Industry Program for Managing Aging and Degradation of PWR Reactor Internals

EPRI MRP-227 Revision 2 Topical Report

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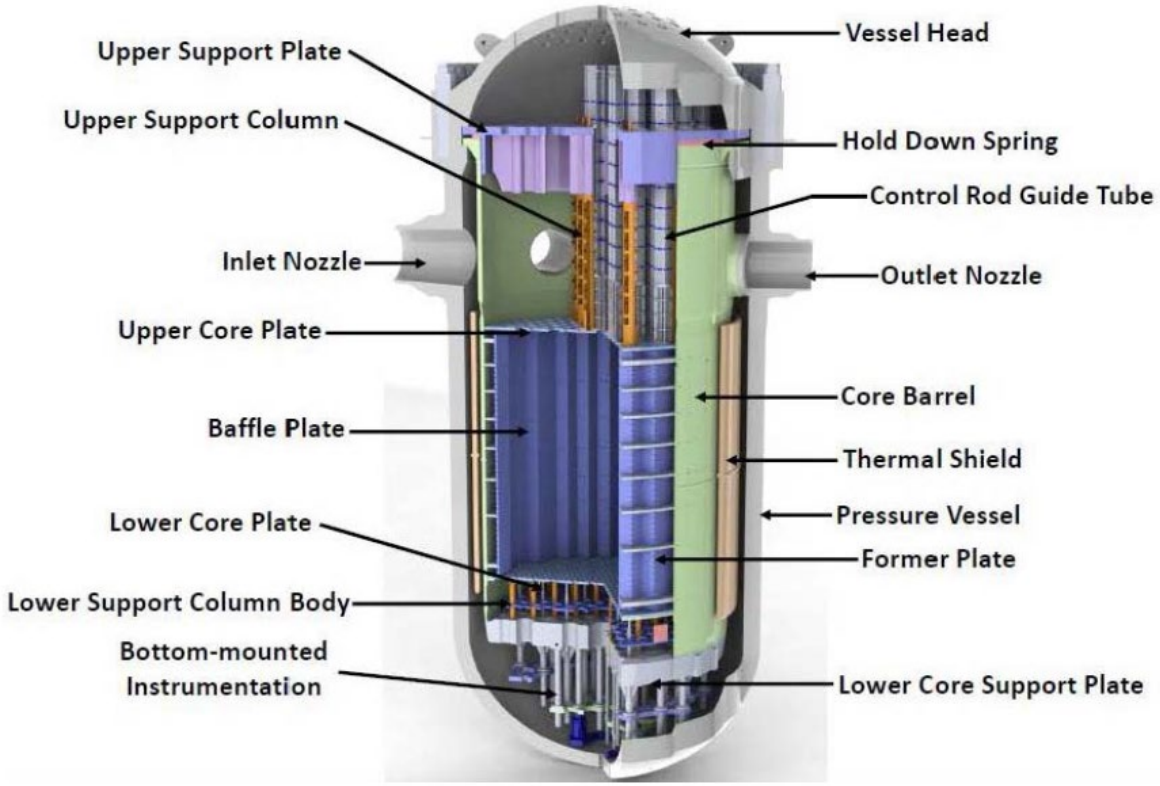
History of MRP-227 Guidance

PWR Internals Aging Management for Beyond 40-Years (LTO)

EPRI Activities on Reactor Internals Aging Management

PWR Internals I&E Guidelines Rev.0 was initially published in Dec.2008

- US NRC's approved version of PWR Internals Inspection and Evaluation (I&E) Guidelines, MRP-227-A (Product ID 1022863) published Dec.2011
  - RVI components have not been thoroughly inspected since fabrication/construction
  - Perform exams at year-40 and year-50 ISI outage
- Updated EPRI guidelines:
  - MRP-227, Rev.1 published in October 2015 (Product ID 3002005349)
  - NRC approval via Safety Evaluation was received in May 2019
  - MRP-227, Rev.1-A published in Dec.2019 (Product ID 3002017168)
  - GALL-SLR "Gap Analysis" Guidance in 2018 for "Lead SLR Plant Applicants" **(WEC/CE only)** ***(EPRI letter report MRP 2018-022 [ML19081A061])***
  - MRP-227, Rev.2 published in Sept.2021 (ID 3002020105) and submitted to US NRC
    - *US utility sites will enter SLR in 2029-2030*
  - NRC anticipates final SE end of 2024



Overview of Typical Westinghouse Internals

Background on EPRI's PWR Internals Aging Management

Technical Foundation supporting the guidance in MRP-227

- Built upon successful model of GE-design Boiling Water Reactors
  - BWRVIP-76-A Aging management component inspections used since 1990s
- Technical basis supporting PWR internals aging management
  - MRP-134 – Framework and Strategies for Managing Materials Aging
  - MRP-175 – Materials Degradation Screening Parameters for PWR Internals
  - MRP-191 – Screening and Ranking Process for PWR Internals
    - *Failure rankings for PWR reactor internals components address "risk/consequence"*
  - MRP-230 – Engineering Analysis and Finite Element Modeling (FEM)
  - MRP-232 – Strategies for Managing the Aging of PWR Internals
  - MRP-228 – NDE Inspection Standard for PWR Internals Inspections
- Used for Aging Management Program (AMP) for PWR Internals
  - Complies with "10-Elements" from US NRC's GALL(-SLR) report for LR and SLR
  - Utility companies submit AMP to US NRC as part of LR and SLR application

