EPRI ELECTRIC POWER RESEARCH INSTITUTE

MRP-335R2 Topical Report for PWSCC Mitigation by Peening Surface Stress Improvement

Public Meeting to Discuss MRP Comments on the NRC Draft Safety Evaluation

NRC Offices, Rockville, Maryland

December 9, 2015

Opening Remarks

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(1/2)

- Surface Stress Improvement by peening is well understood and has been implemented commercially for many decades for mitigating metal fatigue and SCC. The MRP guidelines for mitigating PWSCC are based on proven technology and experience in the U.S. and abroad, including extensive applications of peening in the Japan PWR fleet to mitigate PWSCC initiation
- Peening to mitigate PWSCC provides a nuclear safety risk reduction and asset preservation benefit to the nuclear industry
- Peening reduces the probability of leakage by about an order of magnitude
- MRP-335 and future relief requests approvals are necessary to encourage proactive mitigation, minimize dose, and further lower risk

Opening Remarks

(2/2)

- The industry goal for the remaining portion of this meeting is to develop a path going forward for revising MRP-335
- Draft Condition 5.3.1 cannot be satisfied by peening service providers
- Other draft SE conditions limit the value of proactive peening mitigation
- Based on NRCs response to the industry comments on the draft SE, it is clear that a revision to MRP-335 is needed
- The probabilistic assessment in MRP-335 uses the same methodology as the technical basis for Code Case N-729-1, which has been approved with conditions by the NRC
  - The probabilistic assessment in MRP-335 is independent of xLPR
  - The probabilistic approach has been used in risk-informed ISI and reactor vessel integrity issues as endorsed in 10 CFR 50.61a
- To support the review, MRP will be incorporating several deterministic analyses into MRP-335R3 which will confirm the probabilistic results
- If additional confirmation of the probabilistic results are needed by the NRC, a review of the existing probabilistic analyses will be needed

Key Background and Key Points on Draft Conditions 5.3.1, 5.3.3, 5.2.1, and 5.2.2

Draft Condition 5.3.1

- **Condition:** For the remaining life of a plant, from 0.002 in. (0.051 mm) below the peened surface to the depth prescribed in MRP-335R2 for that component, the maximum stress at operating conditions shall not be greater than 0 ksi
- **Impact:** This draft condition creates a barrier that peening technology can not meet
- **Basis not needed:**
  - Benefit of peening mitigation is derived from the prevention of new PWSCC initiations, not from the arrest of shallow pre-existing flaws
  - The effectiveness of the MRP approach is shown by both deterministic and probabilistic calculations
  - Provides limited safety benefit

Draft 5.3.1. Condition

MRP-335R2 Technical Basis for Inspection Relief (Probabilistic Safety Analysis)

- Probabilistic analyses assess the benefit of peening on the probability of pressure boundary leakage or rupture assuming reduced frequency of inspection
- Follow-up and ISI exams address the possibility of growth of pre-existing PWSCC flaws that were not detected in the pre-peening exam
- The probabilistic analysis results are compared to acceptance criteria:
  - Alloy 82/182 piping butt welds: Peening mitigation with the MRP-335R2 inspection interval results in a large reduction in the probability of leakage compared to no mitigation and standard intervals
  - RPVHPNs: Peening mitigation with the MRP-335R2 inspection interval results in an acceptably low nozzle ejection frequency, a nozzle ejection frequency that is below that calculated for no mitigation and standard intervals, and about an order of magnitude reduction in leakage frequency

