PWSCC Mitigation by Peening

Peening Topical Report (*MRP-335 R1*)
Safety Evaluation Update

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NRC-Industry Materials R&D Tech Update Meeting

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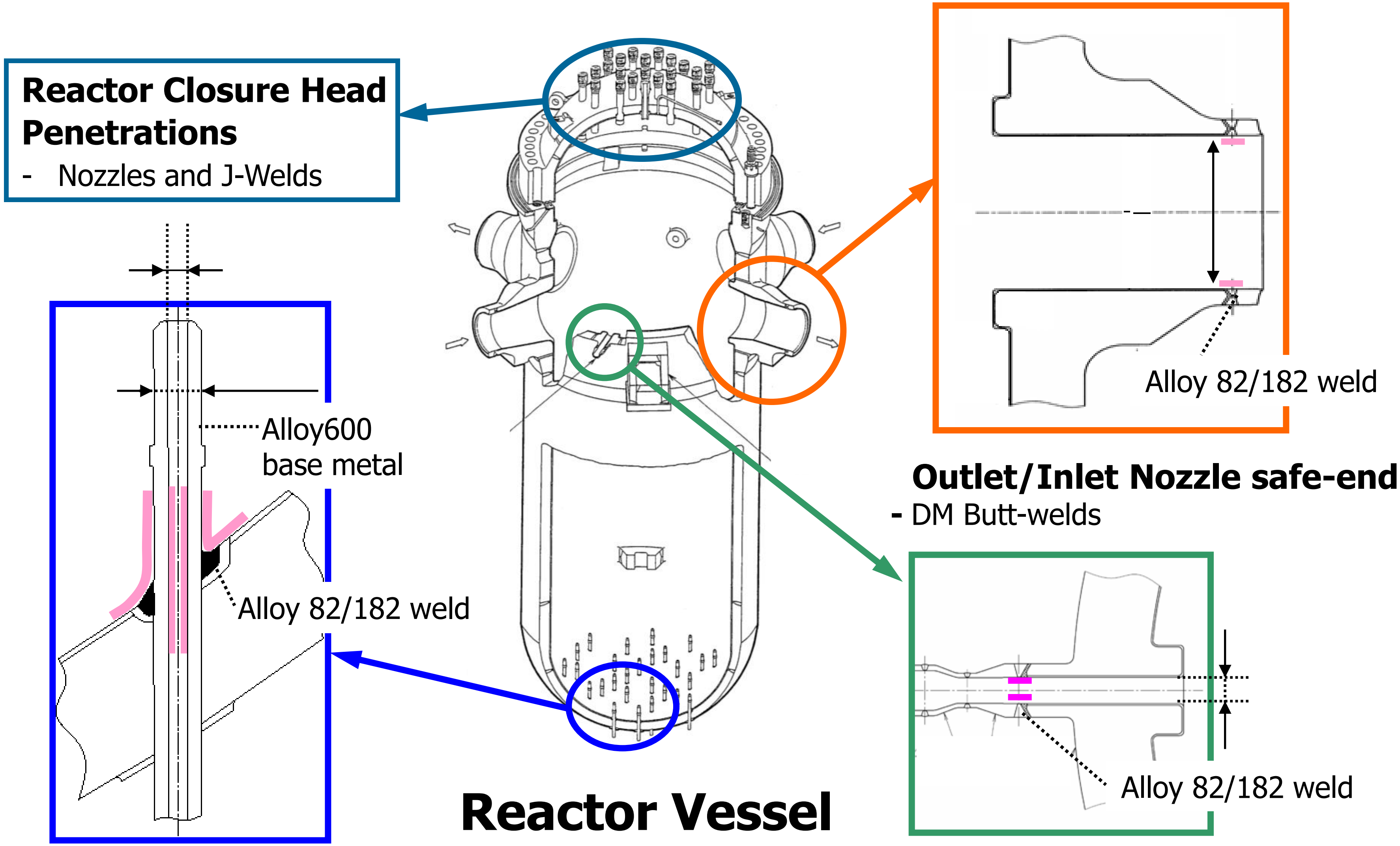
Background

