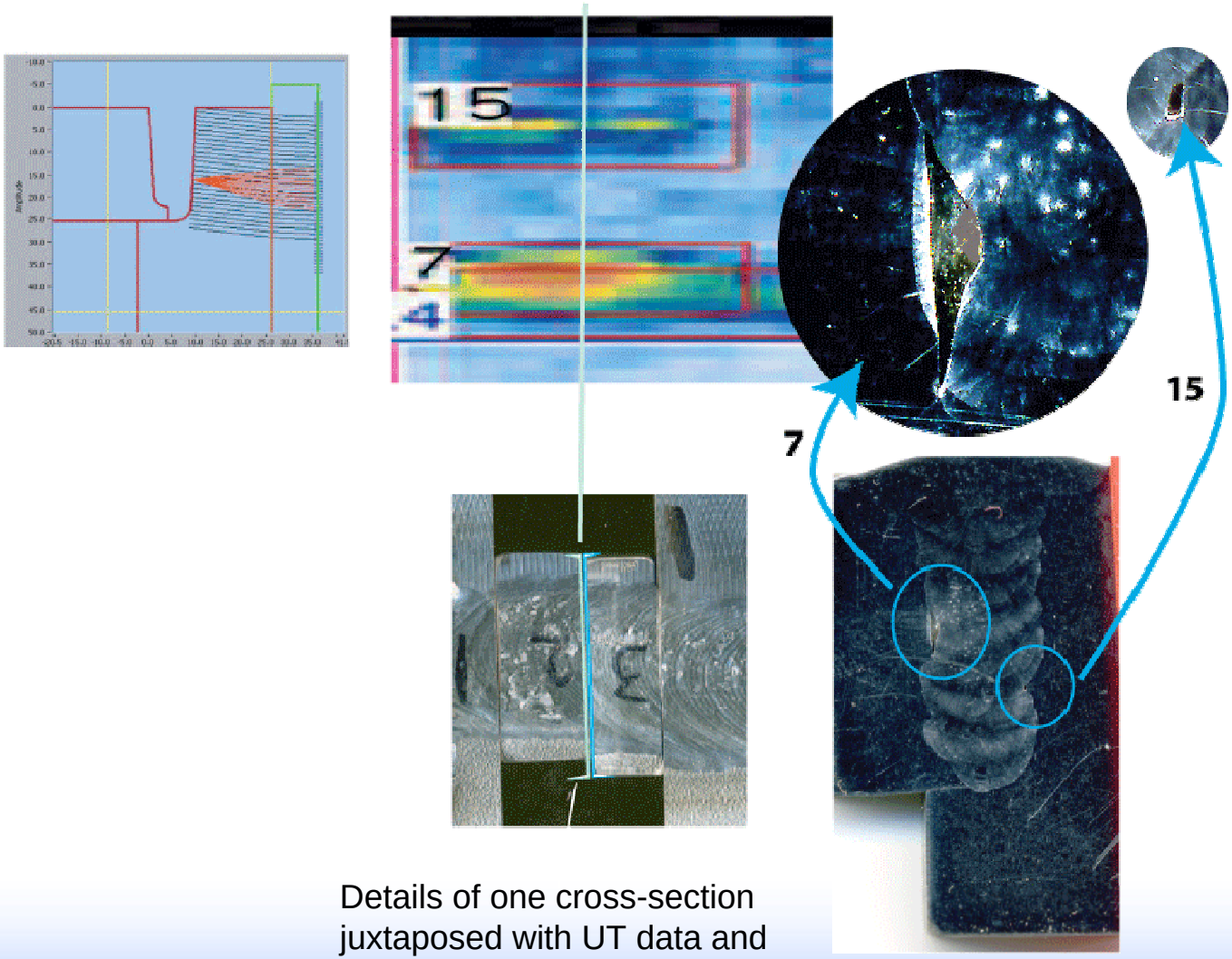
UT – Defect Sample



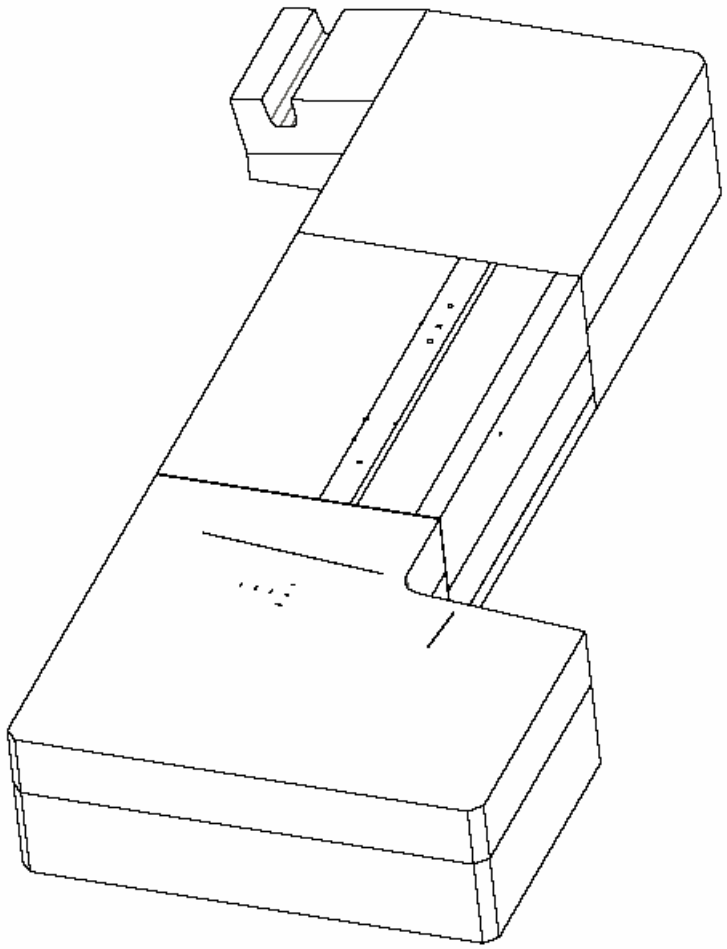
UT Validation – Cross Section Details



Details of one cross-section juxtaposed with UT data and focal laws.

Calibration Block

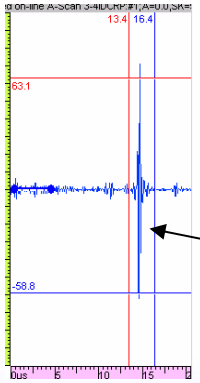
- Designed for Single Pass Calibration Data Collection
- Targets for normalizing across phased array channels
- Sensitivity Targets.
- ET/UT and Repair Groove ET



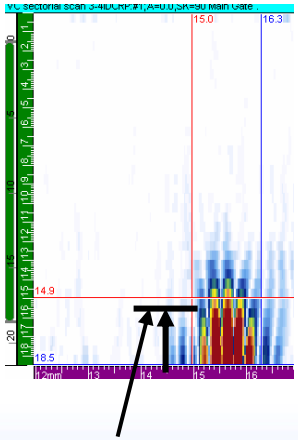
ISOMETRIC VIEW
(SHOWN FOR CLARITY)
SCALE: NONE

Lots of possible innovation for extracting more details. Example.

- Scan part with ID creeping wave.
- When an indication occurs, manipulate probe to peak up the creeping wave signal.
- Refer to the tandem display with the probe in the peaked position.
- The height of the flaw will be shown on the tandem display.



Peaked Creeping Wave



Height of flaw

T. R. McJunkin‡, J. M. Davis, D. C. Kunerth and A. D. Watkins, "Ultrasonic phased array implementation of the inside diameter creeping wave sizing methodology," in 5th International Conference on NDE in Relation to Structural Integrity for Nuclear and Pressurized Components, pp. 690-696, San Diego, California, May 2006.

