Calvert Cliffs Pressurizer Safety Relief Nozzle-to-Safe-End DM Weld Flaw
EPRI Nondestructive Evaluation Technology Week
June 2016
Overview

- During the 2016 RFO examination of the Unit 1 pressurizer safety relief valve (RV-201) 4-inch dissimilar metal (DM) safe end weld, an axial indication contained within the weld was identified using phased-array automated UT.
- This indication was identified to be approximately 81.6% thru-wall from the interior diameter
  - Second, confirmatory inspection using manual phased array UT completed by Level III confirmed the indication
  - Reviews by EPRI, Exelon and NDE Vendors supported the finding
  - This is a significant change in the reported through wall extent from previous examinations (2006 and 2010)
  - The weld had the Mechanical Stress Improvement Process (MSIP®) applied in 2006.
- Due to the unacceptable examination results, Calvert Cliffs implemented a previously approved relief request and installed a full structural weld overlay repair
- Past operability was confirmed by analytical evaluation
- All twenty-seven N-770-1 DM welds were examined in the 2016 RFO with no additional unacceptable flaws found
Unit 1 Alloy 600 DM Weld Exam History Summary

Twenty-seven (27) N-770-1 Dissimilar Metal (DM) Butt Welds (> 1” NPS)
- 20 cold leg DM welds (zinc injection mitigation & probabilistic/flaw tolerance evaluation model)
- 7 hot leg/pressurizer DM welds (MSIP mitigation 2006)
  - 2006: Three potential PWSCC flaws were identified on Unit 1 using manual conventional UT (WesDyne).
    - 4” RV-201 pressurizer nozzle safe end (0.6” axial at ID, 8% thru wall [within Code allowable]) – 2016 RFO Issue
    - 12” surge line to hot leg (2.4” circumferential at ID, 25% thru-wall)
    - 2” hot leg drain (0.5” circumferential at ID, 18% thru-wall)
  - All were mitigated by MSIP and re-examined by automated conventional UT (WesDyne)
  - 2008: The 12” surge line and 2” hot leg drain welds were re-examined with no indication found (manual conventional UT)
  - 2010: All three welds were re-examined using manual phased array (Structural Integrity Associates (SIA))
    - No change in the 4” pressurizer safe end weld indication; separate embedded non-PWSCC flaws identified
    - No detectable indications were seen in the 12” surge line and 2” hot leg drain welds
  - 2016: Change in 4” pressurizer safe end weld indication characterization from 8% to 81.6% thru-wall. Examination of the 12” surge line and 2” hot leg drain welds were acceptable with no significant changes in the flaws being observed.
Calvert Cliffs Unit 1 4-inch Pressurizer Safety Relief Nozzle-to-Safe-End DM Weld (RV-201)
Final call in 2010 grouped two embedded non-PWSCC flaws
Final call in 2010 grouped two embedded non-PWSCC flaws

2016 Indication
2016 RV-201 Examination Flaw Geometry

- Flaw as imaged with Phased Array UT
- Flaw as illustrated with CAD software
Cause Investigations

Potential Causes Considered (see next slides):
• MSIP Related
• New Indication
• Pre-existing Flaw/NDE Related
Potential Cause – MSIP Related

• Documentation Review
  – Westinghouse and NuVision performed review of documentation associated with the 2006 MSIP application in 2010
    • Original Finite Element Analysis
    • Evaluation of As-Found Flaws
    • Field Service Report Package/Data Results
    • Post-MSIP stress results (axial and hoop stresses)
  – No errors or anomalies suggesting the improper analysis or application of MSIP were identified
  – Review by Exelon personnel also identified no errors or anomalies

• In Field Measurements
  – Westinghouse performed physical measurements using tape measures and calipers and verified that as-found conditions were acceptable and within process allowances
  – Measurements were re-performed in 2016 RFO and confirmed prior results

• Conclusion: **MSIP was applied correctly** (unlikely cause)
**Potential Cause – New Indication**

- Not expected to occur since weld had been mitigated – no other instance of new indications once MSIP applied correctly
- MSIP verified to have been performed correctly in 2006
- Previous indication confirmed at this same location
- Indication is at area of previous shop repair which are known to be the location of embedded manufacturing flaws.
- Improved NDE technology has greater sensitivity and software diagnostic capability
- Conclusion: *Unlikely cause*
Potential Cause – Pre-existing Flaw/NDE Related