- Peening for PWSCC Mitigation



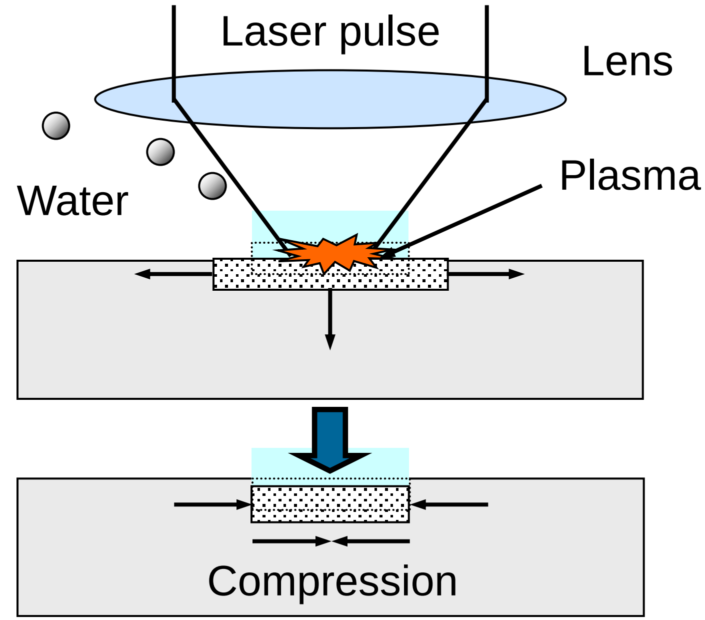
BMN penetrations
- Nozzles and J-Welds

Safety Injection Nozzle safe-end
- DM Butt-welds

Peening Technologies

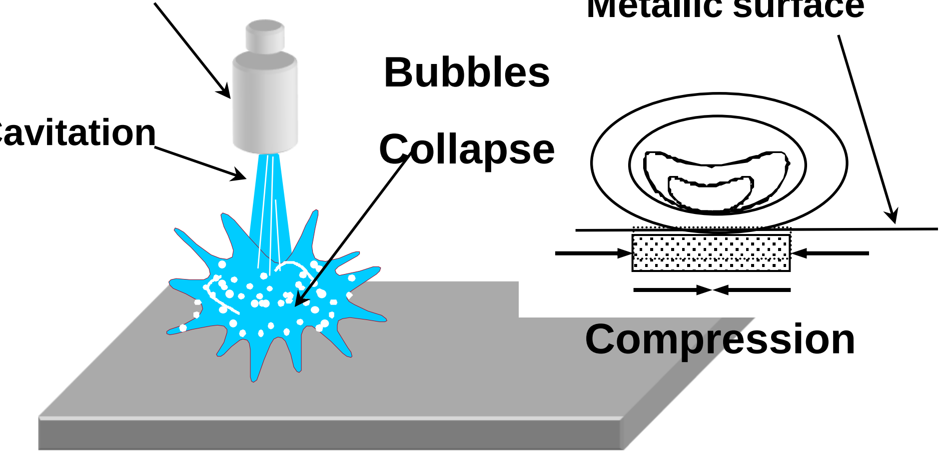
Laser

- *Laser pulse irradiates metal surface*
- *High-pressure plasma forms*
- *Shock wave creates permanent local strains*
- *Compressive residual stress results from constraint*



Cavitation (Water Jet)

- *Pressure drops below vapor pressure*
- *Vapor bubbles form in water*
- *Bubbles collapse at surface generating high pressures*
- *Compressive residual stress results from constraint*



