

Notable Failures in Nondestructive Testing

Stephen Cumblidge
June 5 2013

Goals of NDE

- Assure structural integrity of components
- Assure leak tightness of reactor pressure boundary
- Detect flaws before they exceed acceptance criteria
- Detect and size flaws that meet acceptance criteria

When Does NDE Fail?

- Rationalizing away detected defects
- Use of NDE techniques that have not been properly qualified through Appendix VIII blind testing
- Poor implementation of Appendix VIII-qualified NDE procedures
- When Appendix VIII-qualified procedures miss flaws
- When NDE is not Used

Rationalizing away detected defects

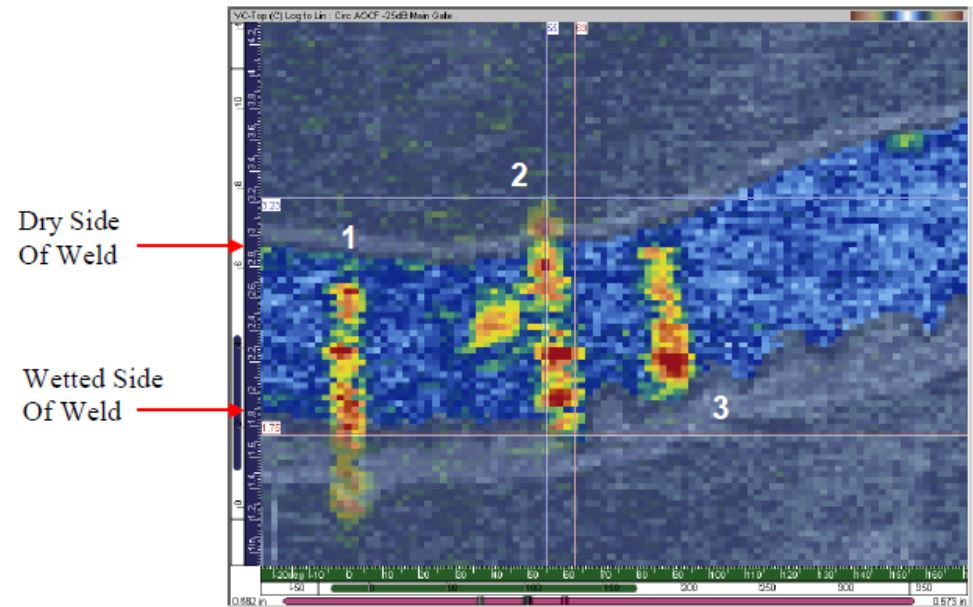
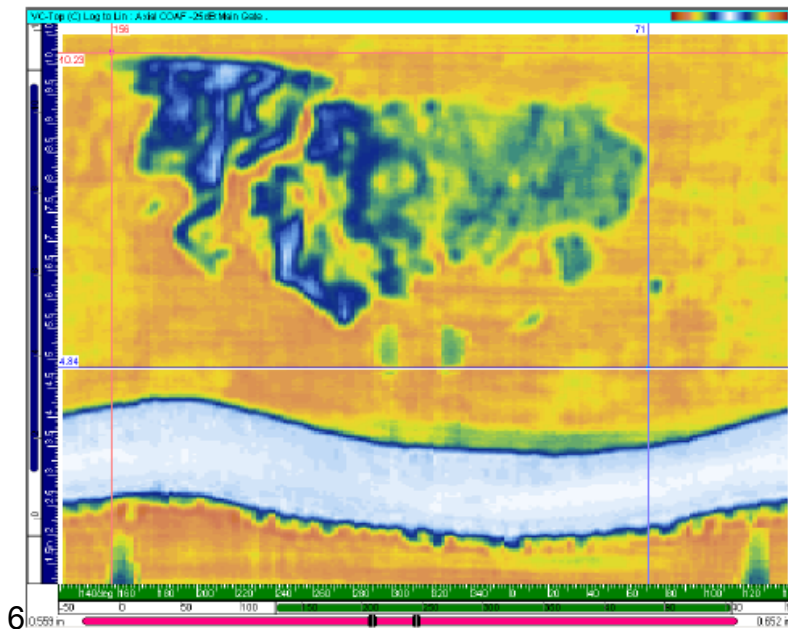
2000 Davis Besse Head Leakage

