Exelon Generation Reactor Pressure Vessel Head Penetration Nozzle Post Peening Follow-up Inspection Relief Requests for Byron Unit 2 and Braidwood Unit 1

NRC/Exelon Meeting

August 8, 2018

Exelon Generation®

Agenda

- Introductions and Opening Remarks
- Objectives
- PWSCC History
- RPV Head Penetration Peening Technology
- Authorized Peening Reliefs
- Off-Sequence of NDE N+2
- Proposed Peening Relief Requests
- Technical Basis for Relief Requests
- Relief Request Submittal Schedule
- Summary

Objectives

- Present Exelon's proposed reactor pressure vessel (RPV) head post peening follow-up inspection schedule and relief requests for Byron Unit 2 and Braidwood Unit 1

- Obtain NRC feedback on Exelon's initiative and identify technical and regulatory challenges
  - Achieve an understanding of questions or concerns
  - Discuss approach for resolving questions or concerns

PWSCC History

- Byron and Braidwood RPV heads are B&W T-Cold Heads with the RPV head penetration nozzles fabricated using material supplied by B&W Tubular Products
- Inspections to date have identified the following flaws:
  - Byron Unit 2 – two nozzles (Spring 2007, Fall 2014)
  - Byron Unit 1 – four nozzles (Spring 2011)
  - Braidwood Unit 1 – one nozzle (Spring 2012)
- Exelon repaired the seven RPV head PWSCC induced flaws by implementing an embedded flaw weld overlay
  - Reactive due to unknown scope prior to outage
  - Significant dose, outage extension, and cost
  - Fails to provide a complete solution for long term asset (i.e., RPV) management or improve reliability of non-repaired penetrations

RPV Head Penetration Peening Technology

- Ultra high velocity jet results in pressure below vapor pressure in water resulting in vapor bubbles forming in the water - Cavitation
- Cavitation bubbles collapse at the surface generating high pressures on the material
- The shockwaves caused by collapsing voids impart compressive stresses in the surface layer of material
  - The water-jet force does NOT perform the peening
  - The peening is performed by the collapse of the vapor bubbles
- Peening satisfied performance criteria of MRP-335, Revision 3-A:
  - After peening, the residual stress plus operating stress on peened surfaces must not exceed +10 ksi (tensile)
  - Peening must be applied to the full wetted area of susceptible material that has a pre-peened residual plus operating stresses at component surface of at least +20 ksi (tensile)
  - Testing shall demonstrate nominal depth of compressive surface residual stress field produced by peening is at least 0.04 in. on the nozzle OD/weld surfaces and at least 0.01 in. on the nozzle ID surfaces

Authorized Peening Reliefs

- Exelon pursued proactive RPV head penetration peening technology with Framatome (formerly AREVA NP) to improve the RPV head penetration integrity and mitigate PWSCC to reduce vulnerabilities that could impact public health and safety

- The following Byron and Braidwood relief requests were submitted and authorized by the NRC:

Plant	Relief Request Submittal Date	NRC Authorization Date	ADAMS Accession Number
Byron U2	12/16/2016	9/19/2017	ML17249A241
Braidwood U1	3/31/2017	11/13/2017	ML17249A298
Byron U1	6/15/2017	1/10/2018	ML17325B571
Braidwood U2	12/20/2017	6/04/2018	ML18162A184

Authorized Peening Reliefs

- As required by the authorized relief requests for Byron Unit 2 and Braidwood Unit 1:
  - Inspections scheduled in accordance with MRP-335, Revision 3-A, with the exception of follow-up examinations to be performed only during the second refueling outage (N+2) after application of peening
- Initial Peening was completed for Byron Unit 2 and Braidwood Unit 1 with the following exceptions:
  - 9 nozzles at Byron Unit 2 – not initially completed
  - 4 nozzles at Braidwood Unit 1 – not initially completed
  - This required 13 nozzles to be re-peened one cycle (N+1) after the majority of the nozzles were peened
  - Currently all nozzles on both units have been successfully peened to the MRP requirements
- Result: Off-sequence of NDE N+2 inspections for Byron Unit 2 and Braidwood Unit 1 (13 total nozzles)

Off-Sequence of NDE N+2

- Current NRC approved NDE inspection schedule:

	Baseline						N+2							
	2016		2017		2018		2019		2020		2021		2022	
	Spring	Fall	Spring	Fall	Spring	Fall	Spring	Fall	Spring	Fall	Spring	Fall	Spring	Fall
Byron Unit 2	B2R19 N+0 (70)			~~B2R20 N+1 (70)~~[1]			B2R21 N+2 (70)			B2R22			B2R23	
				B2R20 N+0 (9)			~~B2R21 N+1 (9)~~[1]			B2R22 N+2 (9)			B2R23	
Braidwood Unit 1		A1R19 N+0 (75)			~~A1R20 N+1 (75)~~[2]			A1R21 N+2 (75)			A1R22			A1R23
					A1R20 N+0 (4)			~~A1R21 N+1 (4)~~[2]			A1R22 N+2 (4)			A1R23

Notes:

1) Skip Byron Unit 2 N+1 – RR I4R-14 authorized 9/19/2017

2) Skip Braidwood Unit 1 N+1 – RR I3R-22 authorized 11/13/2017

- *Follow-up examination to be performed only during the second refueling outage (N+2) after application of peening*

Off-Sequence of NDE N+2

- Proposed NDE inspection schedule with Peening relief requests:

	Baseline						N+2							
	2016		2017		2018		2019		2020		2021		2022	
	Spring	Fall	Spring	Fall	Spring	Fall	Spring	Fall	Spring	Fall	Spring	Fall	Spring	Fall
Byron Unit 2	B2R19 N+0 (70)			~~B2R20 N+1 (70)~~			B2R21 N+2 (70)[1]	Move to align inspections		B2R22 N+3 (70)			B2R23	
				B2R20 N+0 (9)			~~B2R21 N+1 (9)~~			B2R22 N+2 (9)			B2R23	
Braidwood Unit 1		A1R19 N+0 (75)			~~A1R20 N+1 (75)~~			A1R21 N+2 (75)[2]	Move to align inspections		A1R22 N+3 (75)			A1R23
					A1R20 N+0 (4)			~~A1R21 N+1 (4)~~			A1R22 N+2 (4)			A1R23

Notes:

1) Byron Unit 2 RR to extend N+2 NDE inspection requirement to N+3
2) Braidwood Unit 1 RR to extend N+2 NDE inspection requirement to N+3
   - *Performing inspections at N+3 is approximately 6 months more operating time when compared to a N+2 inspection at a 2-year cycle plant*

Proposed Peening Relief Requests

- Exelon plans to submit two separate relief requests:
  - Extend N+2 NDE inspection requirement for 70 Byron Unit 2 nozzles to N+3 to align with N+2 required for 9 nozzles (re-sequenced to perform the follow-up inspections for all 79 nozzles in a single refueling outage in the fall of 2020)
  - Extend N+2 NDE inspection requirement for 75 Braidwood Unit 1 nozzles to N+3 to align with N+2 required for 4 nozzles (re-sequenced to perform the follow-up inspections for all 79 nozzles in a single refueling outage in the spring of 2021)

Technical Basis for Relief Requests

- Key supporting EPRI-MRP reference documents:
  - MRP-335, Revision 3-A, “Materials Reliability Program: Topical Report for Primary Water Stress Corrosion Cracking Mitigation by Surface Stress Improvement,” November 2016
  - Proceedings of the ASME 2016 Pressure Vessels & Piping Conference, “Deterministic Technical Basis for Re-Examination Interval of Every Second Refueling Outage for PWR Reactor Vessel Heads Operating at T_{cold} with Previously Detected PWSCC,” ASME, PVP2016-64032, July 17-21, 2016

Technical Basis for Relief Requests

- The deterministic crack growth results per Section 5.2.3.2 of MRP-335, Revision 3-A, also demonstrate how N+3 follow-up inspection timing for cold heads with 18-month fuel cycles is as effective as N+2 timing for such heads

- An N+2 follow-up inspection per MRP-335, Revision 3-A, applies to cold heads operating at both 18-month or 24-month fuel cycles
  - The proposed N+3 follow-up inspection for an 18-month fuel cycle is 4½ years vs. N+2 follow-up inspection for a 24-month fuel cycle being 4 years
  - The delta is only +6 months

Technical Basis for Relief Requests

- The additional cycle for an N+3 interval has the advantage of providing more time for potential shallow and slow-growing flaws to become more readily detectable during the follow-up inspection with an acceptable level of quality and safety

- Bare metal visual examinations will be performed every refueling outage in accordance with MRP-335, Revision 3-A, and corresponding NRC Safety Evaluation

- The experience for unmitigated heads in the U.S. operating at T_{cold} shows that in practice, and without taking credit for the peening surface stress improvement, through-wall cracking and leakage are unlikely to occur during an alternative N+3 interval

Relief Request Submittal Schedule

- Exelon plans to submit two separate relief requests to obtain inspection frequency relief:
  - Projected submittal date for Byron Unit 2 peening relief request is August 2018
    - NRC authorization will be requested by March 4, 2019, to support the Byron Unit 2 B2R21 refueling outage starting in early April 2019
  - Projected submittal date for Braidwood Unit 1 peening relief request is September 2018
    - NRC authorization will be requested by September 3, 2019, to support the Braidwood Unit 1 A1R21 refueling outage starting in October 2019

Summary

- Application of the peening technology on RPV head penetrations is a proactive approach to mitigate PWSCC
  - Improves safety by reducing the potential for nozzle cracking and associated leakage
  - Results in significant reduction in dose related to reactive repairs
- Relief approval would allow alignment of the timing of follow-up inspections of all 79 nozzles to a single refueling outage
- Alignment of follow-up inspections will reduce containment entries and dose, providing an acceptable level of quality and safety pursuant to 10 CFR 50.55a(z)(1)

Summary

- The technical basis supports an alternative N+3 follow-up examination interval based on:
  - Deterministic crack growth results
  - Industry operating experience for unmitigated heads
  - Extension interval is only 6 months longer than for 24-month cycle head inspection interval
  - Extended duration allows more time for slow growth flaws
  - Bare metal visual examinations will be performed every outage to assess head condition