Peening for PWSCC Mitigation

- Status and Readiness

Light Water Reactors in Japan

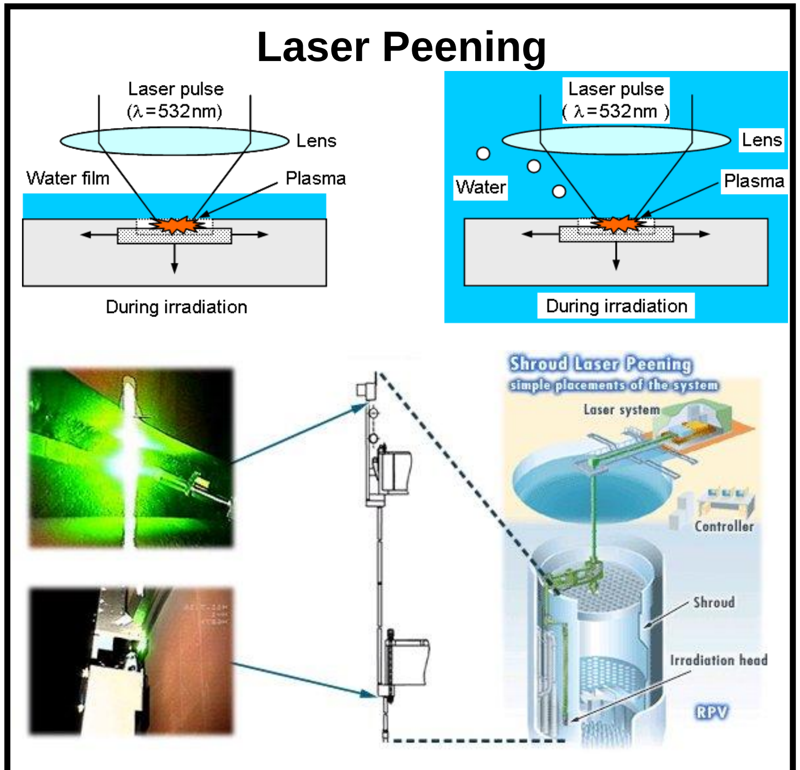
- 12+ years of peening OE in PWRs and BWRs
- 23+ PWRs mitigated, in-situ during RFOs
- Laser and Cavitation technologies
- Alloy 600 Nozzles, J-Welds and DM Butt-welds
  - Bottom-mounted Nozzles/J-welds
  - Reactor Inlet and Outlet Nozzles
  - Safety Injection Nozzles

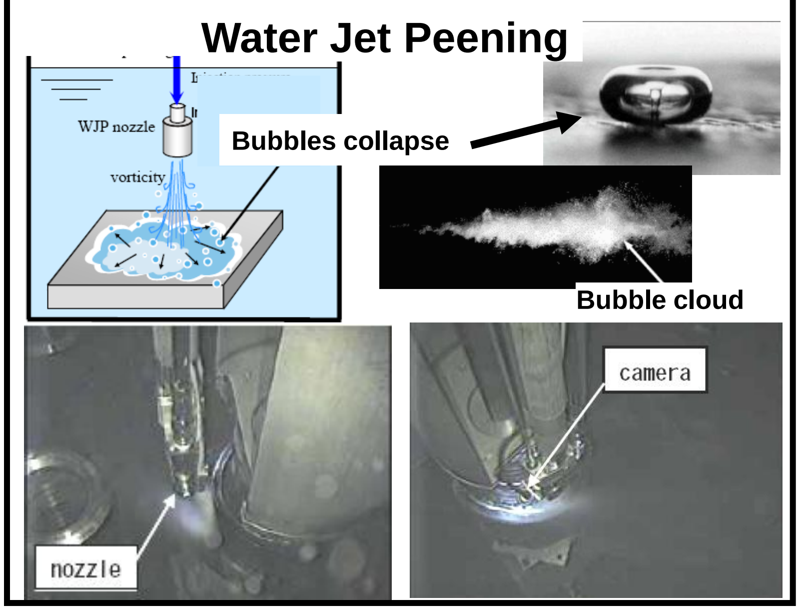
MRP R&D Program Complete

- PWSCC Initiation Testing
- Residual Stress Relaxation
  - Testing and Modeling
- Vendor Technical Basis Information

Implementation Documentation Submitted to NRC for SE and for ASME Code Cases

- Technical Basis Document (MRP-267, Rev 1)
- Topical Report for Inspection (MRP-335, Rev 1)





Current Objective and Scope of Peening Program

- **Objective:**
  - Gain regulatory approval for inspection credit of peening mitigation of PWSCC for Reactor Pressure Vessel Head Penetration Nozzles (RPVHPN) and Dissimilar Metal Butt-Welds (DMW)
- **Scope**:
  - Revise MRP-335R1 to address comments and for SE
    - Produce comment and RAI resolution tables
  - Support ASME Code Committee
    - Ensure consistency between future ASME and SE process outcomes
    - Revise ASME Code Case N-770 and N-729
      - Code Case N-770 first through process, then N-729 will adopt approaches consistent with N-770

