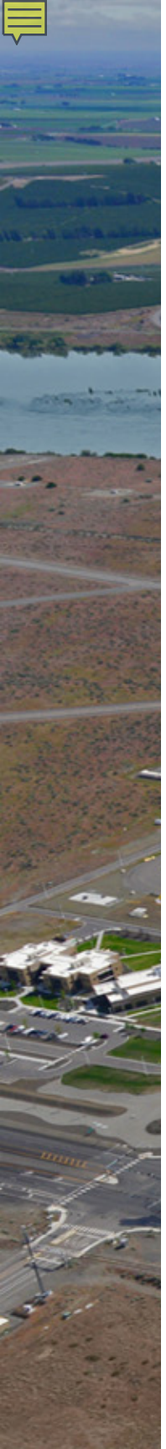

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PNNL-SA-150350

Evaluating Flaw Detectability Under Limited Coverage Conditions

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Technical Information Exchange
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U.S. DEPARTMENT OF ENERGY BATTELLE

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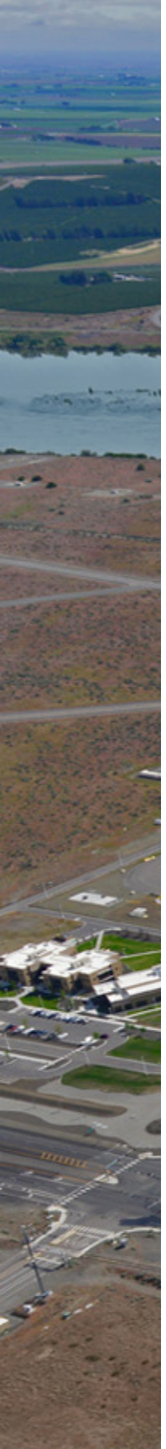

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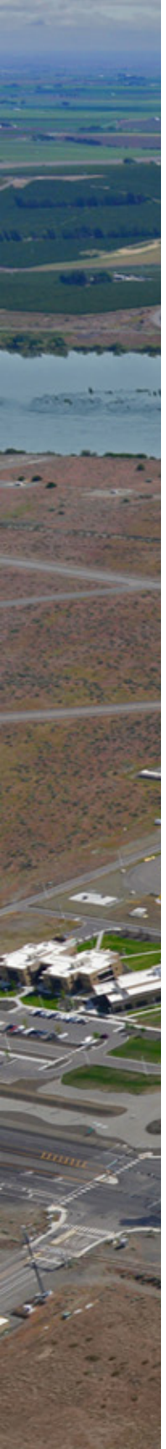
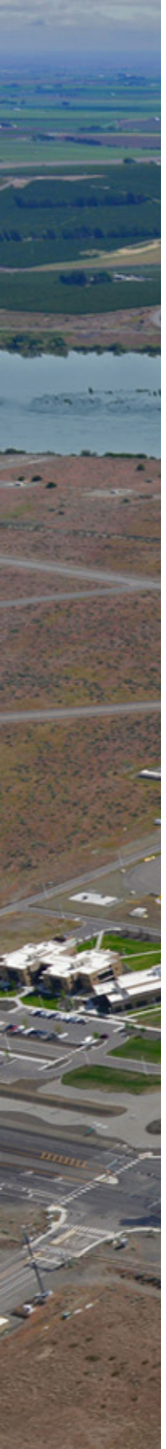
Introduction: Limited Inspection Coverage

- Incomplete examination coverage of welds is a very common issue in the nuclear power industry that exists in every plant.
- In cases where welds susceptible to degradation are not inspectable or partially inspectable, the condition must be addressed in order to determine the structural integrity of the component
- Assuming a flaw existed in an uninspectable region, to what extent would it have to propagate into the inspectable region before it would be detected?



Historical Perspective of Limited Examinations

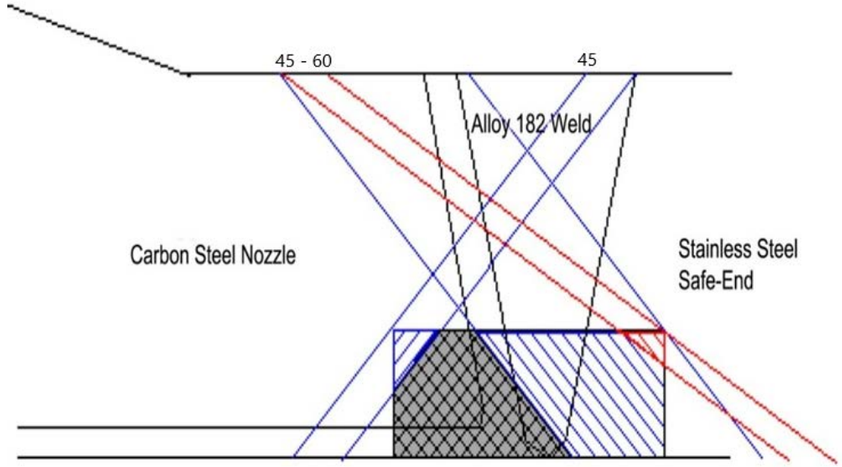
- Conventional wisdom has driven industry's position on limited examination coverage:
  - Shear Waves will not effectively propagate through austenitic material
  - Longitudinal waves produce varying flaw responses, although more effective than shear waves in propagating through austenitic material
- A variety of UT techniques have been applied to address limited coverage conditions
  - A broad assessment of these techniques has not been conducted.
  - The Performance Demonstration process only offers a Yes/No assessment
- No formal study has previously been initiated to evaluate and document the extent by which a flaw must propagate outside a limited coverage area in order to be detected