Conclusions

- Benefits
  - Flexibility to cover cross-sections with linear scans. Eliminates some mechanical rastering
  - Focus at various depths and use various angles.
  - Interrogate a indication from numerous points of view without modifying hardware.
- Cons
  - Hardware/Software is more expensive
  - Probe may be more complex.
  - Calibration may be more complex.

INL Contacts

- **Tim McJunkin timothy.mcjunkin@inl.gov (208) 526-7895 Technical Lead NDE of Yucca Mountain Waste Package Closure System**
- **Colleen Shelton-Davis colleen.shelton-davis@inl.gov (208) 526 3344 Project Manager Yucca Mountain Waste Package Closure System**
- **Sandra Birk sandra.birk@inl.gov (208) 526-1866 Manager Nuclear Materials Disposition Engineering**

References

- T. R. McJunkin‡, J. M. Davis, D. C. Kunerth and A. D. Watkins, “Ultrasonic phased array implementation of the inside diameter creeping wave sizing methodology,” in 5th International Conference on NDE in Relation to Structural Integrity for Nuclear and Pressurized Components, pp. 690-696, San Diego, California, May 2006.
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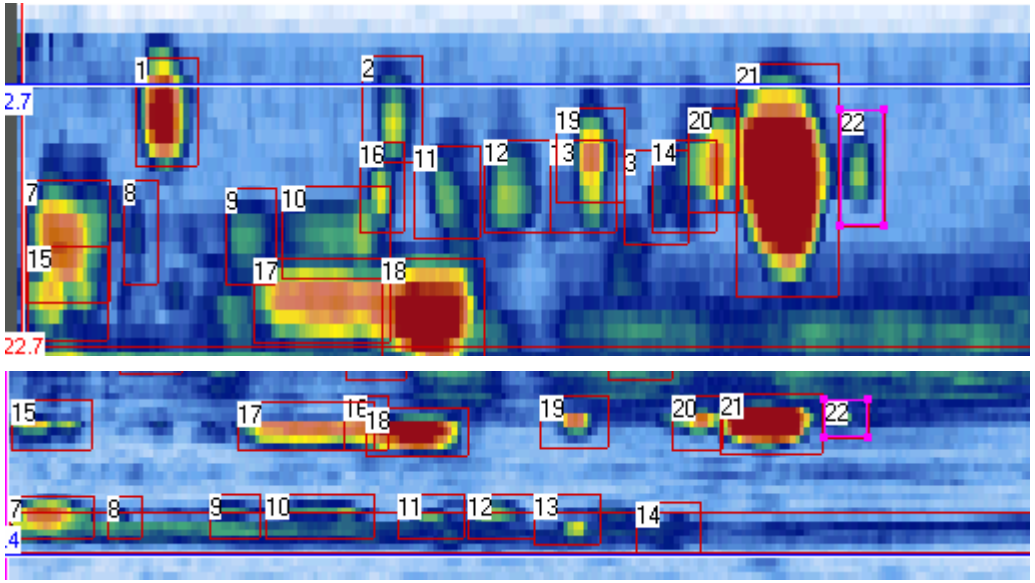
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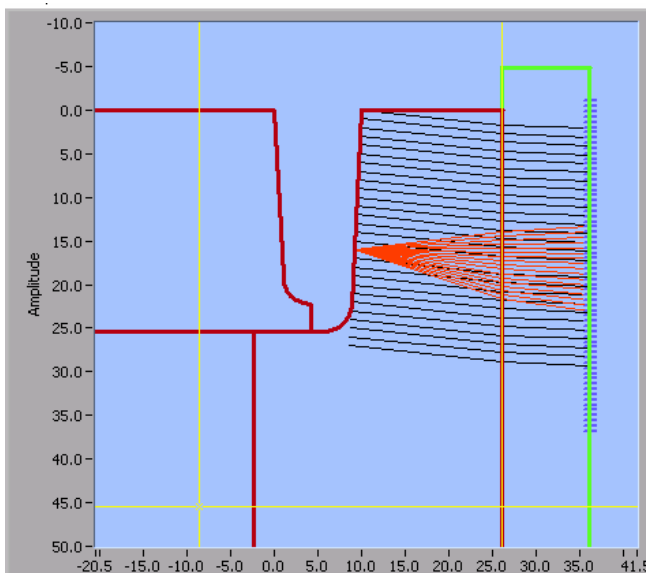
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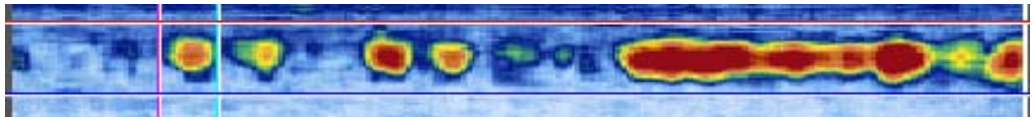