Pre-existing Flaw/NDE Related
- Industry operating experience related to new technology discovering historical flaws
  - At least 3 previous industry examples of flaws > 30% through-wall identified in previous MSIP components (years later)
  - Auto-encoded technique uses software which enhances technicians ability to evaluate
  - Lower frequency used in 2016 resulted in more energy and better detection
  - Flaw could have existed beyond MSIP’s effectiveness but undetectable by technology at that time (2010 – manual-encoded)
- Conclusion: **Most Likely Cause**

- NDE Level III personnel from EPRI, LMT, IHI, Wesdyne, Westinghouse and Exelon reviewed the historical examination data, compared it to the 2016 examination results and collectively agreed on the cause of the change in flaw characterization from 2006 to 2016.
RV-201 NDE Review Results: Possible %TW for Each Exam

- Flaw reported to be 8% through wall in 2006.
- The 2016 analyst indicated that there is no evidence of an upper tip or embedded indication.

- Flaw reported to be 8% through wall in 2006.
- The 2016 analyst identified evidence of an embedded indication in the upper volume of the weld near the previously identified axial flaw.
- The 2016 analyst was unable to accurately report the position of the embedded indication with respect to the previously identified axial flaw due to data issues.

- In 2010 the flaw remained unchanged from what was previously recorded.
- The 2016 analyst identified evidence of an embedded indication above the axial flaw.
- This embedded indication was imaged in the data with the ID connected axial flaw but there is no evidence that the two flaws are related.

- In 2010 the axial flaw remained unchanged from what was previously recorded.
- The 2010 examiner also reported the presence of an indication which was related to the acoustic interface of a weld repair.
- Unable to correlate the circumferential location of the acoustic interface indication.

- The 2016 examiner reported the size of the previously identified axial flaw to be 81.6% through wall.
Root Cause Evaluation was completed March 2016 and site approved April 2016. Supported by EPRI NDE Center Internal Review Report.

- **Root Cause(s):** Limitations in UT sizing data collection and analysis techniques in examinations of this weld prior to 2016 were unable to connect the detected inner diameter axial indication, originally detected in 2006, to the full through-wall signal response of the flaw. Therefore, the flaw depth was incorrectly sized in 2006 and 2010.

- **Contributing Cause(s):** A mechanical stress improvement process (MSIP®) compressed the flaw making the flaw at the upper (deeper) limit more difficult to associate with the ID connected flaw.

- **Corrective Actions:** Perform a weld overlay with corrosion resistant material to restore weld 4-SR-1006-1 (RV-201) to meet ASME Code requirements.

- **Extent of Condition:** All Unit 1 Alloy 82/182 dissimilar metal (DM) butt welds 2” NPS and greater were inspected in the 2016 RFO and all Unit 2 DM welds 2” NPS and greater will be inspected during the Unit 2 2017 RFO. There are three DM welds on Unit 1 that had PWSCC flaws prior to applying MSIP®. Unit 2 has no DM welds that displayed PWSCC flaws prior to applying MSIP®.

- **Extent of Cause:** Applicable to Alloy 82/182 DM butt welds mitigated by MSIP® with prior UT indications only. All DM welds 2” NPS and greater will be inspected with the technology used for identification of this indication. Exelon continues to pursue the latest technologies for NDE examinations.
Comparison of Flaw Signal & Post-MSIP® + Operating Stresses

Plot of 2006 Post MSIP®+Operating Stress Calculated Hoop Stress Through Wall at Nominal Flaw Position (Path along butter/weld interface) aligns relatively well with the flaw signal

• Signal is weaker where compressive stress is highest
Industry/NRC Interaction Summary

- Industry calls held with MRP per industry guidance on 2/19 with follow-up information communicated 2/22
  - Aligned with plan for repairs without performing boat sample
- Utility call with NRR held 2/24 to inform the staff we would be submitting a report per 10CFR50.55a(g)(6)(ii)(F)(6). Staff concurred there was no NRC approval required for this report.
  - 10CFR50.55a(g)(6)(ii)(F)(6) states: “For any mitigated weld whose volumetric examination detects growth of existing flaws in the required examination volume that exceed the previous IWB–3600 flaw evaluations or new flaws, a report summarizing the evaluation, along with inputs, methodologies, assumptions, and causes of the new flaw or flaw growth is to be provided to the NRC prior to the weld being placed in service other than modes 5 or 6.”
  - Report was submitted to the staff 2/25.
- The EPRI NDE IC issued Alert letter 20160509-001 providing a recommendation based upon Calvert Cliffs experience.
Questions?