Aging Management Implementation by International PWRs

MRP-227 is not just for PWR utility owners in the USA

- Many international utility owners have successfully applied the generic aging management program guidance in MRP-227
  - Guidance is useful for long-term operations beyond original licensing period
  - Many international utility owners receive license renewals in 10-year terms
- MRP-227 has been implemented for LTO/license renewal overseas in:
  - Sweden (Ringhals)
  - Switzerland (Beznau)
  - Spain (Almaraz/Asco)
  - Brazil (Angra)
  - Slovenia (Krško)
  - China (Qinshan)
- Swedish utility (Vattenfall), Chinese utility (CNNP), and Spanish utility (CNAT) received EPRI Technology Transfer Awards in 2016 and in 2023 for implementation of MRP-227 guidance during LTO at PWR units

Generic Acceptance Criteria for PWR Internals Exams

Acceptance Criteria for MRP-227 PWR Internals Exams

- ASME B&PV Code Section XI does not address LWR core internals
- Simple acceptance criteria was established in MRP-227 Section 5
  - Best way to think about this is "component does not look correct anymore"
- Any reportable indication of any size must be evaluated for structural acceptability and continued service during LTO
  - Question to Answer: Will as-found condition preclude component from serving its intended design function during long-term operation? (60yrs, 80yrs)
- Similar to ASME Section XI, MRP-227 mandates use of utility owner's Corrective Action Program (CAP) process for conditions
  - MRP-227 Sect.7.5: *"Examination results that do not meet the examination acceptance criteria defined in Section 5 of these guidelines shall be recorded and entered in the plant corrective action program and dispositioned."*

Generic Acceptance Criteria for PWR Internals

MRP-227

- Provides examination acceptance and expansion criteria

NOT STRUCTURAL ACCEPTABILITY

WCAP-17096

- Provides a methodology for the engineering analysis process

CALCULATION METHODS/EQUATIONS

WCAP-17451-P

- Provides assessment and projection tools for guide card wear

CALCULATION METHODS/EQUATIONS

Acceptance Criteria for MRP-227 PWR Internals Exams

Examples of simplified criteria:

Examination acceptance criterion for visual examination is the **absence** of the specified relevant condition(s)

- A specific relevant condition is a detectable crack-like surface indication.
- A specific relevant condition is loss of material, damaged or distorted or missing bolt locking devices or welds.
- A specific relevant condition is wear that could lead to loss of control rod alignment and impede control assembly insertion.
- Detection of a flaw, as characterized by the UT examination technical justification, shall be cause for rejection of the bolt.
- The examination acceptance criteria shall be established as part of the examination technical justification (required by MRP-228).

Acceptance Criteria for MRP-227 PWR Internals Exams

- MRP-227 Section 7.6 requires use of an NRC-approved engineering evaluation method for calculations for acceptance
  - ASME Section XI Code flaw evaluation techniques is one such method
- PWR Owners Group topical report WCAP-17096-NP is another
  - *Engineering evaluations used to disposition an examination result that does not meet the examination acceptance criteria in Section 5, shall be conducted in* ***accordance with NRC approved evaluation*** *methods (i.e., ASME Code Section XI, PWR Owners Group topical report WCAP-17096-NP-A or equivalent method).*

WCAP-17096-NP Acceptance Criteria

- Philosophy
  - Determine the allowable criteria (e.g., maximum crack length) that will permit the PWR unit to return to service for the entire inspection cycle (typically 10 years)
  - An alternate approach would be to provide acceptance criteria to allow a return to power for 1 fuel cycle
    - This prevents an impact to the current outage and allows the utility time to decide how to disposition the inspection finding

LATEST NRC-APPROVED VERSION IS WCAP-17096-NP-A REVISION 3

COMPANION DOCUMENT TO MRP-227

EPRI MRP-227 Inspection Results Reporting to US NRC in Support of Long-Term Operations/License Renewal

EPRI MRP-227 Inspection Results Reporting to US NRC

- Prior EPRI MRP-227 Inspection Results Reporting
  - Six reports have been promulgated to US NRC in past 10 years
    - MRP 2014-009, dated 5/12/2014 (NRC ML14135A383-85)
    - MRP 2016-008, dated 5/18/2016 (NRC ML16144A789)
    - MRP 2018-025, dated 7/19/2018 (NRC ML18204A161)
    - MRP 2020-015, dated 8/14/2020 (NRC ML20229A000)
    - MRP 2022-017, dated 9/30/2022 (NRC ML22273A155)
    - MRP 2024-018, dated 9/26/2024 (NRC ML24270A195)
- Similar to BWRVIP utility inspection reports submitted by EPRI
- Next biennial summary report to US NRC scheduled for 3Q 2026