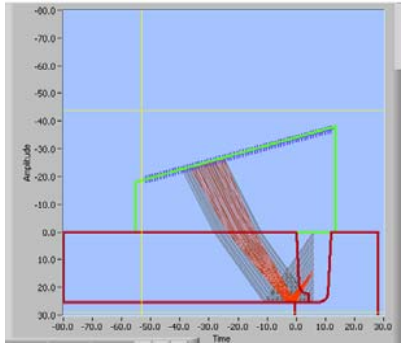

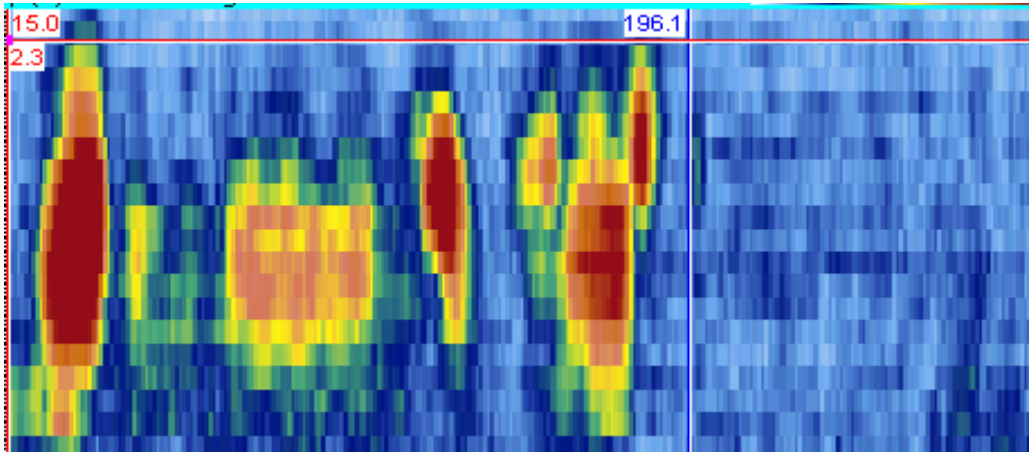
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