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PWROG-NRC Meeting to Discuss a Supplement to WCAP-15987-P/NP-A Rev. 2 for Reduction in PT Exam Frequency

August 8, 2024

Agenda

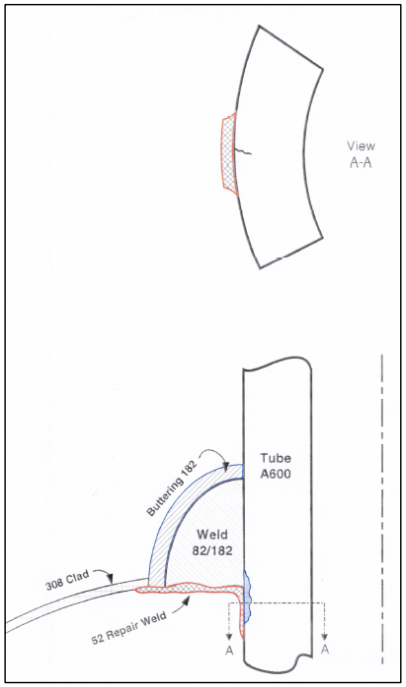
- Introductions
- Objective of the Meeting
- Background
- Proposed Supplement to WCAP-15987-P/NP-A, Rev. 2
- EFR Performance History
- Improved Examination Requirements
- Fracture Analysis for EFRs
- Weld Process Improvements
- Summary and Conclusions

Objective of the Meeting

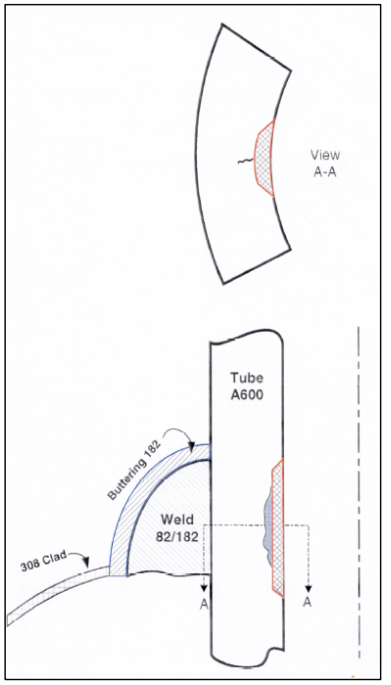
- To obtain NRC feedback regarding a supplement to WCAP-15987-P/NP-A, Rev. 2, “Technical Basis for the Embedded Flaw Process for Repair of Reactor Vessel Head Penetrations,” to revise the Penetrant Test (PT) examination frequency.

Background

- The embedded flaw repair (EFR) process is used to repair flaws in Alloy 600 RV head penetrations and welds
- WCAP-15987-P/NP-A, Rev. 2 was approved by the NRC in 2003 (ML040290246) and provides the basis for the repair method
- The EFR isolates the PWSCC susceptible material from the primary water environment with PWSCC-resistant Alloy 52M weld metal preventing further degradation
  - OD Repair
    - A minimum of 3 weld layers over the J-groove weld
    - A minimum of 2 weld layers over the A600 nozzle
  - ID repair (only one application in the US)
    - Minimum excavation of 3/16 inches
    - A minimum of 3 weld layers
    - The ID repair surface must be flush with the nozzle ID
- A plant-specific flaw growth analysis is performed to demonstrate the acceptability of the EFR until the allowable flaw size is reached



OD Flaw Repair



ID Flaw Repair

Background

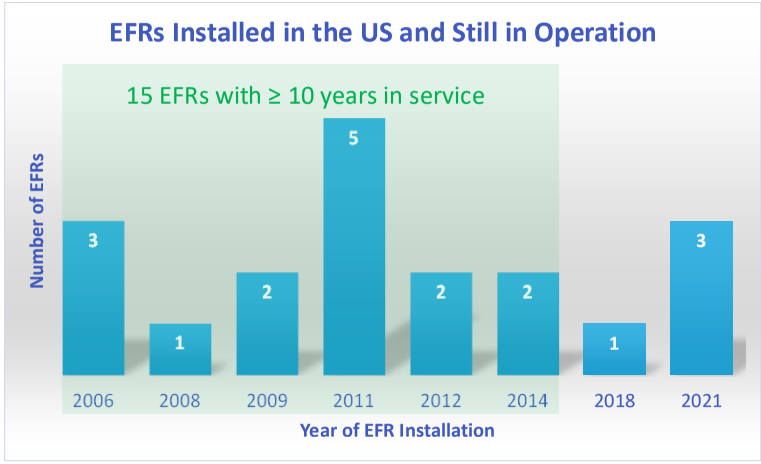
- The NRC Safety Evaluation (SE) for WCAP-15987-P/NP-A, Rev. 2 requires PT examinations to be performed every refueling outage
  - The NRC granted relief for performing PT examinations to every other refueling outage via relief requests after acceptable results per NB-5350 are confirmed for two consecutive refueling outages after the repair [examples: ML18227A733 (Beaver Valley Unit 2), ML17062A426 (Byron Units 1 & 2), ML21117A129 (Catawba Unit 2)]
- These PT examinations result in radiation exposures of up to 3.3 REM (depending on number of penetrations and locations), even if surface flaw removal or reduction to acceptable dimensions is not required
- PT examinations every refueling outage are no longer needed:
  - The historical performance of the EFR has been excellent
  - Current examination requirements per 10CFR50.55a(g)(6)(ii)(D) provide adequate detection of degradation and leakage without the need for PTs
  - The welding process has also been improved since 2003 when the WCAP was approved