ASME Code Case N-729 Technical Basis

MRP-117 and MRP-105

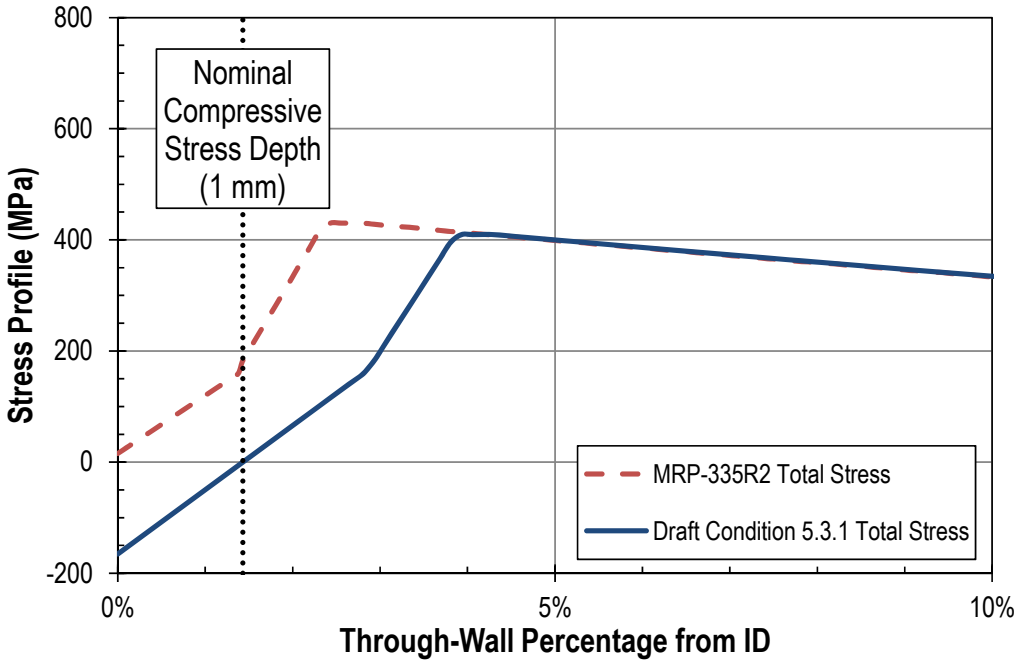
- Documents probabilistic fracture mechanics (PFM) evaluation of circumferential cracks developing and growing to a critical size for nozzle ejection
  - Included sensitivity studies and benchmarking to plant OE
  - Analyzed a series of inspection scenarios
  - Assessed probability of leakage
- Major elements of the PFM code developed include:
  - Computation of stress intensity factors, determination of critical circumferential flaw sizes, Weibull model for PWSCC initiation, statistical analysis of PWSCC crack growth rates, and simulation of crack detection in inspections
- ASME Code Case N-729-1 is currently accepted by NRC
  - Examination zone in Code Case N-729-1 is based on a 20 ksi tensile operating surface stress threshold for PWSCC initiation

Probabilistic analyses in MRP-335 are based on the same basic methodology

Draft Condition 5.3.1

Probabilistic Analysis Cases – MRP Model

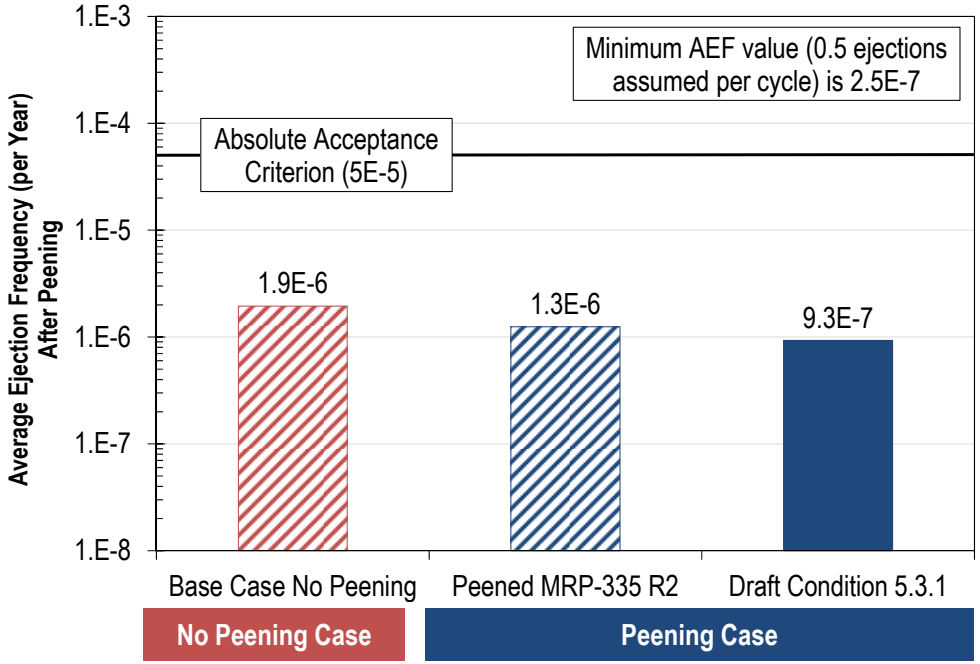
- Effect of draft Condition 5.3.1 modeled by assigning a greater value for the compressive residual stress depth and a more compressive peening surface residual stress
- Average ejection frequency (per year) of 5E-5 corresponds to a core damage frequency of no greater than 1E-6
  - NRC's published definition of acceptably low risk