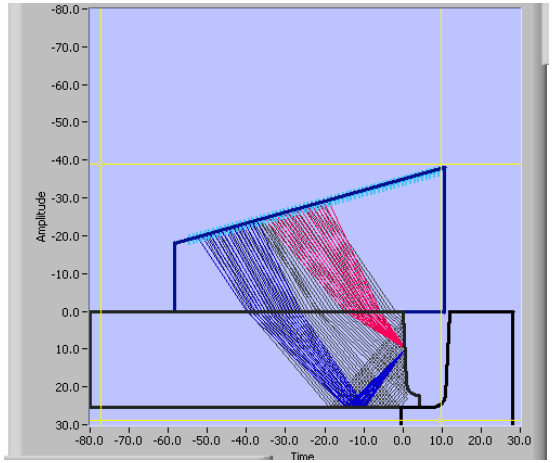
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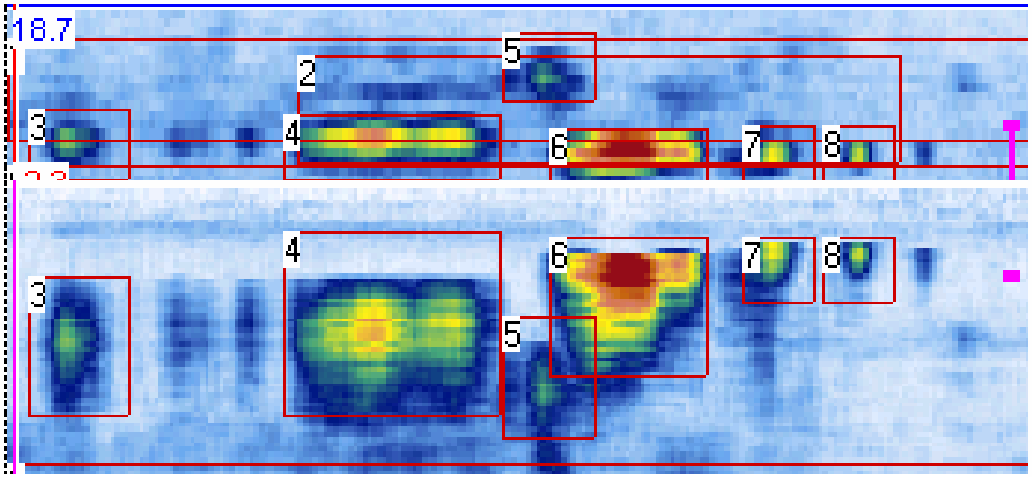