Proposed Supplement to WCAP-15987-P/NP-A, Rev. 2

- Revise the PT examination frequency via a Supplement to WCAP-15987-P/NP-A Rev. 2
  - A surface examination will be performed during the first and second refueling outage after installation
  - If the first and second surface PT examinations are confirmed to be acceptable per NB-5350, the surface examination frequency will transition to once every successive ISI interval
    - If the first or second examination identify unacceptable results per NB-5350, then a flaw reduction to an acceptable size per NB-5352 or welded repair will be performed, and a surface examination will be required during subsequent refueling outages until acceptable results are achieved per NB-5350, after which the surface examination frequency shall transition to once every successive ISI interval
    - VE and UT examinations will continue to be performed in accordance with 10CFR50.55a(g)(6)(ii)(D), which requires implementation of Code Case N-729-6 with conditions, or NRC-approved alternatives

EFR Performance History

- The EFR has an excellent performance history
- The repair method was first implemented in 1996
- There have been EFRs installed at 18 separate units since 2001
  - 13 US units
  - 5 International units
  - 60 total penetrations
- 19 repairs remain in operation in the US at 6 units
  - 3 EFRs have been in continuous service since 2006 (18 years in service)
  - 1 in service since 2008 (16 years in service)
  - 2 in service since 2009 (15 years in service)
  - 5 in service since 2011 (13 years in service)
  - 8 EFRs installed after 2011 (3 to 12 years in service)
  - **Total of 15 EFRs with ≥ 10 years in service**



- The historical PT examination results show that EFRs with repaired indications typically have acceptable results (no unacceptable indications per NB-5350) after 2 operating cycles
- There has been no reported flaw growth or new flaws within the repaired material

Improved Examination Requirements

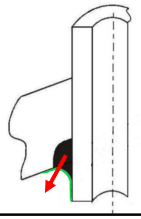
- When WCAP-15897-P/NP-A, Rev. 2 was approved by the NRC in 2003, the current ASME examination requirements, with conditions in accordance with 10CFR50.55a were not in place. RV head examinations were performed in accordance with NRC Order EA-03-009.
- ASME Code Case N-729 was prepared in response to the NRC Order and was published in 2004. Examination requirements for RV heads have continued to evolve over several revisions of N-729 and currently provide enhanced detection of leakage and degradation.
- Current examination requirements for RV heads with A600 penetrations and welds are performed in accordance with the requirements and conditions in 10CFR50.55a(g)(6)(ii)(D). These requirements include:
  - UT leak path examination, which provides detection of potential leakage through the j-groove welds.
  - VE of the RV head, which provides leakage monitoring every refueling outage.

Fracture Analyses for EFRs

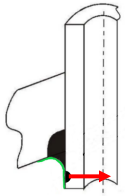
- Plant specific ASME Section XI fracture analyses have been performed for all EFRs based on conservative postulated flaws considering the following:
  - Postulated flaws encompassing the entire J-groove weld have been evaluated for fatigue crack growth through the weld repair
  - Head penetration base metal flaws with aspect ratios (l/a) from 2 to 10 have been evaluated
  - Level A, B, C, and D operating stresses have been evaluated using FEA
  - Residual weld stresses were included in the fracture analyses
  - Design transient cycles were considered
  - Location (uphill and downhill) were considered
  - Both Axial and Circumferential flaw orientations were considered

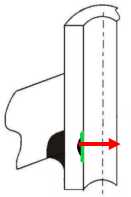
Summary of Historical Fracture Analysis Results

- Flaw growth through J-groove weld EFR **(Limiting Case)**
  - Limiting case > 10 years
  - Plants operating in the US > 20 years



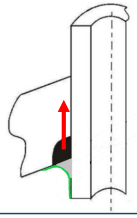
- Flaw growth through the reactor head penetration
  - Considering 20 years of flaw growth for postulated flaws with an aspect ratio of 6 (l/a = 6)
  - US operating plants show tolerance for initial flaws > 40% through-wall





ID flaw case not limiting

- Flaw growth through the RV head
  - Acceptable for > 40 years for all cases



Worst-case flaw scenarios demonstrate acceptable results for greater than 10 years

Weld Process Improvements

- Weld process improvements have reduced the potential for EFR weld defects.
- Since 2003, when WCAP-15987-P/NP-A, Rev. 2 was approved, the welding process has been significantly improved to reduce the potential for welding defects
- Prior to 2008, Alloy 52 filler metal was used for EFRs
- Since 2008:
  - Alloy 52M was introduced to improve weldability
  - Stainless steel (ER309L) buffer layers were added to eliminate hot cracking at the cladding interface
    - Buffer layers extend at least 0.5-inches beyond the cladding interface to eliminate hot cracking
  - Tighter controls over the welding parameters have also been implemented since 2003 SM0

Slide 11

SM0 I think this is better wording.
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Summary and Conclusions

- PT examinations of EFRs performed every refueling outage result in significant and unnecessary levels of radiation dose to plant personnel
- PT examinations performed every ISI interval after the first two operating cycles will provide an acceptable EFR surface examination frequency while maintaining ALARA principles for radiation exposure and reduce the cost of the examinations
- Operating experience over 28 years shows excellent performance of EFRs
- Current examination requirements and conditions in 10CFR50.55a(g)(6)(ii)(D) provide leakage monitoring every refueling outage.
- Worst-case fracture analysis results demonstrate acceptable operation for a minimum of 10-years, though plant-specific fracture analyses are performed for each EFR demonstrating acceptability
- Weld process improvements since 2003 have reduced the potential for EFR weld defects
- Submit the draft Supplement to WCAP-15987-P/NP-A Rev. 2 (targeted for January 30, 2025) to be discussed in a Robust Pre-Submittal Meeting.
- Docket the Supplement to WCAP-15987-P/NP-A Rev. 2 targeted for February 20, 2025.