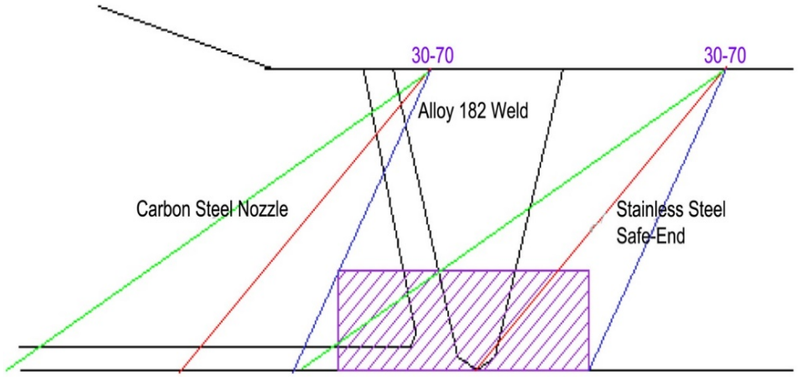


Limited Inspection Coverage

- PNNL conducted a search of NRC's ADAMS database to locate relief requests and reports associated with limited UT examination coverage issues.
  - ML17318A120 (PNNL-26157)
- Several weld configurations that often result in limited coverage were identified and were used to prioritize PNNL's assessment of the impact of incomplete coverage.
- Conditions that limit UT coverage of a specified examination volume restrict probe movement and include excessive weld crown width and outside surface configuration.

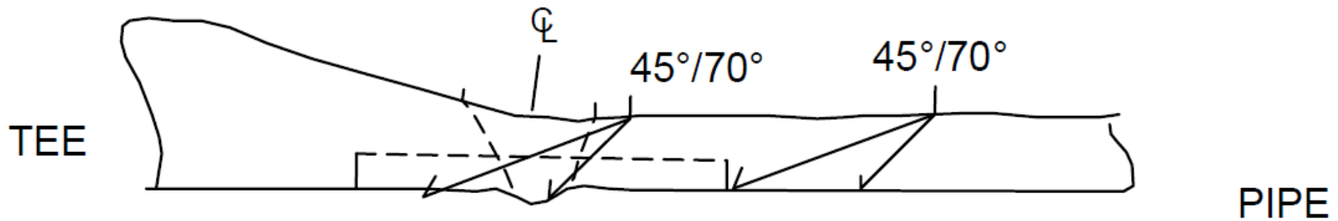
Examples of Limiting Conditions

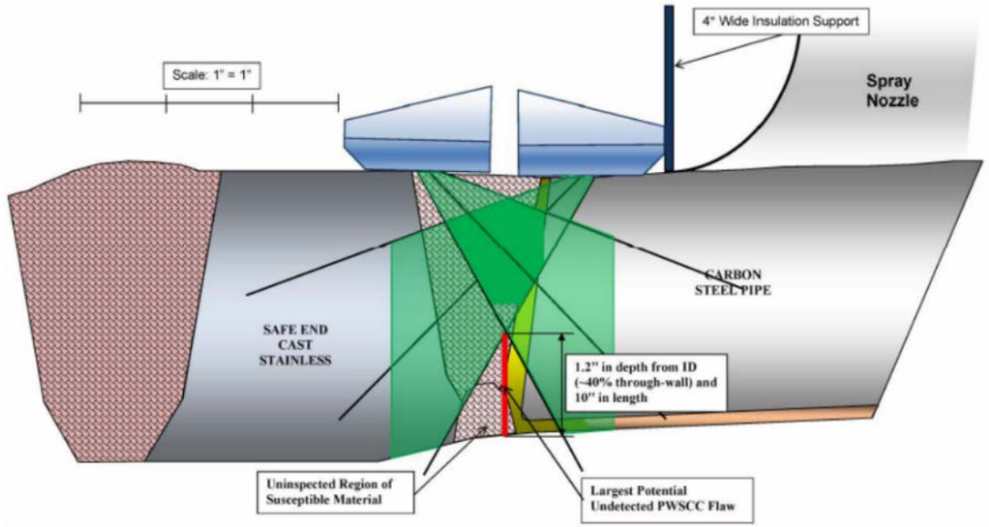


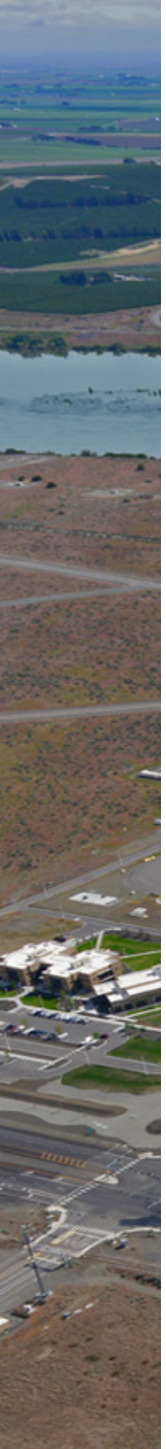


Examples of Limiting Conditions

- Configuration limited due to taper from tee and weld geometry
- Material limited due to no single sided qualification for austenitic SS welds
- Component supports block probe motion