EPRI MRP-227 Inspection Results Reporting to US NRC

2020

MRP-227 Related Inspections Performed in USA through mid-2020

1. Surry unit 2, May 2014, 31.28 EFPY
2. Calvert Cliffs unit 1, Feb. 2018, 34 EFPY
3. Catawba unit 2, March 2018, 27.1 EFPY
4. Indian Point unit 2, March 2018, 32.76 EFPY
5. DC Cook unit 2, March 2018, 27.884 EFPY
6. North Anna unit 1, March 2018, 32.44 EFPY
7. Farley unit 1, April 2018, 33.89 EFPY
8. Beaver Valley unit 1, May 2018, 30.71 EFPY
9. McGuire unit 2, Sept.2018, 29.58 EFPY
10. Turkey Point unit 3, Oct. 2018, 34.45 EFPY
11. ANO unit 2, Oct. 2018, 31.63 EFPY
12. Catawba unit 1, Nov. 2018, 28.47 EFPY
13. Sequoyah unit 2, Nov. 2018, 28.3 EFPY
14. Indian Point unit 3, March 2019, 30.3 EFPY
15. Calvert Cliffs unit 2, March 2019, 35 EFPY
16. North Anna unit 2, March 2019, 32.5 EFPY
17. D.C. Cook unit 1, March 2019, 29.1 EFPY
18. Farley unit 2, April 2019, 32.83 EFPY
19. McGuire unit 1, April 2019, 30.15 EFPY
20. Salem unit 1, April 2019, 29.5 EFPY
21. Millstone unit 3, April 2019, 26.3 EFPY
22. Beaver Valley unit 1, Oct.2019, 32.12 EFPY
23. Saint Lucie unit 1, Oct. 2019, 34.95 EFPY
24. Oconee unit 3, March 2020, 37.4 EFPY
25. Vogtle unit 1, March 2020, 29.6 EFPY

2022

MRP-227 Related Inspections Performed from 2017-2022

Baseline PEO Exams (40±3 Calendar Years (CY))

1. Turkey Point unit 4, October 2017, 33.6 EFPY
2. DC Cook unit 2, October 2019, 29.248 EFPY
3. McGuire unit 1, September 2020, 31.55 EFPY
4. North Anna unit 2, September 2020, 33.9 EFPY
5. Salem unit 1, October 2020, 30.7 EFPY
6. Farley unit 2, October 2020, 34.3 EFPY
7. DC Cook unit 2, Spring 2021, 30.6 EFPY
8. Wolf Creek unit 1, April 2021, 30.15 EFPY
9. McGuire unit 2, September 2021, 32.4 EFPY
10. VC Summer, October 2021, 32.3 EFPY
11. Salem unit 2, October 2021, 29.5 EFPY
12. Davis Besse, March 2022, 31.74 EFPY
13. Vogtle unit 2, March 2022, 29.75 EFPY
14. Salem unit 1, April 2022, 32 EFPY
15. Callaway, April 2022, 31.76 EFPY

Second PEO Exams (50±3 CY)

16. Ginna, April 2020, 41.9 EFPY (50CY)
17. Oconee unit 1, October 2020, 38.1 EFPY (48CY)
18. Surry unit 1, May 2021, 37.8 EFPY (48CY)
19. Oconee unit 2, November 2021, 39.48 EFPY (48CY)
20. Surry unit 2, November 2021, 38.1 EFPY (48CY)
21. Point Beach unit 1, March 2022, 42.2 EFPY (50CY)
22. Oconee unit 3, May 2022, 39.39 EFPY (47CY)

2024

MRP-227 Related Inspections Performed from 2022-2024

Baseline PEO Exams (40±3 Calendar Years (CY))

1. Comanche Peak-1, Apr. 2022, 32 CY, 28.4 EFPY (guide cards)
2. Sequoyah-1, Oct. 2022, 42 CY, 31.6 EFPY
3. Beaver Valley-1, Oct. 2022, 46.75 CY, 34.88 EFPY
4. St. Lucie-2, Feb. 2023, 40 CY, 33.8 EFPY
5. Byron-1, Mar. 2023, 37 CY, 32.95 EFPY (guide cards)
6. Catawba-1, May 2023, 38 CY, 32.64 EFPY (guide cards)

Second PEO Exams (50±3 CY)

7. HB Robinson-2, Nov. 2022, 52.3 CY, 39.73 EFPY
8. Oconee-1, Nov. 2022, 49.75 CY, 40.0 EFPY
9. Surry-1, Nov. 2022, 50.5 CY, 39.2 EFPY
10. Point Beach-2, Mar. 2023, 50 CY, 42.9 EFPY
11. Surry-2, May 2023, 50.3 CY, 39.6 EFPY
12. Prairie Island-2, Oct. 2023, 49 CY, 42.5 EFPY
13. Oconee-2, Nov. 2023, 50.1 CY, 41.3 EFPY
14. Beaver Valley-1, April 2024, 48 EFPY, 36.28 EFPY
15. Oconee-3, May 2024, 49.8 CY, 41.3 EFPY
16. Surry-1, May 2024, 52 CY, 40.5 EFPY

EPRI MRP-227 Inspection Results Reporting to US NRC

2014

MRP-227-Related Inspections from 2011-2014

1.Ginna 41.6 Years, 33.51 EFPY, 5/2011
2.Kewanne 38 Years, 31.1 EFPY, 4/2012^
3.Surry unit 1 40 Years, 29.6 EFPY, 5/2012
4.Surry unit 2 40 Years, 30.04 EFPY, 11/2012
5.Oconee unit 1 39.75 Years, 30.61 EFPY, 11/2012
6.North Anna unit 1 34 Years, 26.9 EFPY, 3/2012
7.North Anna unit 2 31 Years, 25.7 EFPY, 9/2011
8.Point Beach unit 1 42 Years, 33.64 EFPY, 3/2013
9.Millstone unit 3 27 Years, 20.7 EFPY, 4/2013
10.HB Robinson 2 43 Years, 31.4 EFPY, 10/2013
11.Shearon Harris 25.5 Years, 21.7 EFPY, 10/2013
12.Surry unit 1 41 Years, 30.98 EFPY, 10/2013
13.Prairie Island unit 2 39 years, 34 EFPY, 11/2013
14.Oconee unit 2 40 Years, 31.82 EFPY, 11/2013
15.Point Beach unit 2 41 Years, 34 EFPY, 3/2014