Deliverables

- ***Approved Topical Report for PWSCC Mitigation by Surface Stress Improvement (MRP-335, Revision 2A)***
  - **Applicability/Use**:
    - Support of inspection credit subsequent to peening mitigation of PWSCC on Alloy 600 reactor pressure vessel head penetration nozzles (RPVHPNs) and Alloy 82/182 dissimilar metal welds (DMWs) in primary system piping
    - US Utility application through the regulatory process

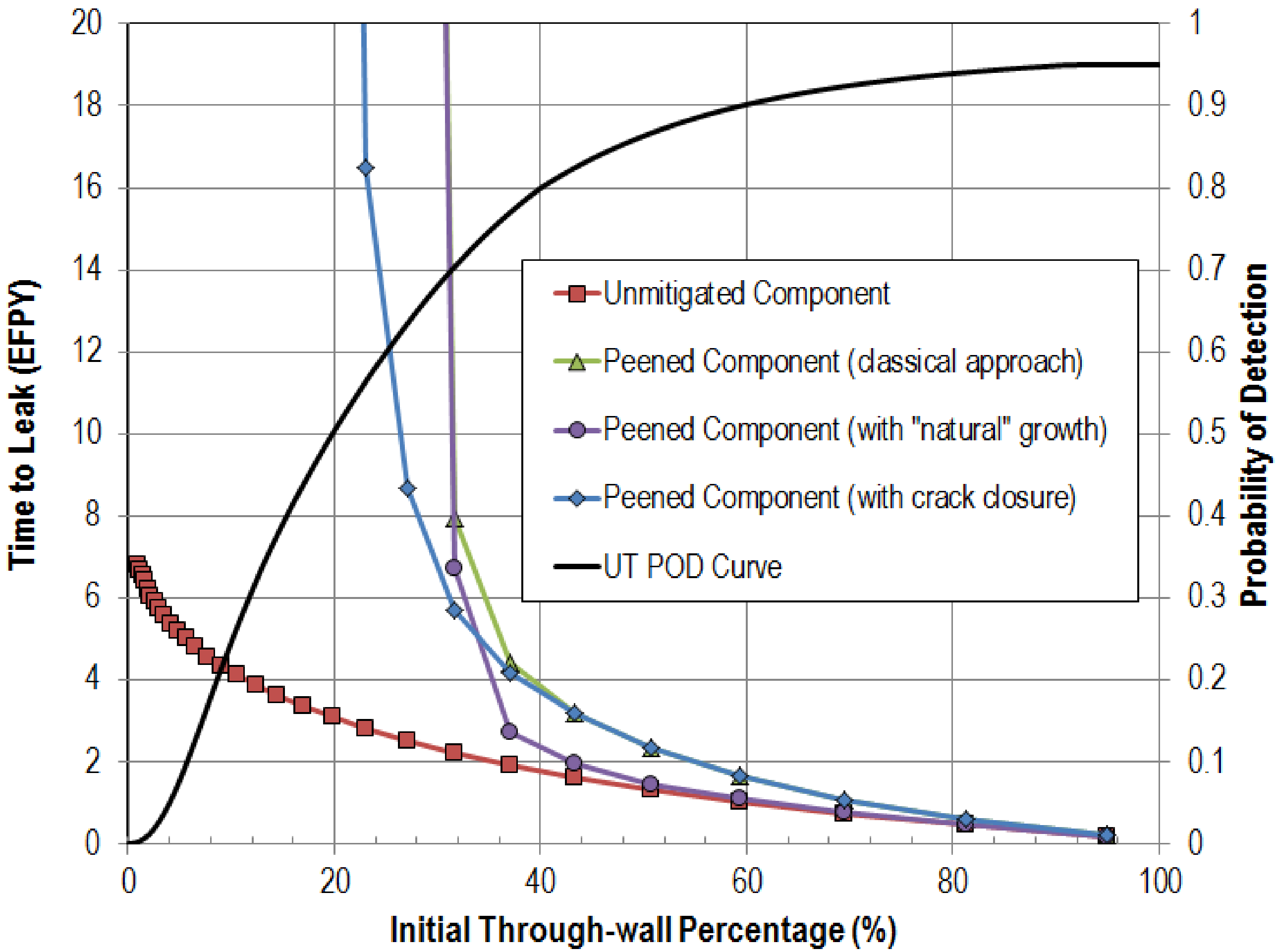
Technical Justification Basis
- MRP-335

- Deterministic and probabilistic analyses were used to determine appropriate inspection requirements for key Alloy 600/82/182 components mitigated by peening
  - MRP-335 Risk Neutral Inspection Table; for DMWs, the calculations showed a large reduction in risk with peening and the proposed inspection intervals (see slide #10)
- Deterministic analyses assess the effect of peening on crack growth as a function of time for various crack types at different locations
- Probabilistic analyses assesses the effect of peening on the probability of pressure boundary leakage or rupture assuming reduced frequency of inspection
  - Component loading including effect of peening on residual stress field
  - PWSCC crack initiation
  - PWSCC crack growth
  - Various inspection options including UT, ET, and bare metal visual