Design of Experiments: Factors and Levels

- Factor and levels based on typical conditions in the field
- Conditions limiting coverage include taper (weld and/or component), physical access restrictions, weld geometry, and material microstructure (CASS)
- Metrics for quantifying coverage will be tabulated
- How do these factors limit Probability of Detection

Factors	Number of levels	List of levels	Notes
Materials	3	WSS – WSS CASS – CS CASS – SS	No scans to be performed from the CASS sides.
Wall Thickness	2	Thin, Thick	Thin ≤ 1.6 in.; Thick > 1.6 in.
Weld Root Condition	1	None	Assuming best case scenario of no weld root, although some specimens may have existing weld root.
Probe Aperture	2	Small, Large	
Probe Type	3	Single Element, Phased Array, Dual-Element TRL	
Refracted Angle	4	30° ,45° ,60° ,70°	PA – 30°-70° Conventional – 45°, 60°, 70° TRL – 45°, 60°
Wave Mode	2	Shear, Longitudinal	Shear is only applicable for conventional probes and near-side exams.
Probe Frequency	3	2 MHz, 2.25 MHz	Conventional – 2.25 MHz, Phased Array – 2 MHz TRL – 2 MHz
Length/Depth Ratio	3	<3 3-5 >5	Ranges have been adjusted due to lack of specimens with high aspect ratios
Flaw Parameters	Ongoing assessment with respect to size distributions, location, orientation, and tilt. Other factors may also be included as assessment progresses.		

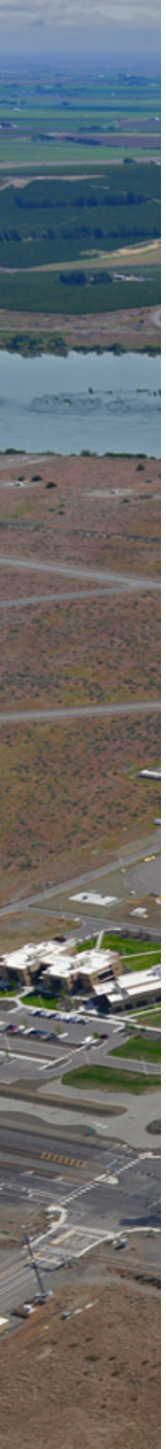
Design of Experiments Matrix

- Data acquisition matrix resulting from the Design of Experiments analysis.
- Specimen list to include austenitic or dissimilar metal welds only.

WALL THICKNESS ≤ 1.6”				
WSS/SS	TW%	Length/Depth Ratio		
		< 3	3 - 5	> 5
	0 - 30%	✓	✓	✓
	30% - 50%	✓	✓	
	>50%	✓		

WALL THICKNESS >1.6”				
WSS/SS	TW%	Length/Depth Ratio		
		< 3	3 - 5	> 5
	0 - 30%			
	30% - 50%		✓	
	>50%			

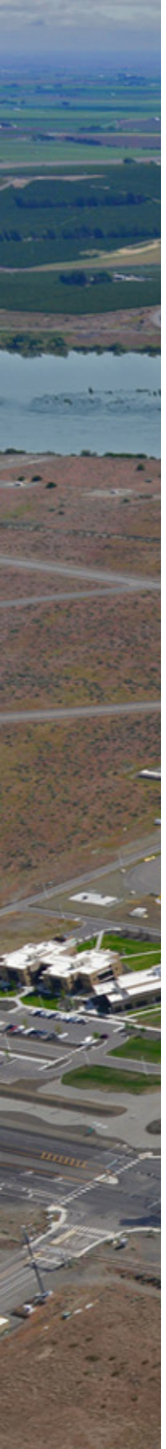
WALL THICKNESS ≤ 1.6”				
DMW (CS/SS)	TW%	Length/Depth Ratio		
		< 3	3 - 5	> 5
	0 - 30%	✓	✓	
	30% - 50%	✓	✓	✓
	>50%	✓		



Data Partitioning

Data has been acquired and partitioned to simulate the following conditions:

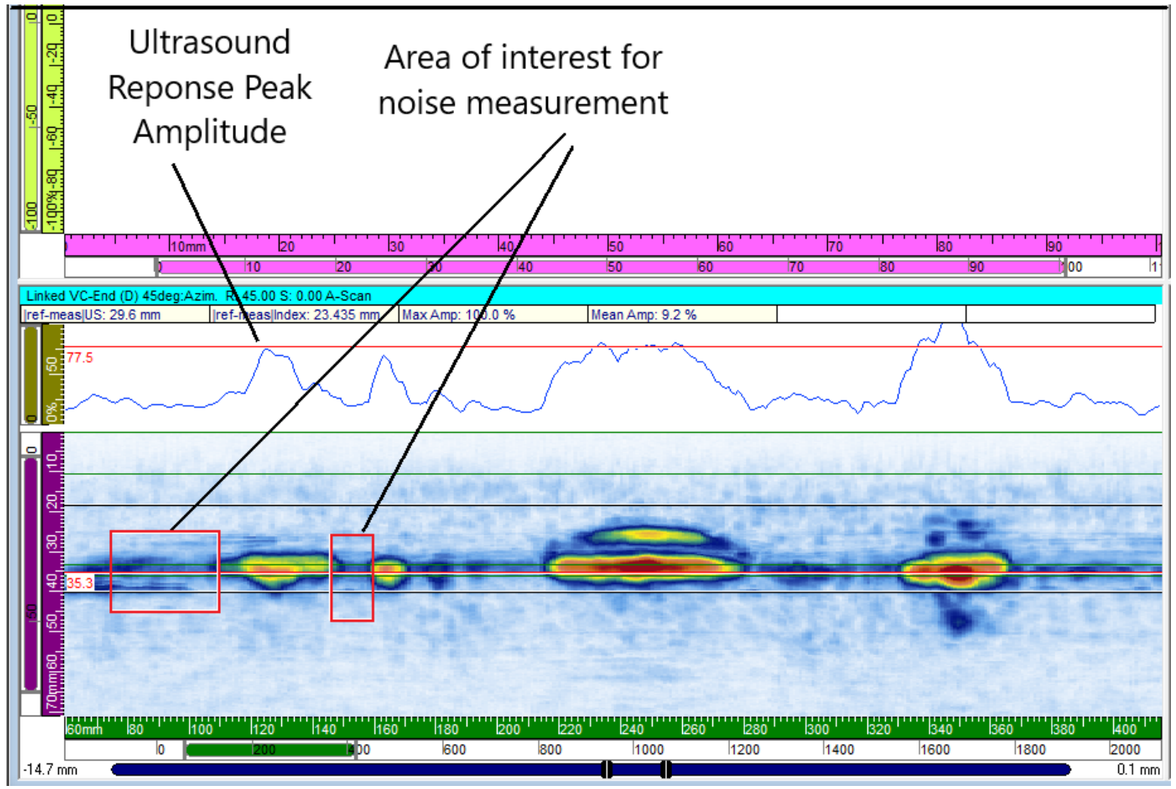
1. No obstructions
   - Unrestricted probe movement across the weld and away from the weld
2. Weld Crown Obstruction
   - Probe cannot move across the weld; however, probe movement away from the weld is unrestricted
3. Component or Support Obstruction
   - Probe can move across the weld; however, an obstruction prevents movement back away from the weld