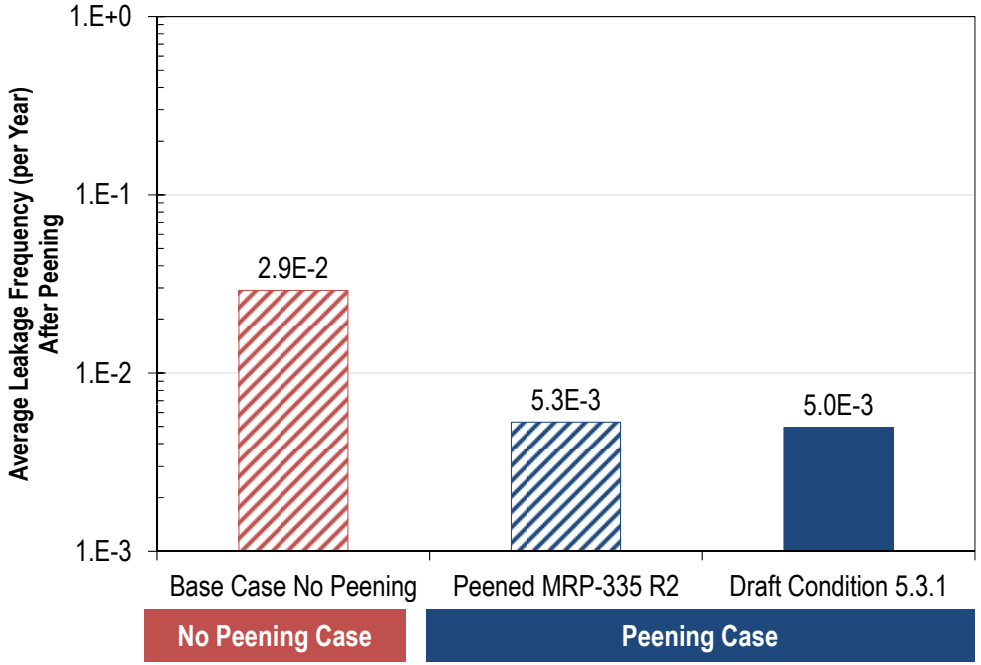
DMW — Azimuth of Maximum Global Bending Stress

Draft Condition 5.3.1

Probabilistic Analysis Cases – Example Results



Cold Head — Ejection



Cold Head — Leakage

Improved risk with peening per MRP-335R2 versus unmitigated case with current inspection intervals, including about order of magnitude improvement in leakage risk

Condition 5.3.1 provides only limited risk benefit for peened RPVHPNs and DMWs

MRP-335R3 Potential Resolution to Draft Condition 5.3.1

- MRP to revise the topical report to make clear throughout that arrest of shallow flaws is not credited in the MRP-335R2 analyses
- MRP could include a matrix of deterministic crack growth cases covering range of conditions showing effectiveness of MRP-335R2 exams to prevent leakage
- Uncertainty in stress measurement is best addressed in plant relief requests

Draft Condition 5.3.3

- **Condition:** The use of inspection schedules proposed in MRP-335R2 is prohibited for peened components in which surface-connected flaws or unexpected flaw growth is observed after completion of follow-up examinations, irrespective of whether a component is re-peened
- **Impact:** This condition would discourage the industry from pursuing this risk mitigation and safety/leakage prevention benefit
- **Basis not needed:** The draft condition applies an overly conservative assumption, for which inspection credit should not be automatically withdrawn. The plant corrective action would be triggered to review implications of the crack detection for the effectiveness of the peening mitigation

MRP-335R3 Potential Resolution to Draft Condition 5.3.3

- Preliminary deterministic crack growth calculations show the possibility that some pre-existing RPVHPN flaws could be detected in the long-term ISI exams with the intended stress effect of the peening application
  - As shown in the probabilistic analyses, the ISI exams are intended to address this residual risk
- Plant Appendix B Corrective Action Program would be triggered to review implications of the crack detection for the effectiveness of the peening mitigation
- Inspection of embedded flaw repair is addressed by separate NRC SEs

