ASSESSMENT OF SMALL DIAMETER DISSIMILAR-METAL WELD INSPECTION INTERVALS USING XLPR

xLPR User Group Meeting

August 18, 2021

Key Research Question

- With the updated Alloy 82/132/182 crack growth rates in EPRI report MRP-420, Rev. 1, is a change in the reinspection interval warranted for PWR cold leg dissimilar metal (DM) butt welds from those that are currently established in ASME Code Case N-770?
  - Code Case N-770 was developed using crack growth rates of Alloy 82/182 from MRP-115

Excerpt from ASME Code Case N-770-6, Table 1

Item	Parts	Inspection Requirement
B-1	Unmitigated butt weld at Cold Leg operating temperature ≥ 274°C (525°F) and < 304°C (580°F), less than NPS 14 (DN 350)	Visual exam once per interval Volumetric exam every second inspection period not to exceed 7 years
B-2	Unmitigated butt weld at Cold Leg operating temperature ≥ 274°C (525°F) and < 304°C (580°F), NPS 14 (DN 350) or larger	Visual exam once per interval Volumetric exam once per interval

Methodology

- Individual steps performed are as follows:

1. Cold leg DM butt welds and the various configurations from each Nuclear Steam Supply System (NSSS) plant type were reviewed and grouped by size
2. Additional input data were collected, including welding residual stresses, material properties, environmental conditions, and inspection detection capabilities
3. Probabilistic fracture mechanics (PFM) evaluations were performed using the recently released xLPR (Extremely Low Probability of Rupture) software
4. Deterministic fracture mechanics (DFM) evaluations were performed using average parameters to provide verification of the PFM analysis results

Component Grouping

- A compilation of all the cold leg temperature DM butt weld components was developed for the U.S. operating pressurized water reactor (PWR) fleet
  - NSSS designs from Westinghouse, Combustion Engineering, and Babcock & Wilcox were considered
  - All welds less than reactor coolant loop (RCL) size were grouped as either medium or small
    - Medium > nominal pipe size (NPS) 8 (DN200)
    - Small < NPS 8 (DN200)
      - The small size was further divided based on wall thickness
- Bounding geometry and stresses were determined for each grouping

Westinghouse

- Auxiliary Head Adapter Nozzle – Small Diameter

Combustion Engineering

- Charging Nozzle – Small Diameter
- Spray Nozzle – Small Diameter
- Letdown/Drain Nozzle – Small Diameter
- Safety Injection Nozzle – Medium Diameter

Babcock & Wilcox

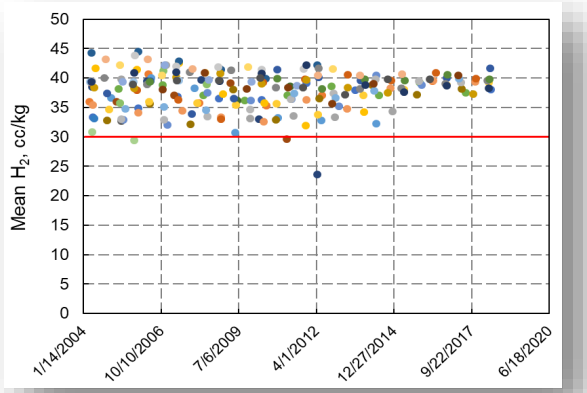
- High Pressure Injection Nozzle – Small Diameter
- Letdown/Drain Nozzle – Small Diameter
- Core Flood Nozzle – Medium Diameter

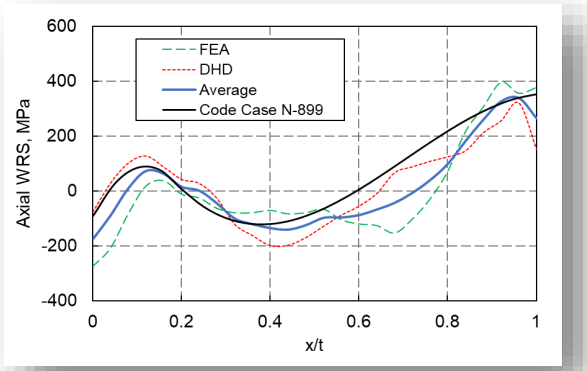
PFM Methodology

- The PFM evaluations were performed using the xLPR software
- Probabilistic analysis considers three inservice inspection (ISI) scenarios
  - Current 7-year interval using Code Case N-770 inspection criteria based on MRP-115 *(baseline)* and MRP-420, Rev. 1 crack growth rates
  - Investigating 10-year interval with MRP-420 crack growth rates
  - Also included mixed ISI cases representing two ISI intervals of 7 years followed by 10-year intervals