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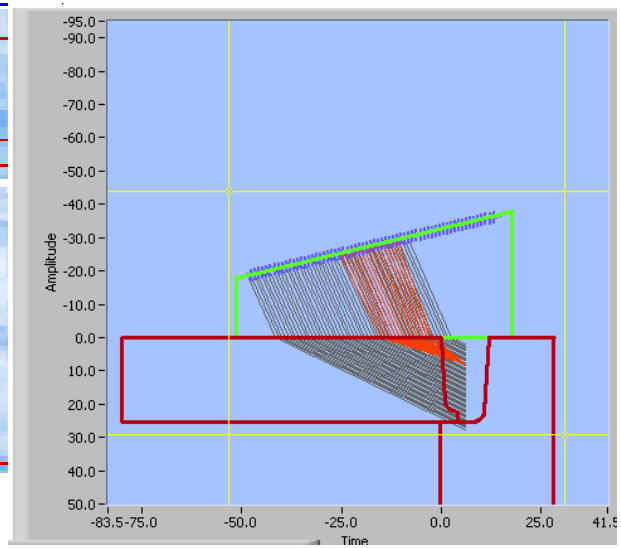
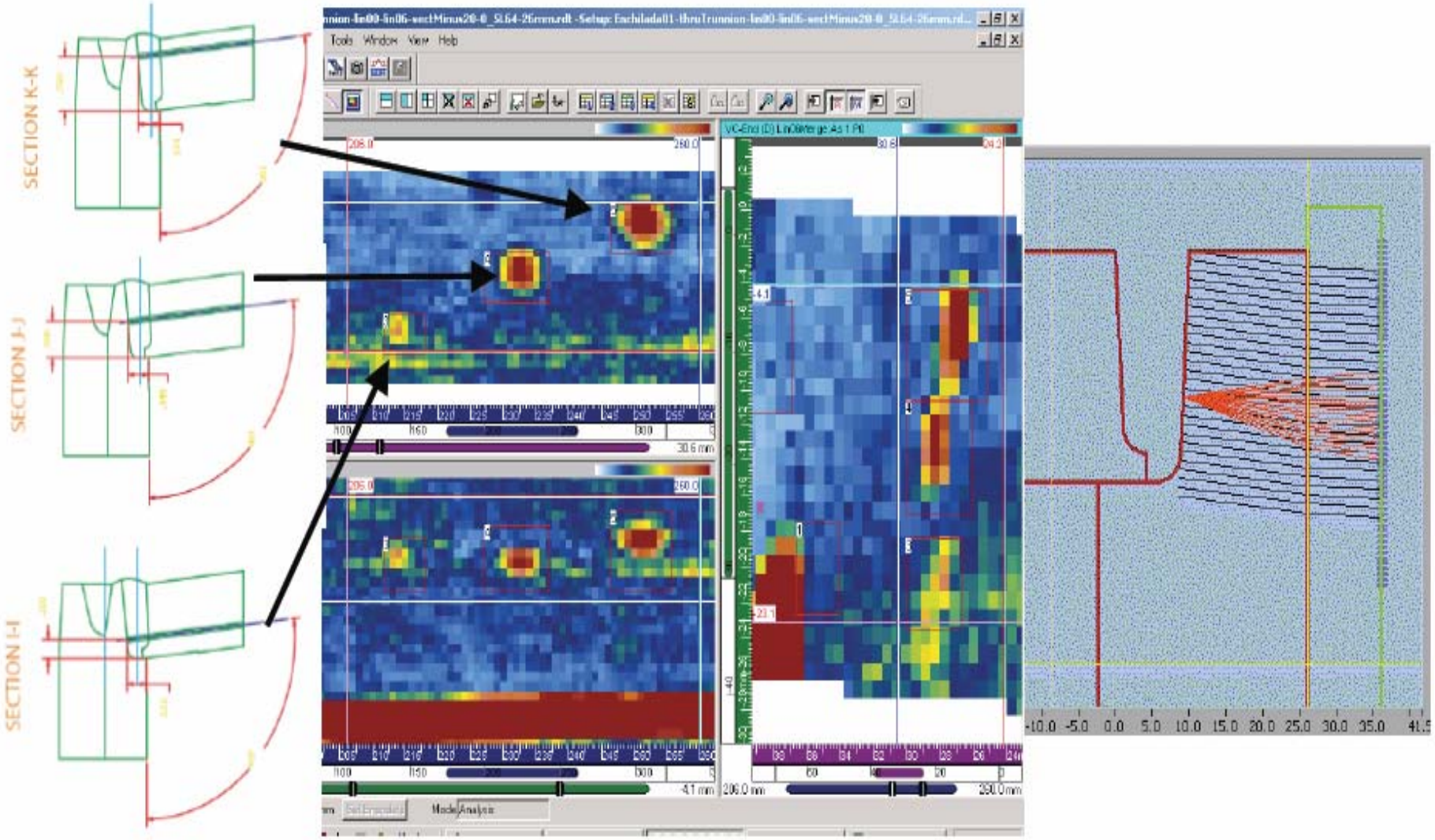