2016

MRP-227 Related Inspections Performed from 2014-2015

^Palisades - 2/2014, 26.1 EFPY

Turkey Point 3 - 4/2014, 30 EFPY

Oconee 3 - 4/2014, 31.7 EFPY

Turkey Point 4 - 10/2014, 31 EFPY

Prairie Island 1 - 10/2014, 34 EFPY

Point Beach 2 - 10/2015, 35 EFPY

Turkey Point 3 - 11/2015, 31.7 EFPY

Prairie Island 2 - 11/2015, 35.5 EFPY

^Three Mile Island 1 - 11/2015, 30.4 EFPY

2018

MRP-227 Related Inspections Performed from 2016-2018

1.Turkey Point 4 3/2016, 32.2 EFPY
2.Indian Point 2 3/2016, 31.05 EFPY
3.Salem 1 4/2016, 26.98 EFPY
4.Diablo Canyon 2 5/2016, 26.38 EFPY
5.North Anna 1 9/2016, 31.05 EFPY
6.Catawba 2 9/2016, 25.65 EFPY
7.DC Cook 2 10/2016, 26.7 EFPY
8.Farley 1 10/2016, 32.36 EFPY
9.Prairie Island 1 10/2016, 36 EFPY
10.ANO-1 10/2016, 32.4 EFPY
11.Indian Point 3 3/2017, 28.62 EFPY
12.Salem 2 4/2017, 25.4 EFPY
13.Seabrook 4/2017, 23.14 EFPY
14.Millstone 2 4/2017, 28.77 EFPY
15.Diablo Canyon 1 5/2017, 27.67 EFPY
16.Salem 1 10/2017, 28.16 EFPY
17.DC Cook 1 10/2017, 29.1 EFPY
18.Diablo Canyon 2 2/2018, 28.05 EFPY
19.Calvert Cliffs 1 2/2018, 34 EFPY
20.St. Lucie 1 3/2018, 33.65 EFPY
21.Catawba 2 3/2018, 27.1 EFPY
22.North Anna 1 3/2018, 32.44 EFPY
23.Indian Point 2 3/2018, 32.76 EFPY
24.DC Cook 2 3/2018, 27.884 EFPY
25.Shearon Harris 4/2018, 27.13 EFPY
26.Farley 1 4/2018, 33.89 EFPY
27.Beaver Valley 1 4/2018, 30.71 EFPY
28.Sequoyah 1 4/2018, 27.49 EFPY

^ Kewaunee, Palisades and TMI-1 have permanently shut-down for economic reasons

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MRP-227, Revision 2 – Inspection & Evaluation Guidelines for PWR Reactor Vessel Internals

Materials Aging Management Strategy Development Methodology

Regulatory Guidance

- NRC guidance for SLR focused on developing a “gap analysis” between the latest approved version of MRP-227 and SLR operation
  - Analysis includes enhancements and additions to the 10 GALL elements
  - Generic industry evaluation of RVI for SLR used this gap analysis approach (ref.MRP 2018-022) [ML19081A061]
  - MRP-227, Revision 2 and its technical basis address Elements 1-6:
    1. Scope of Program
    2. Preventive Actions
    3. Parameters Monitored or Inspected
    4. Detection of Aging Effects
    5. Monitoring and Trending
    6. Acceptance Criteria
  - Remaining Elements (7-10) are addressed by the Licensee
- Specific guidance:
  - ***NUREG-2191, AMP XI.M16A – “PWR Vessel Internals”***: “Because the guidelines of MRP-227-A are based on an analysis of the RVI that considers the operating conditions up to a 60-year operating period, these guidelines are supplemented through a gap analysis that identifies enhancements to the program that are needed to address an 80-year operating period. In this program, the term “MRP-227-A (as supplemented)” is used to describe either MRP-227-A as supplemented by this gap analysis, or an acceptable generic methodology such as an approved revision of MRP-227 that considers an operating period of 80 years.”
  - ***Safety Evaluation on MRP-227, Revision 1-A***: “The NRC staff finds MRP-227, Revision 1, as modified by this SE and subject to the A/LAI detailed in Section 4.0 of this SE, provides an acceptable baseline or starting point for an AMP for SLR subject to a gap analysis as described in the SRP-SLR Section 3.1.2.2.9 and GALL-SLR, AMP XI.M16A. An exception to GALL-SLR AMP XI.16A must be identified in such cases.”

Industry Gap Analysis of MRP-227 (Ref. MRP 2018-022)

[ML19081A061]

No.	Gap ID	Approach	Action
1	Component List	Verify that there have been no component replacements or modifications since original license renewal	Modify component list as required
2	Screening Criteria	Review MRP-175 and confirm or update screening criteria (impacts of additional time or latest materials research)	Revise MRP-175 and validate by expert review
3	Degradation Mechanism Input Parameters	Identify screening parameters that are time dependent (e.g. neutron fluence, CUF, relative movement [wear]).	Update input values for SLR operation (80 yrs)
4	Component Screening	Compare updated component conditions to update screening values.	Identify any components with new degradation mechanisms identified.
5	Impact of Components Elevated from 60 year "Category A"	Review components previously classified as "Category A": • No screened in degradation mechanisms • Screened in mechanisms had no impact on function or integrity	Identify components where SLR operation causes damage issue to become credible.
6	Impact of SLR on Components Resolved by Analysis	Review all components originally classified as resolved by analysis.	Identify components where SLR operation would adversely impact analysis results.
7	Affected Components	Combine results of activities 4-6.	Compile list for consideration in aging management programs.

