

AMP XI.11B, Cracking of Nickel Alloys, BMNs

Robin Dyle and Eric Blocher

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GALL-SLR

- In addition, this program performs a baseline inspection of bottom-mounted instrumentation (BMI) nozzles of reactor pressure vessels (RPVs) using a qualified volumetric examination method. The inspection is conducted on all susceptible nickel alloy BMI nozzles prior to the subsequent period of extended operation. If this inspection indicates the occurrence of PWSCC, periodic volumetric inspections are performed on these nozzles and adequate inspection periodicity is established. Alternatively, applicant-proposed and staff-approved mitigation methods may be used to manage the aging effect for these components.

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- (E) *Augmented ISI requirements: Reactor coolant pressure boundary visual inspections* ¹⁰—(1) All licensees of pressurized water reactors must augment their inservice inspection program by implementing ASME Code Case N-722-1, subject to the conditions specified in paragraphs (g)(6)(ii)(E)(2) through (4) of this section. The inspection requirements of ASME Code Case N-722-1 do not apply to components with pressure retaining welds fabricated with Alloy 600/82/182 materials that have been mitigated by weld overlay or stress improvement.
- (2) If a visual examination determines that leakage is occurring from a specific item listed in Table 1 of ASME Code Case N-722-1 that is not exempted by the ASME Code, Section XI, IWB-1220(b)(1), additional actions must be performed to characterize the location, orientation, and length of a crack or cracks in Alloy 600 nozzle wrought material and location, orientation, and length of a crack or cracks in Alloy 82/182 butt welds. Alternatively, licensees may replace the Alloy 600/82/182 materials in all the components under the item number of the leaking component.
- (3) If the actions in paragraph (g)(6)(ii)(E)(2) of this section determine that a flaw is circumferentially oriented and potentially a result of primary water stress corrosion cracking, licensees must perform non-visual NDE inspections of components that fall under that ASME Code Case N-722-1 item number. The number of components inspected must equal or exceed the number of components found to be leaking under that item number. If circumferential cracking is identified in the sample, non-visual NDE must be performed in the remaining components under that item number.
- (4) If ultrasonic examinations of butt welds are used to meet the NDE requirements in paragraphs (g)(6)(ii)(E)(2) or (3) of this section, they must be performed using the appropriate supplement of Section XI, Appendix VIII, of the ASME BPV Code.

Aging Management History

- In April 23, 2013, industry presented the status of industry programs to address bottom mounted J-groove welded nozzle
- Included in the detailed technical discussions were:
 - CC N-722 Technical Basis
 - BMN Safety Assessment (MRP-206; 2009)
 - Nozzle Structural Integrity
 - Head Wastage (MRP-167)
 - MRP-206 Inspection Conclusions
 - Subsequent BAC Wastage Evaluations
 - MRP BAC Test Program (MRP-288 etc.)
 - BAC Implications Report (MRP-308)
 - Related Industry Developments
 - Subsequent Assessment of PWSCC Experience at Tcold
 - Inspection Conclusions

MRP-206

- Summarizes safety assessments of relevant failure modes
- Provides inspection and evaluation guidelines for bottom-mounted nozzles (BMNs) for US PWRs, including guidelines for:
 - Periodic bare metal visual (BMV) examinations for evidence of primary coolant leakage, or
 - Periodic non-visual nondestructive examinations for indications of service-induced cracking
- Constitutes a technical basis supporting BMN inspection requirements in ASME Code Case (CC) N-722
- Provides inspection alternatives to CC N-722 with an equivalent level of risk significance
- The risk evaluations that support MRP-206 show that periodic inspections as defined by this I&E guideline provide
 - Reasonable assurance against nozzle ejection and significant head wastage
 - An extremely low frequency of damage to the nuclear fuel core associated with the potential for age-related degradation of nickel-based alloy BMNs

MRP-167 Assessment of Head Wastage

- Objective: Determine inspections that maintain an acceptably small effect on nuclear safety given the concern for wastage
- Approach:
 - Use deterministic and probabilistic calculations of PWSCC and boric acid corrosion to evaluate the potential for structurally significant wastage of the low-alloy steel head material
 - Boric acid corrosion testing completed by MRP subsequent to publication of MRP-167 confirms that the inspection requirements based on MRP-167 are conservative
- Acceptable inspection strategies include:
 - Program of bare metal visual examinations every other refueling outage (identical to ASME Code Case N-722-1 requirement for BMNs), or
 - Program of volumetric examinations every 10 years with “supplemental visual” examinations every refueling outage

MRP-206 Inspection Strategies Considered

- Effective generic inspection strategies to ensure BMN failure risk is acceptably low for the remaining service life of the plants combined results from
 - Deterministic fracture mechanics analyses
 - BMN risk assessment
 - RV lower head wastage risk assessment
- The core damage frequencies calculated for nozzle ejection were at least about an order of magnitude lower than that for RVLH wastage; this is attributed to the use of a CCDP of 1.0 for the RVLH wastage assessment
- A wide range of candidate inspection plans were considered
- The options involving NDE presumed that NDE capabilities exist to detect relatively small flaws (e.g., POD of 90% for a 0.023-inch deep flaw)
- MRP-206 Inspection conclusions:
 - A program of visual exams every other refueling outage per N-722-1 results is acceptable
 - A program of volumetric examinations every 10 years with “supplemental visual” examinations every refueling outage is also acceptable.
 - Performing a program of periodic volumetric exams of the BMN tubes in addition to the N-722-1 requirements was shown in the safety assessments to have relatively little additional benefit

April 2013 Conclusions

- Industry has concluded BMV is adequate to ensure PWR safety
- Industry evaluated potential impact of UT Periodic tube wall UT will not preclude leakage
- NDE research on closing the B&W BMN examination gap has been unsuccessful to date
- Probability of core damage frequency with periodic volumetric examination in addition to BMV (CC N-722-1) was shown to be essentially equivalent to that for BMV alone
- Significant impact to perform volumetric exams during non vessel ISI exams (core barrel removal required)
- Marginal increase in safety or reliability, not commensurate with the required resources to pursue volumetric exam

Code efforts

- Subsequent to the April 2013 technical discussions NRC management and industry executives discussed the BMN issue in a July 2013 meeting
- The two parties agreed there might be advantages to revise ASME rules to allow a volumetric examination in lieu of the bare metal visual (BMV) of N-722-1
- The ASME Section XI task group responsible for this topic worked from mid-2013 through 2015 to consider alternate rules for BMN volumetric examinations (NRC a member)
- The task group concluded the value to be obtained was not commensurate with cost and effort needed – Unanimous approval to drop the effort

Conclusion

- An abundance of technical bases have shown the existing BMV inspection program is adequate to assure public health and safety
- Inspections to-date have revealed two domestic units with minor indications attributed to weld defects and no base metal wastage
- At least 23 plants have performed voluntary UT examinations with no evidence of PWSCC
- Efforts to institute qualified UT at ASME discontinued due to low value
- Some locations are uninspectable by UT
- Efforts to develop and implement a qualified UT program such as use Section XI Appendix VIII would be excessive in cost versus value
- NRC has made no efforts to mandate more than N-722-1 and its BMV examination in the regulations, implying adequacy for safety
- Therefore, the imposition of qualified volumetric examinations via the GALL-SLR is unwarranted



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