- NDE failures can happen even when the detection is clear
- Any technique can fail if assumptions are incorrect



Davis Besse 2010

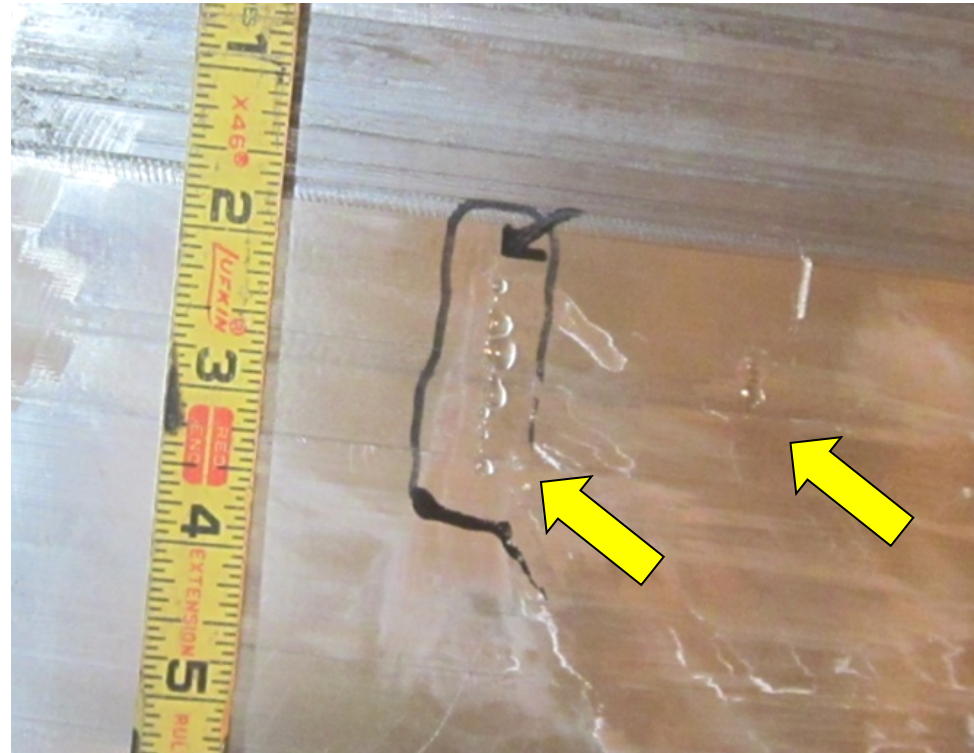
- The replacement pressure vessel head leaked in 2010
- With increased surveillance and a better understanding the degradation was caught quickly
- NDE was used in identifying where the cracking was located



Use of NDE techniques that have
not been properly qualified

North Anna Steam Generator 2012

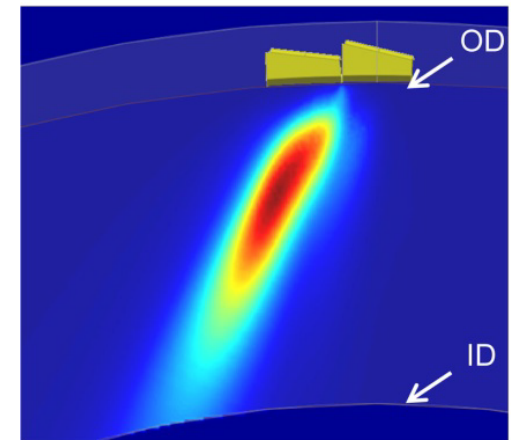
- In March of 2012 at least five axial flaws were missed by an ultrasonic inspection
- The licensee used a site specific mockup to qualify the inspection procedure as PDI has no matching test blocks
- The licensee used an encoded phased array technique to search for circumferential flaws
- The licensee used an unqualified manual ultrasonic search unit to search for axial flaws