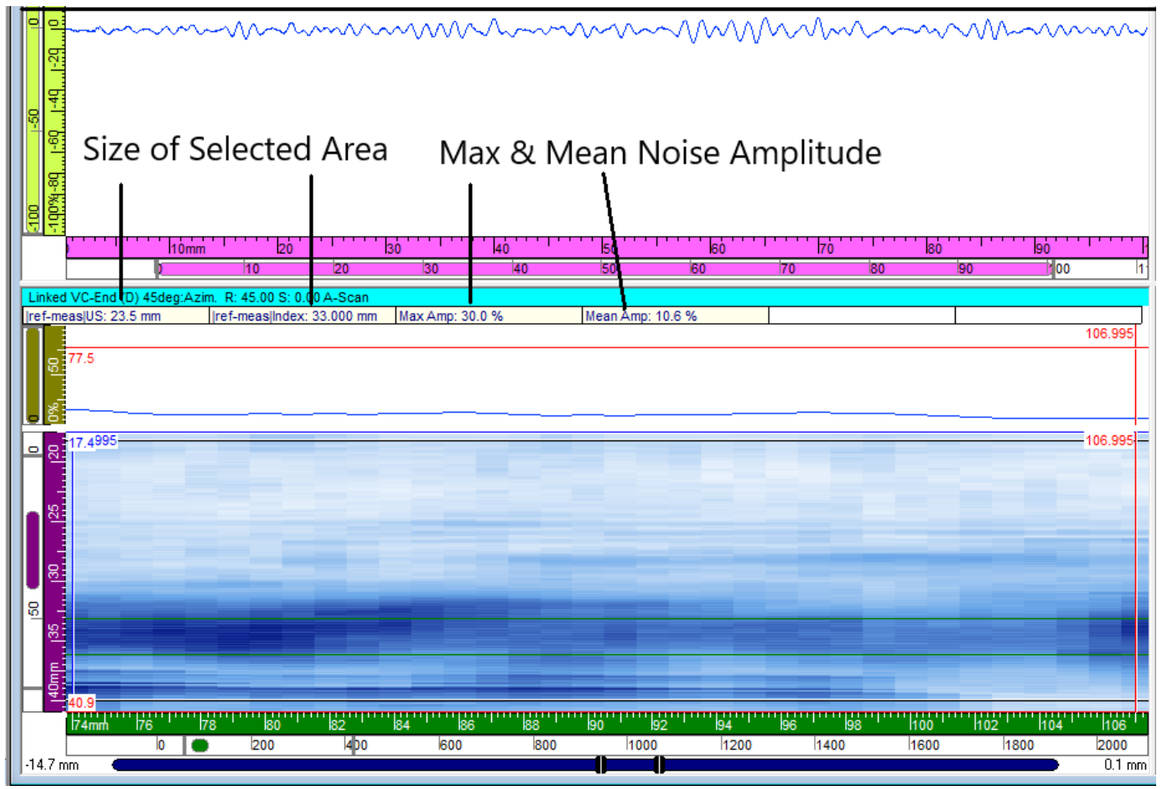


Data Recorded for Each Flaw & Each Probe

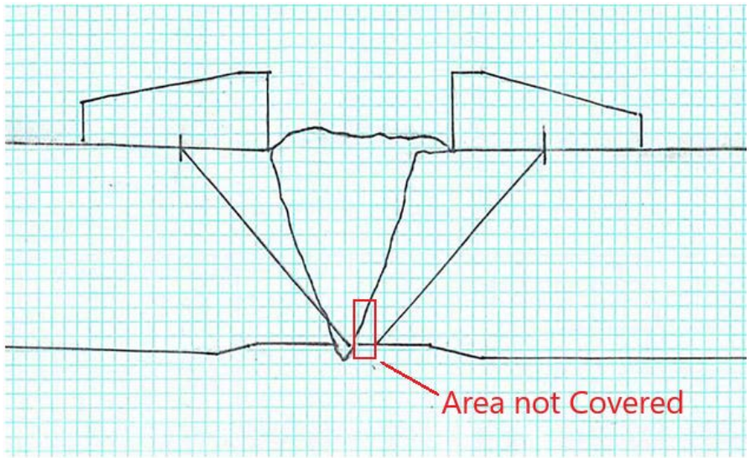
1. Flaw Detected or Not Detected
2. Presence of a Flaw Tip or Not Detected
3. Flaw Response Amplitude
4. Flaw Length at 6 dB Below Max Amplitude
5. Flaw Length at Noise Floor
6. Maximum and Mean Noise on Each Side of the Flaw
7. Signal to Noise Ratio

Determining Signal to Noise

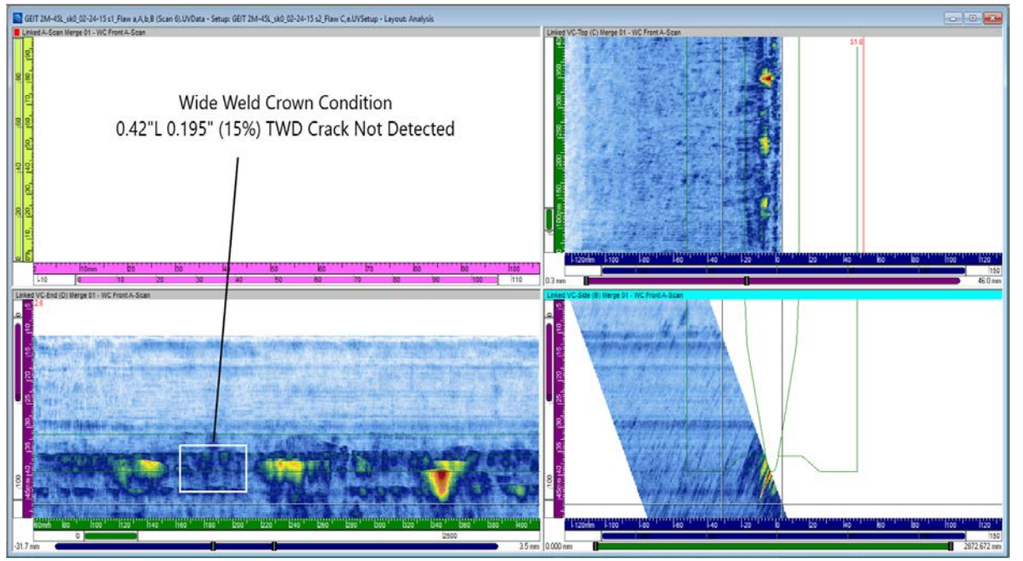




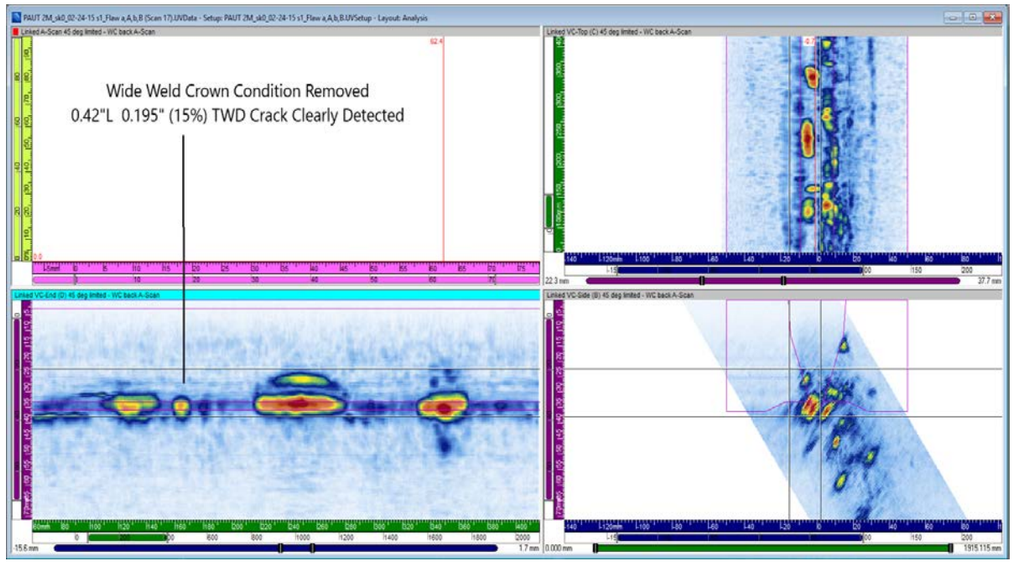
Common Limitation is WSS-WSS Piping



Weld Crown Width Prohibits Coverage of Heat Affected Zone



Missed Detection of Shallow Near Side Flaw and Determining the Full Extent of Deep Flaws