Technical Justification

- *Example Deterministic Analysis*

- Time to Nozzle Leakage for Axial Crack on Downhill Side of CRDM Nozzle Tube OD
- Result is compared to a conservative UT probability of detection (POD) curve



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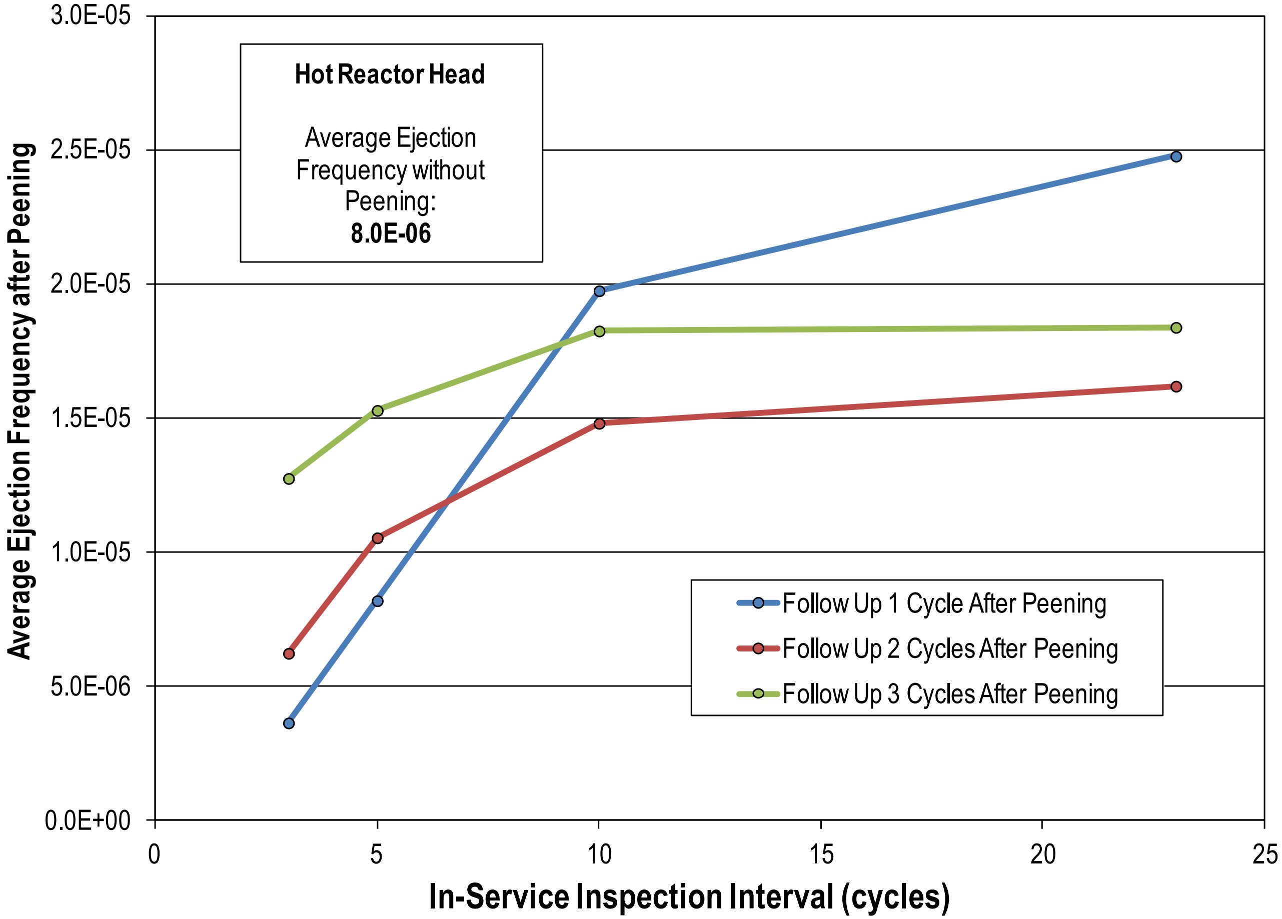
Technical Justification
- *Example Probabilistic Analysis*