Factors in North Anna 2

- The North Anna 2 root cause analysis described inadequate training and oversight
- Team scanning was used
- The search units had not been qualified via the blind Appendix VIII process
 - The ultrasonic search units were more than ten degrees off of the specified angle
 - The ultrasonic search units were unable to get a strong signal off the end of the site specific mockup block
 - Modeling shows that the search units were not optimized for the component
- The probes looked nearly identical but were “Sided”, meaning that if the wrong probe was used the inspection quality would be severely degraded

The average POD required
To miss five flaws is $\approx 13\%$



Sound beam

Poor implementation of qualified techniques

Duane Arnold 2007

- Two recirculation riser nozzle-to-safe end dissimilar metal welds at Duane Arnold, RRC-F002 and RRF-F002, contained surface-breaking cracks
- Evidence shows that the cracks were present as early as 1999
- Inspections conducted in 1999 and 2005 failed to detect the cracks
- The cracks were found during an inspection in 2007 and sized at \approx 6 inches long and 74% through wall in RRC-F002 and \approx 6 inches long and 55% through wall in RRF-F002

Missed Flaws at Duane Arnold

- The 1999 inspection procedure was not Appendix VIII qualified and the weld crown reduced inspection coverage
 - Evidence for the flaws was present but no call was made
- In the 2005 inspection the weld crowns were removed and an Appendix VIII qualified procedure was used
- The 2005 inspection unfortunately used an inappropriate couplant and yielded a low-quality scan
 - The procedure was capable of detecting the flaw
 - The inspectors should have rescanned to obtain better coverage
 - Low quality evidence for the flaw was present but no call was made

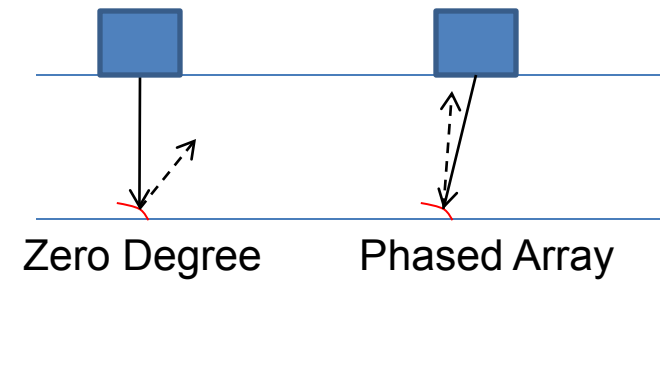
When Appendix VIII Qualified Procedures Miss Flaws

Diablo Canyon 2013

- Diablo Canyon had alloy 52 weld overlays installed in a several pressurizer welds in 2008
- An acceptance examination was performed using an Appendix VIII qualified conventional manual ultrasound procedure, including a zero degree inspection to find fabrication flaws
- An examination in 2013 using manual phased array UT found several laminar flaws missed by the acceptance examination
- One of the flaws was 16 inches long and a second was essentially 360 degrees around the overlay

Diablo Canyon 2013

- Both the 2008 and 2013 techniques were Appendix VIII qualified
- The zero degree beam inspection procedure used for the acceptance examination did provide small responses from the flaws but the flaws were not all found were not sized correctly in 2008
- The procedure used in 2013 used a manual phased array probe that included many more angles than were used in the acceptance examination
- The laminar flaws were at a slight angle and did not peak at zero degrees
- The NRC met with PDI to discuss the Mockups used at PDI and the path forward



When NDE is Not Used

Leaks in Uninspected Components

- Many components prone to leaking are not volumetrically inspected
 - Partial Penetration Welds
 - Pressurizer Heater Sleeves
 - Socket Welds
 - Small Diameter Welds
- If the goal of NDE is to prevent leakage these areas would need to be addressed with more aggressive NDE

Conclusions

- No inspection procedure can succeed if the inspectors and/or the licensees rationalize away detected indications
- When Appendix VIII qualified procedures are used appropriately, ultrasonic inspections have shown to have a high reliability
- The reliability of inspection procedures declines sharply when the procedures deviate from the Appendix VIII-qualified procedures
- Even Appendix VIII qualified procedures can miss flaws
- If the NRC and industry goal is to prevent leakage NDE will need to be implemented in new areas