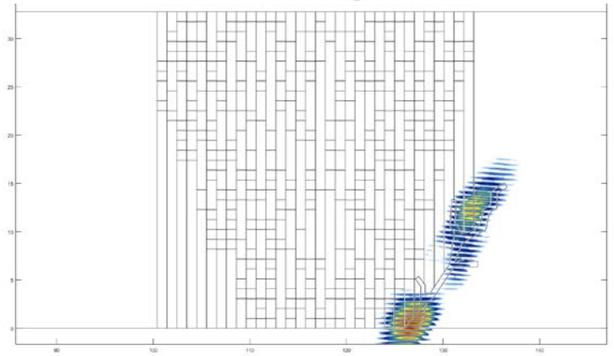


After Weld Crown Removal Shallow Flaw is Detected and Deep Flaw Tips are Identified

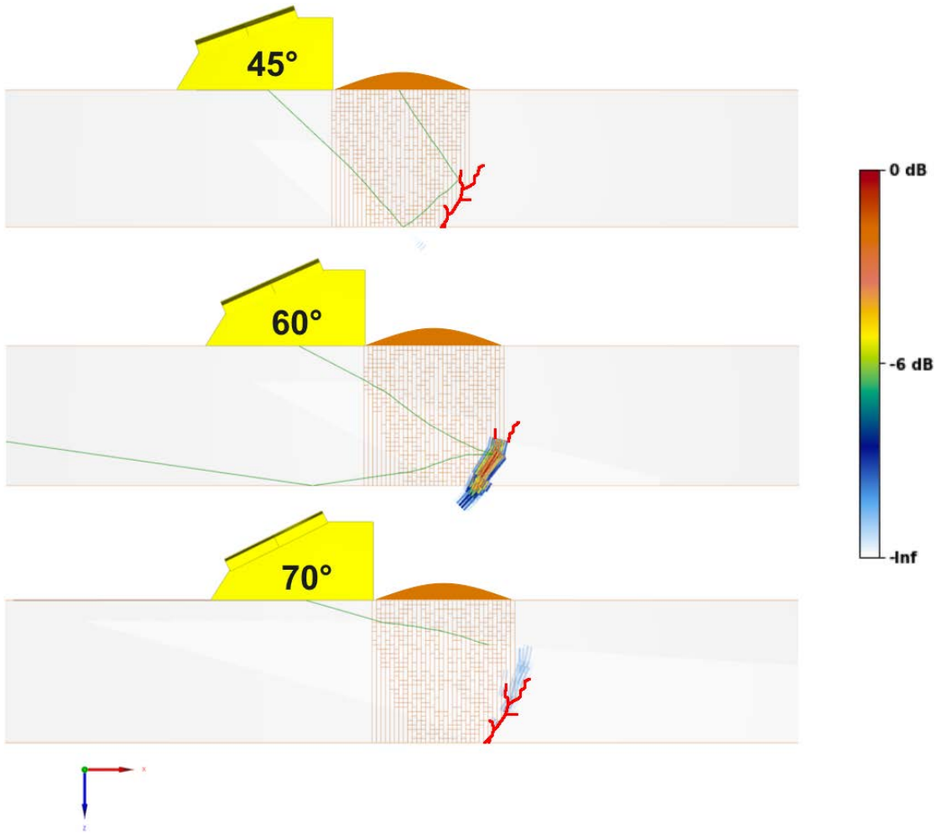
Limited Coverage Flaw Response Simulations

- Probe coverage limited by weld crown obstruction
- Coverage limitation caused:
  - Virtually no response at 45°
  - Incomplete flaw response at 60°
  - Misleading response at 70° (looks like noise or fabrication flaw)

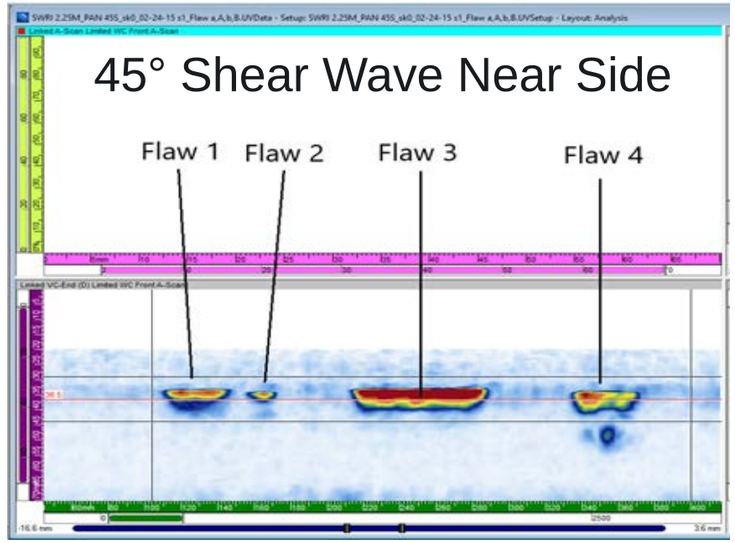
Flaw response simulation, full coverage, 45°