Amplitude
Time



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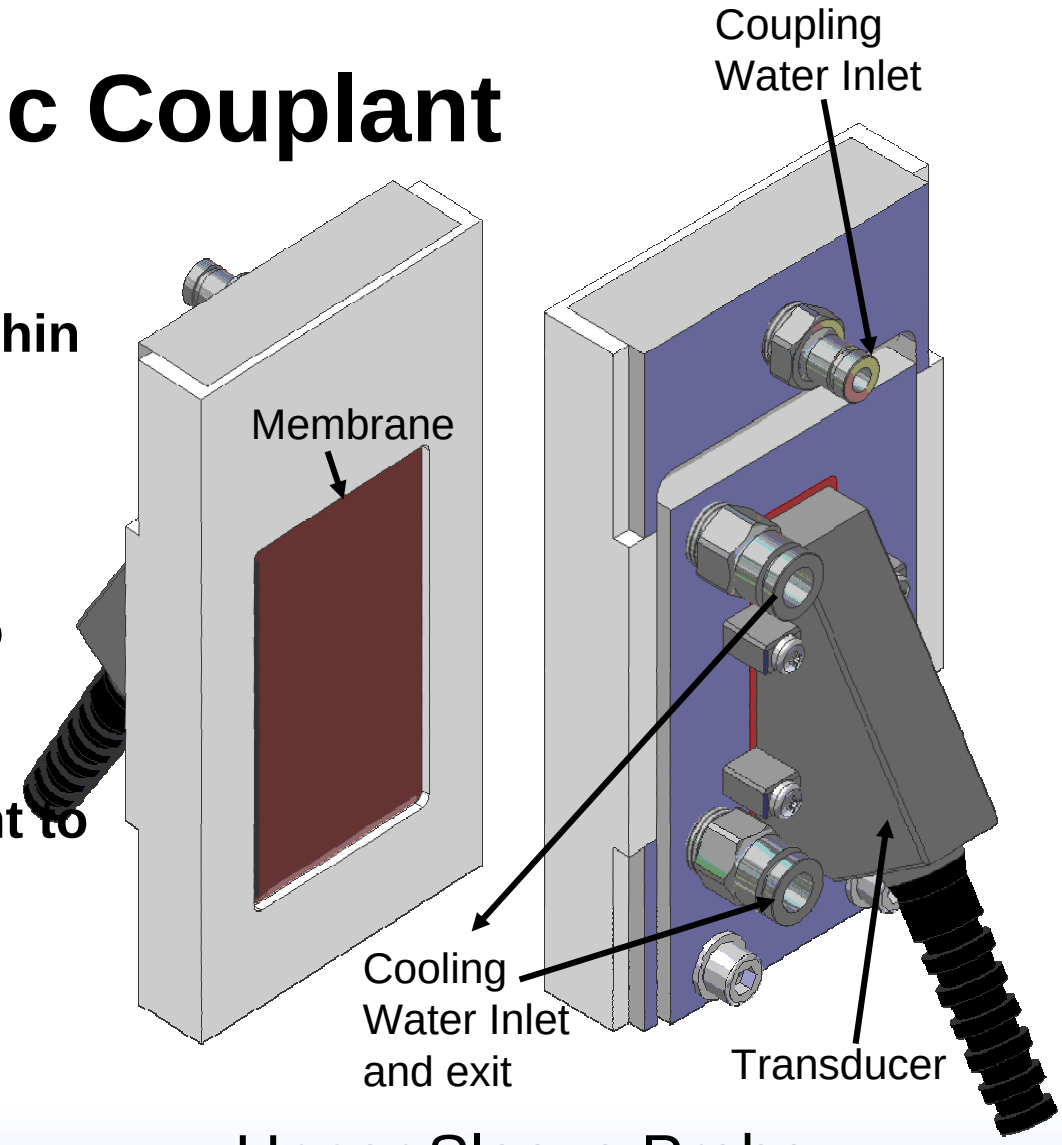
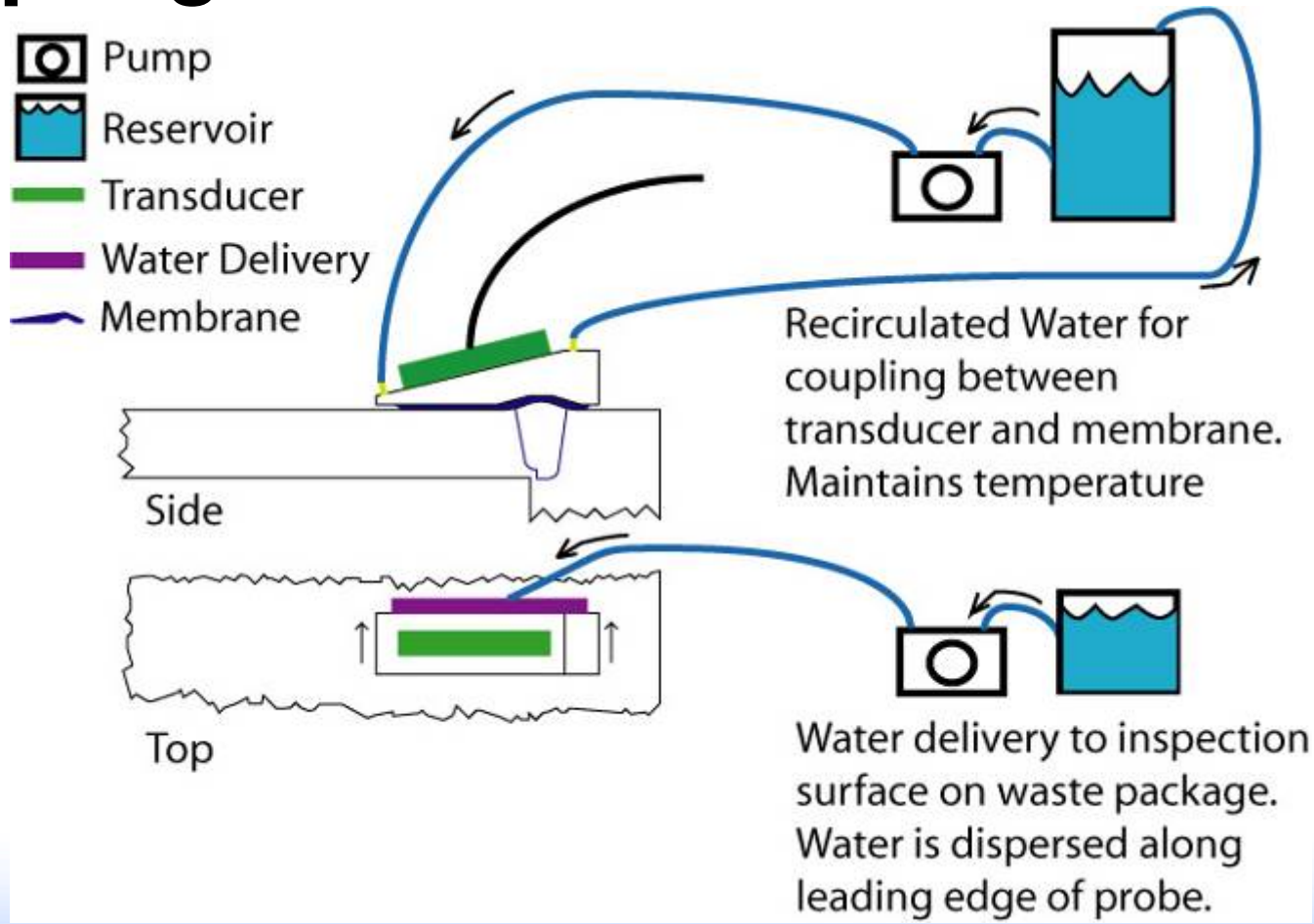
NDE – Ultrasonic Couplant

- **Water wedge design**
  - **Aqualene Membrane allows coupling with thin film of water between membrane and waste package.**
  - **Aqualene similar acoustic properties to water.**
  - **Aqualene radiation tollerant; heat tollerant to > 200C**



Upper Sleeve Probe

Water Delivery for cooling and coupling of ultrasound.



Phased array continued

- Each element is similar to a point source.
- Choose a group of elements (usually contiguous) as the aperture.
- Find the sound path from the center of the element to the desired target and calculate the time of flight to the target for each element.
- Find the longest transit time for the group and delay the other elements by the difference in time.
- Waves from each element get there at the same time to constructively interfere.