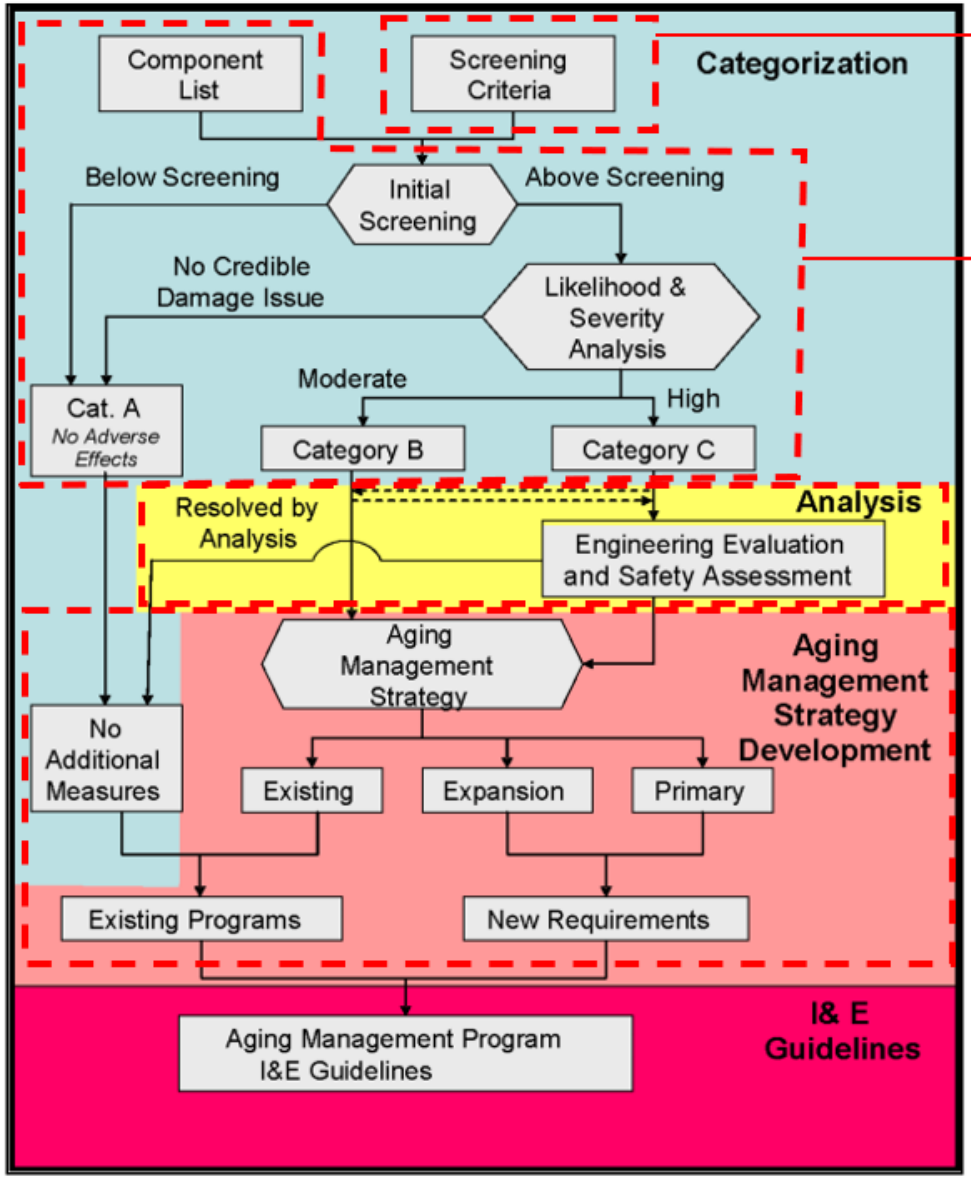
Industry Gap Analysis for MRP-227 (cont.)

[ML19081A061]

No.	Gap ID	Approach	Action
8	Primary Components	Typically expect Primary components to stay as Primary. Consider if risk of degradation or failure is expected to increase in SLR. Does OE indicate that aging has degraded the component function?	Consider adjusting inspection requirements, if needed.
9	Expansion Components	Does Primary inspection link still provide a timely indicator? Does OE indicate that aging has degraded the component function?	Consider making the component Primary or reassigning to a more appropriate lead component, if needed.
10	Existing Components	Do existing inspections continue to adequately monitor for degradation? Does OE indicate that aging has degraded the component function?	Consider promoting component to Expansion or Primary, if needed.
11	Aging Management Strategy	Validate inspection strategy for all Expansion, Existing and Primary examinations (type, scope, coverage, frequency, initial timing).	Adjust MRP-227 as required.
12	Submit MRP-227, Revision 2 for SE	Per existing process from MRP-227-A development.	Submit MRP-227, Revision 2.