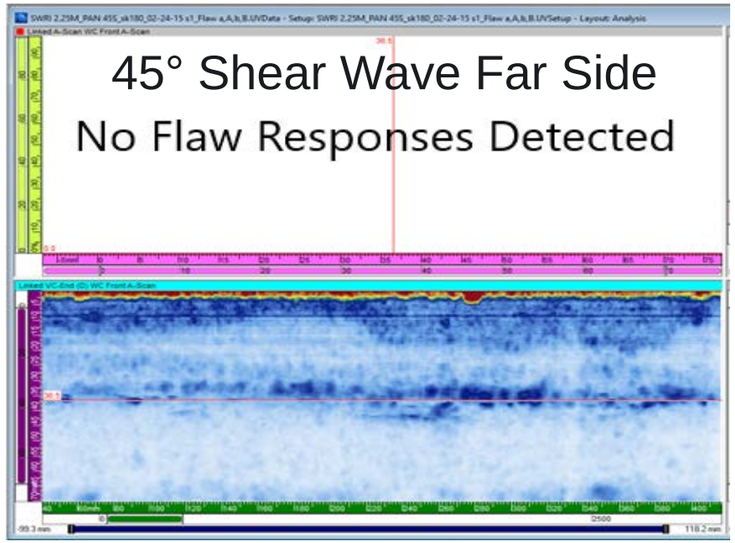


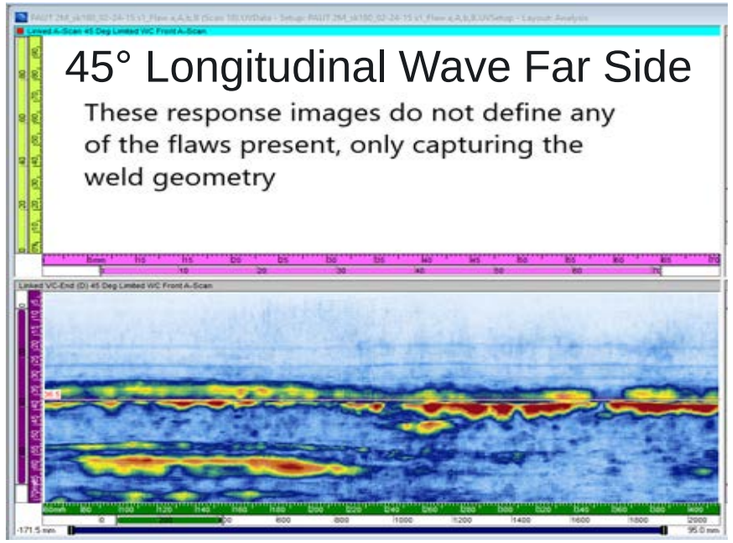
Flaw response simulations with weld crown limitations