- Post-Peening Time-Averaged Nozzle Ejection Frequency for Hot RV Top Head
- Result supports extension of ISI interval to every 10 years (i.e., 5 x 2-year cycles)



Technical Justification
- MRP-335 Conclusions

- Deterministic analyses show that peening eliminates or slows growth for cracks that are sufficiently shallow
- Probabilistic analyses for:
  - Alloy 82/182 piping butt welds show that peening mitigation with the recommended inspection interval results in a large reduction in the probability of leakage compared to no mitigation and standard intervals
  - RPVHPNs show that peening mitigation with the recommended inspection interval results in an acceptably low nozzle ejection frequency, and also a nozzle ejection frequency that is close to that calculated for no mitigation and standard intervals (i.e., risk neutral)

MRP-335 Rev. 1 Inspection Table

Code Case		Nominal Peen Depth (Note 1)	Pre-Mitigation (Note 2)	Follow-up Exams	ISI Volumetric Exam	ISI Direct Visual Exam of Metal Surface (VE)
N-729	Alloy 600 Reactor Vessel Head (EDY ≥ 8)	N/A	N/A	N/A	All nozzles every 8 Yr prior to RIY = 2.25	Each RFO
N-729	Alloy 600 Reactor Vessel Head (EDY < 8)	N/A	N/A	N/A	All nozzles every 8 Yr prior to RIY = 2.25	Every 3rd RFO or 5 Yr, whichever is less (Note 4)
	Peened Alloy 600 Reactor Vessel Head (EDY ≥ 8)	Note 3	Volumetric and ET or PT from nozzle ID only (Note 5)	Volumetric and VE at 1st RFO	Each Interval (Note 6)	Each RFO
	Peened Alloy 600 Reactor Vessel Head (EDY < 8)	Note 3	Volumetric and ET or PT from nozzle ID only (Note 5)	Volumetric and VE at 2nd or 3rd RFO (but within 5 Yr)	Every 2nd Interval (Note 6)	Every 3rd RFO or 5 Yr, whichever is less (Note 6)
N-770	Unmitigated Alloy 82/182 Piping Butt Weld HL Operating Temperature ≤ 625°F (Item A-2)	N/A	N/A	N/A	Every 5 Yr (if not cracked)	Each RFO
N-770	Unmitigated Alloy 82/182 Piping Butt Weld CL Operating Temperature ≥ 525°F and < 580°F (Item B)	N/A	N/A	N/A	Every 2nd Inspection Period, not to exceed 7 Yr (if not cracked)	Each Interval
	Peened Alloy 82/182 Piping Butt Weld HL Operating Temperature ≤ 625°F	ID surface of 82/182 at least 0.04 in. (1 mm)	Volumetric and ET or PT of ID (Note 5)	Volumetric at 1st or 2nd RFO; VE at 1st and 3rd RFOs	Each Interval (Note 6)	Each Interval (Note 6)
	Peened Alloy 82/182 Piping Butt Weld CL Operating Temperature ≥ 525°F and < 580°F	ID surface of 82/182 at least 0.04 in. (1 mm)	Volumetric and ET or PT of ID (Note 5)	Volumetric and VE at 2nd or 3rd RFO	Every 2nd Interval (Note 6)	Each Interval (Note 6)

Notes: (1) The nominal peening depth refers to the depth of the compressive stress produced by the peening treatment.
(2) The pre-mitigation exam may be delayed to after the mitigation outage provided that the inspection requirements for unmitigated component apply until exam is performed and PWSCC must not be detected during the delayed exam for the relaxed inspection requirements to apply.
(3) The nominal peening depth for the Alloy 600 nozzle ID surface is at least 0.02 in. (0.5 mm), and the nominal peening depth for the Alloy 600 nozzle OD surface inboard of the weld and the wetted surface of the Alloy 82/182 J-groove weld is at least 0.12 in. (3 mm). The extent of the required treated surface is defined by the examination volume/area of Figure 2 of N-729-1.
(4) Note 4 of Table 1 of N-729-1 requires that no flaws unacceptable for continued service under -3130 or -3140 have been detected, or else the VE is performed each RFO.
(5) It is not required that the pre-mitigation ET or PT exam meet the requirements of a Performance Demonstration qualification similar to Appendix VIII of Section XI.
(6) Consistent with treatment of other PWSCC mitigation techniques in ASME Code Case N-770-1, detection of planar flaws connected to the wetted surface or leakage shall trigger appropriate additional actions such as flaw disposition and more frequent examinations.