Inspection Scenarios (at Years)		
ISI 1	ISI 2	ISI 3
7, 14, 21, 28, 35, 42, 49 (every 7 years)	10, 20, 30, 40, 50 (every 10 years)	7, 14, 24, 34, 44 (two 7 years + every 10 years)

PFM Methodology (cont'd)

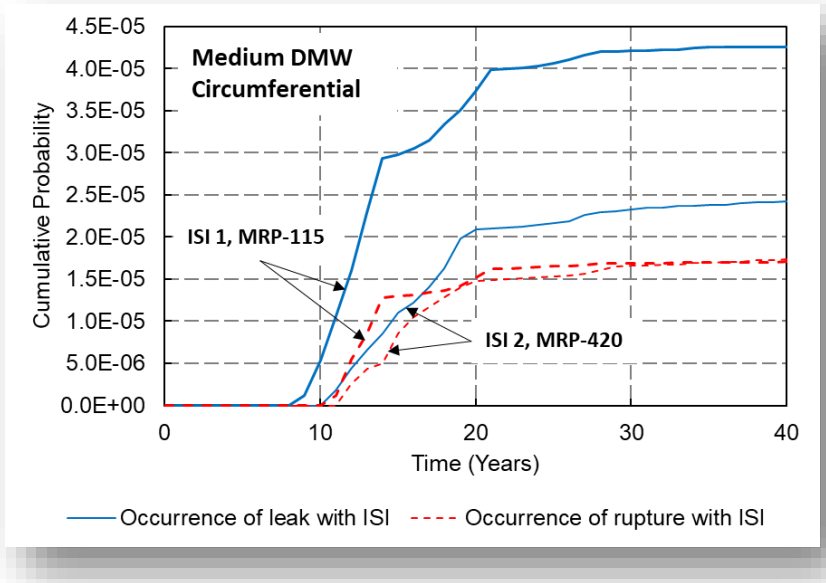




- Operating temperatures, water chemistry, and operating loads were collected for operating plants
- A pre-existing, single, primary water stress-corrosion cracking (PWSCC) flaw in the DM butt weld was assumed with no additional initiation during the evaluation period
  - Consistent with the MRP-139 and ASME Code Case N-770 bases
- Welding residual stresses included the effects of inside diameter weld repairs
- The material properties required for flaw stability are obtained from the material library of xLPR V2.1
- The probability of detection curves from MRP-262, Rev. 3 were used

PFM Methodology (cont'd)

- From the PFM evaluations, probabilities of leak and rupture were calculated
- The acceptance criterion adopted for this study: increase in failure probability per year must be less than 1×10^{-6}
  - Consistent with U.S. NRC Regulatory Guide 1.174 as discussed in the development of the proposed xLPR leak-before-break acceptance criteria



PFM Results

- In total, 24 base cases were evaluated to compare the change in failure probability due to relaxing the inspection interval
  - An additional 5 sensitivity studies were also evaluated

- For the Medium DM butt weld, the changes in leak and rupture probabilities were either zero or negative, which indicates that the proposed 10-year inspection interval satisfies the acceptance criteria

- For Small DM butt welds, the changes in leak and rupture probabilities demonstrated that the proposed 10-year inspection interval is acceptable if two 7-year inspections have been previously performed

Conclusions

- The evaluation demonstrated that the failure probability increase for small and medium diameter DM butt welds was within the acceptance criteria when comparing the current requirements (7 years) and the proposed alternative inspection frequency (10 years)
  - For Small DM butt welds the conclusion is conditional on two 7-year inspections have been previously performed
- The work included bounding values that are intended to be generally representative of the fleet based on various configurations; however, the following areas need to be addressed to demonstrate plant-specific applicability
  - Geometry and stress
  - Welding residual stresses
  - Environmental conditions (temperature and hydrogen addition)
- EPRI MRP-456 should be reviewed for further details
  - Also see PVP2021-62560 for a summary