Road Map for MRP-227, Rev. 2 Development

- Figure 2-2 in MRP-227-A, Rev. 0, MRP-227, Rev. 1-A, and MRP-227, Rev. 2
  - Flow chart summarizes the process and identifies technical basis documents
  - Same process has been applied for each MRP-227 revision
- Each gap identified in the previous slides for SLR was addressed in this process



Summary for WEC- and CE-design components

Scoping, Screening, and Categorization

- Documented in MRP-191, Revision 2 for WEC and CE design plants
  - Updated screening parameter inputs for 80 years:
    - Fluence
    - Fatigue
    - Fresh review of other inputs (stress, wear susceptibility, etc.)
  - Considered list of components for additions or modifications based on lessons learned and expert panel review
  - Updated screening results for 80 years
  - Evaluated components by expert panel failure modes, effects, and criticality analysis (FMECA) to determine risk ranking and final component categorization
    - Fresh consideration of component failure likelihood and consequence
    - Separated consequence into safety and economic
    - Classified components as Categories A (Low), B (Medium), and C (High)
- GALL Elements:
  - 1. Scope of Program (selection of components)
  - 2. Preventive Actions (assumption of controlled PWR water chemistry)
  - 3. Parameters Monitored or Inspected (degradation mechanisms and degradation effects)
- Industry Gap Evaluation: Gap IDs 1-7 (Ref. MRP 2018-022) [ML19081A061]

Functionality Analysis

- Documented in MRP-230, Revision 3 for WEC and CE plants
  - Finite element modeling of the WEC baffle-former-barrel assembly and the CE core shroud-core support barrel assembly → in the core region
  - Analysis serves two purposes:
    - Predicts the combined effects of irradiation-related degradation mechanisms near the core
    - Evaluates multiple medium and high risk category components in more detail
- Functionality analysis included several enhancements for Rev. 3
  - 4-loop downflow and 4-loop upflow models added
  - Sensitivity study of a range of saturation void swelling rates
- Modeling results support aging management strategy development:
  - Identification of key locations for management or dispositioning
  - Support for inspection type, coverage timing, and frequency
- GALL Elements:
  - 3. Parameters Monitored or Inspected (degradation mechanisms and degradation effects)
  - 4. Detection of Aging Effects
  - 5. Monitoring and Trending
- Industry Gap Evaluation: Gap IDs 6-7

Aging Management Strategy Development

- Documented in MRP-232, Revision 2 for WEC and CE plants
  - Combined inputs from previous steps to develop aging management strategies
  - Contains details of each component or assembly and applicable degradation mechanism
  - Focused on medium- and high-risk items (Category A are generally no additional measures)
  - Implemented a “waterfall” strategy, with Primary and Expansion components
- Asset management strategies added for this revision (based on separation of economic risks)
- Aging management strategy results are the key summary input to MRP-227
- GALL Elements:
  - 3. Parameters Monitored or Inspected (degradation mechanisms and degradation effects)
  - 4. Detection of Aging Effects
  - 5. Monitoring and Trending
  - 6. Acceptance criteria
- Industry Gap Evaluation: Gap IDs 8-11

Inspection & Evaluation Guidelines

- Documented in MRP-227, Revision 2 for WEC and CE plants
  - MRP-232, Rev. 2 strategy recommendations are the starting template
  - Contents are focused on pieces needed for a plant to create and implement an aging management program
  - Final Primary, Expansion, and Existing components
- Interim guidance partway through project published in MRP 2018-022 [ML19081A061]
  - Considered MRP-191 expert panel inputs and outputs completed at that time
  - Projected likely guidance that would be present in MRP-227, Rev. 2
  - Evaluated in MRP-227, Rev. 2 Appendix E to show incorporation or disposition
- GALL Elements: 1-6
- Industry Gap Evaluation: Gap IDs 8-11

Key Elements of MRP-227

- Applicability Criteria
  - Criteria in Section 2.4 and Appendix B
  - Each plant using MRP-227 must demonstrate applicability by meeting each of those criteria
- Expansion Criteria
  - Tables 5-1 (B&W), 5-2 (CE), and 5-3 (WEC) (Primary-Expansion links also in Tables 4-1 to 4-6)
  - Provide thresholds for degradation in Primary component to trigger linked Expansion component(s)
- Examination Acceptance Criteria
  - Tables 5-1 (B&W), 5-2 (CE), and 5-3 (WEC)
  - Define the condition or conditions that an inspector will call as relevant for the component
- Flaw Acceptance Criteria
  - MRP-227 does not include flaw acceptance criteria
  - Requires use of an NRC-approved methodology for developing (Section 7.5. “Examination Results Requirement”)
- Mandatory and Needed Implementation Requirements are listed in Section 7

Changes for MRP-227, Revision 2

CE Primary Item Changes Rev. 1-A to 2-A (Table 4-2)

Component	Changes	Basis
C1. Core shroud bolts	Removed from Rev. 2-A	Plants shut down or planned to shut down
C3. Shroud plates	Removed Expansion link to C3.2. Ribs and Rings	See Expansion Component changes
C4. Bolted Core Shroud Assembly	Removed from Rev. 2-A	Plants shut down or planned to shut down
C5. CSB Upper flange weld (UFW)	• Added Expansion link to C5.5 CSBFW • Removed Expansion link to C5.2 UGW • Added UT and ET as inspection options • Increased inspection coverage to 100% of ID and OD surfaces	• Expansion links address adding CSBFW to Expansion and promoting UGW to Primary • Additional inspection options for flexibility • Addresses OE and interim guidance
C5a/C5b. CSB Upper girth weld (UGW)	• Promoted from Expansion to Primary • Added UT and ET as inspection options • C5a: required 100% of OD surface • C5b: Increased coverage to 100% of both the ID and OD	• Additional inspection options for flexibility • Addresses OE and interim guidance • UGW of C5a is inaccessible from the ID
C6. CSB Middle girth weld (MGW)	• Added Expansion to C6.4 fuel alignment plate (for SLR only) • Added UT and ET as inspection options • Noted upper and lower MGW for one design	• Additional inspection options for flexibility • Clarification for specific design
C7. CSB flexure weld (CSBFW)	• Added UT and ET as inspection options • SCC removed from the degradation mechanisms	• Additional inspection options for flexibility • New expansion component C5.5 to manage SCC
C11. CEA Instrument guide tubes and supports	Added “and supports”	Not a change to the inspection coverage or components, just a clarification
C12. Deep beams	Added SCC and IASCC to mechanisms	Consideration of additional time for SLR
C18. Core shroud tie rods & nuts	New component for Rev. 2-A	Added in response to OE
C19. CEA shroud bolts	New component for Rev. 2-A (only applicable during SLR)	Addresses projected increases in neutron fluence