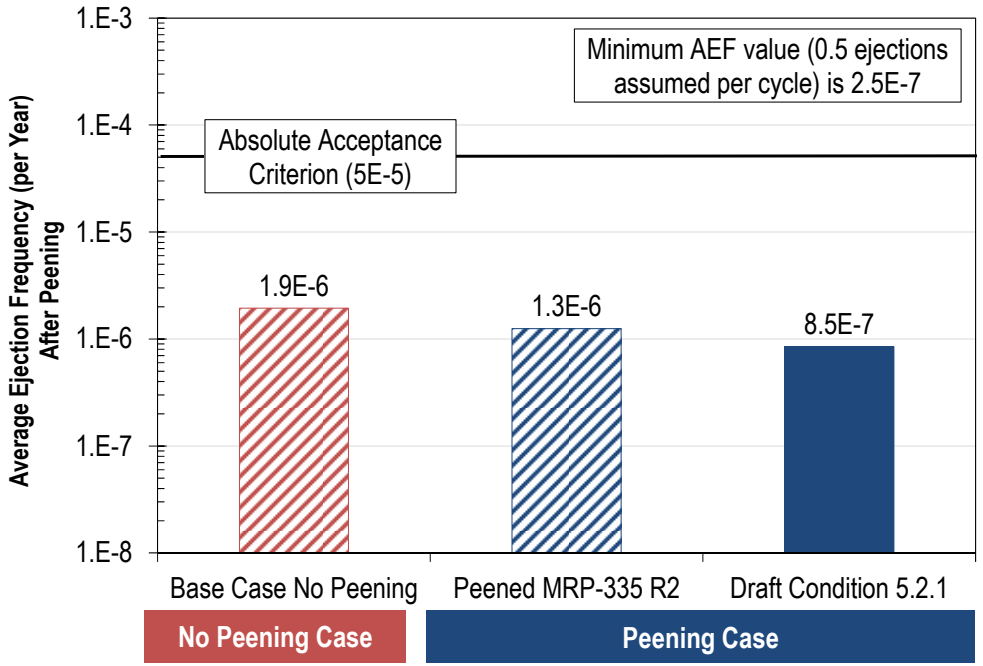
Draft Condition 5.2.1

- **Condition:** When performing bare metal visual examinations, the current applicable requirements in 10 CFR 50.55a shall be used
- **Impact:**
  - Under existing requirements, VE would be required each refueling outage for cold heads with previously detected PWSCC
  - Under proposed 50.55a rulemaking, VE or leak-path UT would be required every refueling outage for cold heads
- **Basis not needed:** MRP-335R2 maintains the same basic VE intervals as for unpeened heads. MRP-335R2 requires VT-2 visual exams of the head under the insulation through multiple access points for all refueling outages in which a VE is not required

Draft Condition 5.2.1

Probabilistic Analysis Cases – Results

- Effect of condition modeled for cold head by simulating bare metal visual (BMV) exams every cycle after peening
  - Sensitivity case overestimates the benefit of the condition as the probabilistic model does not credit the benefit of the VT-2 exam from under the insulation through multiple access points required when BMV is not performed



Cold Head — Ejection

Condition 5.2.1 provides only limited additional risk benefit for nozzle ejection

MRP-335R3 Potential Resolution to Draft Condition 5.2.1

- The NRC staff response to MRP Comment #58 cites a VE interval inconsistent with the requirements of MRP-335R2 and needs clarification
- MRP could provide more information on the benefit of the VT-2 under the insulation through multiple access points to address the boric acid corrosion concern

Draft Condition 5.2.2

- **Condition:** The extent of peening coverage for RPVHNs and associated J-groove welds shall extend to cover the areas defined by the surface examination requirements of Figure 2 of ASME Code Case N-729-1
- **Impact:** Conditioned peening coverage on nozzle OD (where stresses are less than 20 ksi) increases application time and dose
- **Basis not needed:** MRP-335R2 is consistent with the technical basis for the requirements now mandated by NRC for unmitigated heads. The peening coverage proposed by MRP ensures that the areas susceptible to PWSCC initiation are mitigated

MRP-335R3 Potential Resolution to Draft Condition 5.2.2

- The peening coverage proposed by MRP ensures that the areas susceptible to PWSCC initiation are mitigated
- MRP could provide more information on the margin associated with the 20 ksi conservative estimate of the threshold for PWSCC initiation

A Proposed Deterministic Approach

- A proposed deterministic approach would provide standalone results, in addition to complimenting the probabilistic assessment
- Demonstrate low likelihood of leakage through deterministic crack growth cases assuming schedule of follow-up and ISI exams per MRP-335R2
  - Evaluate the follow-up or ISI exam when the assumed flaw becomes detectable prior to leakage
  - Model growth for range of initial flaw depths
  - Vary location, operating temperature, crack growth rate material variability factor, initial crack aspect ratio, and weld residual stress profile
- As for unmitigated heads, any weld cracking is addressed by the visual exams for leakage
  - Peening reduces the probability of leakage due to weld cracking by preventing future initiations
  - MRP-335R2 maintains the same basic visual exam schedule as currently required for unmitigated heads

Recommended Path Forward

- MRP
  - Revise MRP-335R2 to make necessary clarifications
  - Incorporate additional deterministic assessments
  - Incorporate additional probabilistic analyses, if needed
  - Address NRC response to Industry comments
- NRC
  - Stop review of MRP-335R2
  - Review MRP-335R3 and provide SE
- MRP and NRC
  - Establish schedule required to publish final SE by March 31, 2016

Closing Remarks

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