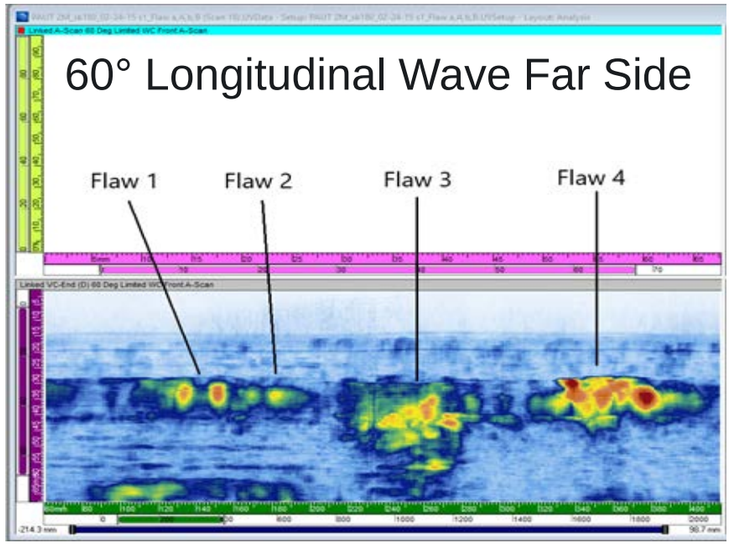


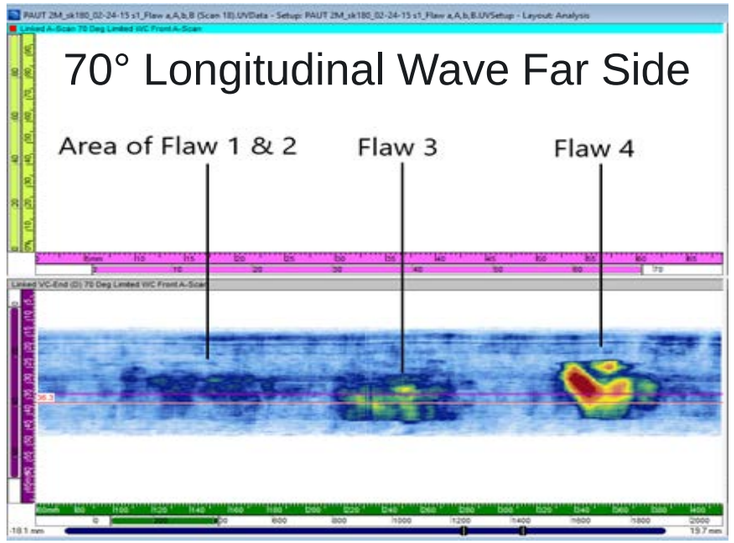
Limited Coverage Actual Flaw Responses



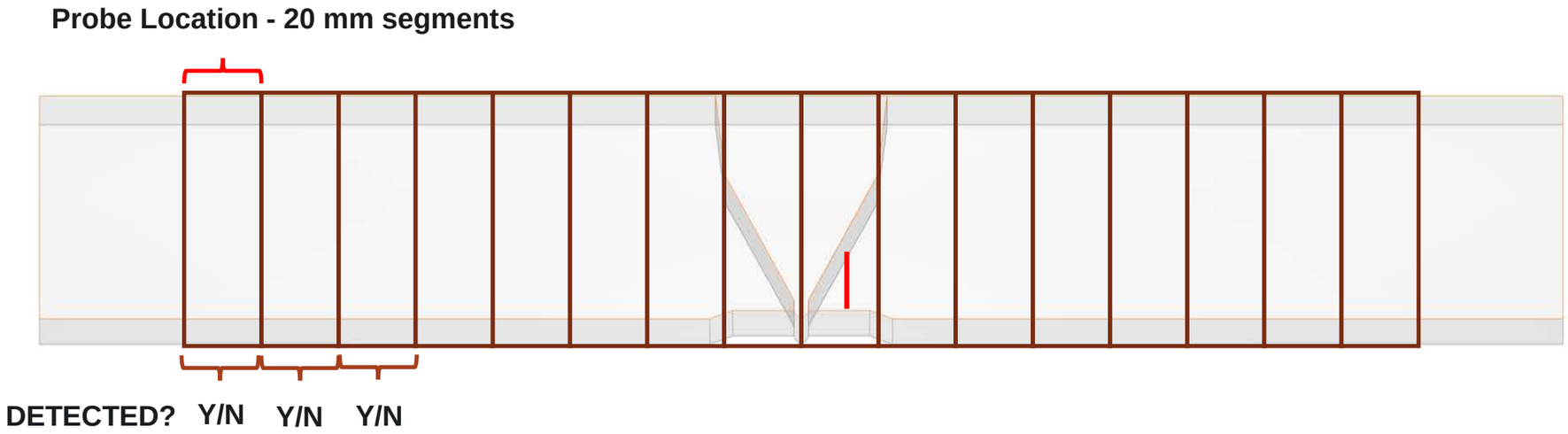




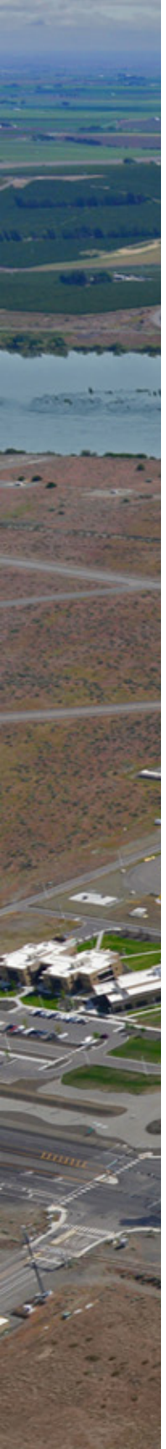




Ongoing Analysis



- Parse data into 20 mm wide sections with 10 mm overlap.
- Determine whether or not the flaw is detected (Yes/No) for each section as objectively as possible (i.e., would an analyst call a flaw from this data?)
- Calculate detectability as a function of probe position and flaw depth.



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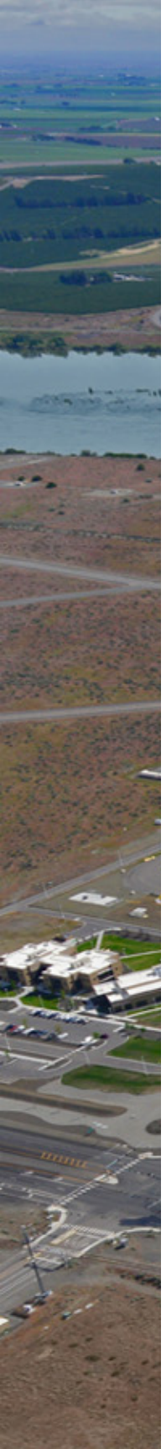
Current Activity

- Complete data collection and analysis activities for WSS-WSS welds
- Creation of Probability of Detection (POD) curves from tabulated stainless steel data
- Technical Letter Report (TLR) March 30, 2020 on Phase 1 wrought stainless to wrought stainless.
- Analysis of dissimilar metal weld data



Summary

- Conditions that limited examination coverage continues to be an industry issue
- The impact a limited examination condition has on the probability of flaw detection must be evaluated and documented.
- The ultrasound response characteristics from a portion of a flaw resulting from inadequate ensonification must be determined in order to enhance the probability of detection

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Thank you