Current Status and Proposed SE Schedule

- MRP-335

Task	Description	Start Date	Status/ Target Date	Deliverable
1	Meet with NRC to discuss TR submission	07/20/12	COMPLETE	Presentation
2	Publish MRP-267 Rev 1, and MRP-335	8/10/12	COMPLETE	Reports
3	Submit MRP-335, Rev 1 for SE with MRP-267 Rev 1 as Companion Reference, and Fee Exemption Request	02/07/13	COMPLETE	Transmittal Letter, Reports, and Fee Exemption Request
4	Issued contract to SE Lead Contractor	02/11/13	COMPLETE	Engineering to support SE
5	NRC performs Fee Exemption Reviews	02/07/13	COMPLETE	Fee Exemption Granted
6	NRC performs Acceptance Reviews and Preliminary Work Plan	04/22/13	In-progress	Acceptance Letter and Work Plan
7	Technical meetings with NRC – *"Kick-off" at Tech Update*	06/06/13	TBD – 12/31/13	Technical Communications
8	Final Work Plan	06/07/13	TBD - 06/14/13	Work Plan
9	NRC Review, Respond to RAIs, and NRC Approval	TBD	TBD – 12/31/13	SE
10	Publish MRP-335 Revision 2A	01/01/14	TBD – 03/31/13	Publish MRP-335 Rev 2A

ASME Code Case and SE Parallel Paths

- MRP-335, Rev 1, and MRP-267, Rev 1, provide the technical bases for Code changes
- Revisions to N770 are in progress and expect to complete in 2013
- Revisions to N729 will start in 2013 and expect to complete in 2014
- These Code Case revisions are in the priority category, but the Code Case process and its end dates are not certain
- Parallel SE and Code case paths will ensure needed NRC requirements are known and accounted for in Utility materials aging management plans
  - Utilities do not want to delay decisions potentially 3 years or longer to understand if there are other NRC requirements to obtain inspection relief
  - Utility Executive Oversight Committee supports parallel paths

Benefits of Safety Evaluation

- Submitting topical report for SE while developing Code Cases
  - Provides immediate NRC feedback
    - ASME process does not provide an “NRC Agency Position” or a complete Staff review with RAIs
  - Removes significant Regulatory Uncertainty
    - Important for Utilities where inspection relief is key factor in evaluating options and making decisions

Backup Slides

ASME Interpretations

ASME Sections addressing peening:

- ***ASME Section III, NB-4422***

  "Controlled peening may be performed to minimize distortion. Peening shall not be used on the initial layer, root of the weld metal or on the final layer unless the weld is post weld heat treated."

  Applicability: *Since peening is not being performed to minimize distortion of the component, this Section would not be applicable to peening for surface stress mitigation*

  APPROVED: By ASME Section III on July 12, 2012; **File # 12- 1192**

- ***ASME Section XI, IWA-4621(c)***

  "Peening may be used except on the initial and final weld layers"

  Applicability*: IWA-4621(c) is not applicable to peening for surface stress improvement. IWA-4621 applicability is intended to apply to the treatment of Temper Bead Welding of Similar Materials, the application of peening for surface stress mitigation is being performed on dissimilar metal welds installed during the construction process*

  APPROVED: ASME Section XI Standards Committee on November 8, 2012; Record #12-1238

- ***ASME Section XI, IWA-4651(g)***

  "Controlled peening of welds may be performed to minimize distortion,…"

  Applicability: IWA-4651(g) is not applicable to peening for surface stress mitigation. IWA-4650 is applicable to 'Butter Bead-Temper Bead Welding for Class MC and for Class CC Metallic Liners"

  APPROVED: ASME Section XI Standards Committee on November 8, 2012; Record #12-1238

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