CE Expansion Item Changes Rev. 1-A to 2-A (Table 4-5)

Component	Changes	Basis
C1.2. Barrel-shroud bolts	Removed from Rev. 2-A	Plants shut down or planned to shut down
C5.1. CSB Lower girth weld (LGW)	• Added UT and ET as inspection options • Added Expansion link to new Primary item C5a/C5b UGW	• Additional inspection options for flexibility • Addresses OE and interim guidance
C5.2. CSB Upper girth weld (UGW)	• Promoted from Expansion to Primary	• Addresses OE and interim guidance • See details in Primary component table
C5.3. CSB Upper axial weld (UAW)	• Added UT and ET as inspection options • Added Expansion link to new Primary item C5a/C5b UGW • Increased inspection coverage to 100% of ID and OD surfaces	• Additional inspection options for flexibility • Addresses OE and interim guidance
C5.4. Lower core support beams	• Added Expansion link to new Primary item C5a/C5b UGW	• Addresses OE and interim guidance
C6.1. CSB Middle axial weld (MAW)	• Added UT and ET as inspection options • Noted upper and lower MAW for one design	• Additional inspection options for flexibility • Clarification for specific design
C6.2. CSB Lower axial weld (LAW)	• Added UT and ET as inspection options	• Additional inspection options for flexibility
C1.1. Core support column bolts	Removed from Rev. 2-A	Plants shut down or planned to shut down
C3.2. Ribs and rings	Removed from Rev. 2-A	Based on finite element modeling, these are not expected to experience degradation
C11.1. Remaining instrument guide tubes and supports	Added “and supports”	Not a change to the inspection coverage or components, just a clarification
C6.3. Core support columns	Updated to remove bolted plant applicability and requirements	Plants shut down or planned to shut down
C5.5. CSB flexure weld (CSBFW)	New Expansion component for Rev. 2-A	Addresses SCC mechanism through Expansion links
C6.4. Fuel alignment plate	• New component for Rev. 2-A • Only applicable during SLR	Addresses increased neutron fluence and applicable degradation mechanisms in SLR

CE Existing Item Changes Rev. 1-A to 2-A (Table 4-8)

Component	Changes	Basis
C17. Alignment and Interfacing Components Core stabilizing lugs and shims Core stabilizing lug shim bolts	• "Core stabilizing lug shim bolts" added • Reference to TB-14-5 added	• Core stabilizing lug shim bolts are like clevis insert bolts and added based on clevis insert bolt OE • TB-14-5 provides relevant interim guidance
C20. Top-mounted ICI ICI thimble tubes—lower	New component added to Rev. 2-A	Plant-specific modifications and actions for 40 and 60 years may not address the longer-term irradiation growth of the tubes for 80 years

CE Components with no Changes Rev. 1-A to Rev. 2-A

- **Primary**
  - C2. Core shroud plate-former plate weld
  - C4a. Welded core shroud assembly
  - C9. Core support plate
  - C10. Fuel alignment plate
- **Expansion**
  - C2.1. Remaining core shroud assembly axial welds
  - C3.1. Remaining core shroud assembly axial welds
- **Existing**
  - C13. Guide lugs
  - C14. Guide lug inserts and bolts
  - C15a./C15b. Fuel alignment pins
  - C16. Core support barrel upper flange

WEC Primary Item Changes Rev. 1-A to 2-A (Table 4-3)

Component	Changes	Basis
W1. CRGT Guide plates (cards)	Moved from Primary to Existing Programs	WCAP-17451-P is an Existing program that provides all the details for Guide Card wear management
W2. CRGT Lower flange welds	Added IASCC to mechanisms	Fluence increases over additional time
W3. CB Upper flange Weld (UFW)	• Removed Expansion link to C5.2 UGW • Added UT and ET as inspection options • Increased inspection coverage to 100% of ID and OD	• UGW promoted to Primary based on OE • Additional inspection options for flexibility • Addresses OE and interim guidance
W3a. CB Upper girth weld (UGW)	• Promoted from Expansion to Primary • Added UT and ET as inspection options • Increased inspection coverage to 100% of ID and OD	• Promoted to Primary based on OE • Additional inspection options for flexibility • Addresses OE and interim guidance
W4. CB Lower girth weld (LGW)	• Added UT and ET as inspection options	• Additional inspection options for flexibility
W6a/W6b/W6c. Baffle-former bolts	• Separated into W6a, W6b, and W6c for Tier 1, Tier 2, and Tier 3 • Clarified Expansion links (secondary and direct Expansions)	• Tier separations from interim guidance based on OE • Provided clarity on secondary expansions and added direct Expansion for large clusters of failed bolts
W8. Internals hold-down spring	• Added text to acknowledge both first license renewal and SLR	• Addresses both periods of extended operation
W9. Thermal shield flexures	• Added SCC to and removed wear from the degradation mechanisms • Change failure effect to focus on fracture and separation • Clarified inspection coverage based on interim guidance	• OE indicated the potential for SCC to contribute • OE indicated that failures would be evidenced by cracking and flexure separation • Location of failures focused by OE

WEC Expansion Item Changes Rev. 1-A to 2-A (Table 4-6)

Component	Changes	Basis
W2.1. Remaining CRGT lower flange welds	Added IASCC to mechanisms	Fluence increases over additional time
W2.2. BMI column bodies and cruciforms	• Added “and cruciforms” • Added TE to degradation mechanisms	• Clarification that cruciform style columns are included • TE is applicable to cast material columns
W3.1. CB Upper girth weld (UGW)	• Promoted from Expansion to Primary	• Addresses OE and interim guidance • See details in Primary component table
W3.2. CB Upper axial weld (UAW)	• Added UT and ET as inspection options • Added Expansion link to new Primary item W3a UGW	• Additional inspection options for flexibility • Addresses OE and interim guidance
W3.3. CB Lower flange weld (LFW)	• Added UT and ET as inspection options • Added Expansion link to new Primary item W3a UGW	• Additional inspection options for flexibility • Addresses OE and interim guidance
W4.1. Upper core plate	• Removed fatigue and wear and added IASCC as degradation mechanisms	• Fatigue removed based on design document review • Wear separated for management under W19 UCP inserts • IASCC added due to longer operating time
W4.2. CB Middle axial welds (MAW)	• Added UT and ET as inspection options	• Additional inspection options for flexibility
W4.3. CB Lower axial welds (LAW)	• Added UT and ET as inspection options	• Additional inspection options for flexibility
W6.1. Barrel-former bolts	• Added details on expansion from a large cluster of degraded baffle-former bolts • Notes included references and requirements for this alternate Expansion path	• Finite element modeling of large clusters documented in MRP 2018-002 • Addresses OE of large clusters of degraded bolts

WEC Existing Item Changes Rev. 1-A to 2-A (Table 4-9)

Component	Changes	Basis
W1. CRGT Guide plates (cards)	Moved from Primary to Existing Programs	WCAP-17451-P is an Existing program that provides all the details for Guide Card wear management
W12. Lower core plate XL lower core plate	Combined into one line from W12a and W12b which separated components by degradation mechanism (cracking and wear)	Inspection technique and requirements were the same for both entries supporting a simplification
W13. Flux thimble tubes	Removed from Rev. 2-A	Addressed by AMP XI.M37 “Flux Thimble Tube Inspection”
W16. Upper fuel alignment pins	New component for Rev. 2-A	Addresses potential for loss of material during SLR operation
W17. Lower fuel alignment pins	New component for Rev. 2-A	Addresses potential for loss of material during SLR operation
W18. XL Lower fuel alignment pins	New component for Rev. 2-A	Addresses potential for degraded pins during SLR operation
W19. Upper core plate inserts	New component for Rev. 2-A	Addresses potential for loss of material during SLR operation
W20. Radial support keys	New component for Rev. 2-A	Addresses potential for loss of material during SLR operation
W21a. Thermal sleeves	New component for Rev. 2-A	Addresses OE of flange wear causing separation of the thermal sleeve and interference with control rod insertion

WEC Components with no Changes Rev. 1-A to Rev. 2-A

- **Primary**
  - W5. Baffle-edge bolts
  - W7. Baffle-former assembly
- **Expansion**
  - W3.4. Lower support forging or castings
  - W4.4. Lower support column bodies (both cast and non-cast)
  - W6.2. Lower support column bolts
- **Existing**
  - W10. Core barrel flange
  - W11. Upper support ring or skirt
  - W14. Clevis bearing Stellite wear surface; Clevis insert bolts
  - W15. Upper core plate alignment pins

Overall Summary of Changes for WEC- and CE-designs

- Changes due to planned (at the time) plant shutdowns
  - Removing bolted CE plant components
- Changes due to more detailed analysis or other guidance
  - Removing: (CE) core shroud ribs and rings; (WEC) Flux thimble tubes
  - Moving CRGT guide cards to Existing Programs
  - Adding or removing degradation mechanisms
- Changes due to increased operating time (wear, fatigue, fluence)
  - Adding degradation mechanisms (particularly fluence-related)
  - Adding: (CE) Fuel alignment plate for SLR, CEA shroud bolts for SLR
- Changes due to OE
  - Increasing the core barrel and core support barrel weld inspection requirements
  - Adding multiple components
  - Separating baffle-former bolts by plant Tier
  - Adding direct Expansion path to barrel-former bolts
  - Revising thermal shield flexure guidance
- Improvements supporting flexibility or clarity

Summary for B&W-design components

Scoping, Screening, and Categorization

- Documented in MRP-189, Revision 3 for B&W design units
  - Updated screening parameter inputs for 80 years:
    - Fluence
    - Fatigue
    - Temperature
    - Fresh review of other inputs (stress, wear susceptibility, etc.)
  - Considered list of components for additions or modifications based on lessons learned and expert panel review
  - Updated screening results for 80 years
  - Evaluated components by expert panel failure modes, effects, and criticality analysis (FMECA) to determine risk ranking and final component categorization
    - Fresh consideration of component failure likelihood and consequence
    - Separated consequence into safety and economic
    - Classified components as Categories A (“Low”), B (“Medium”), and C (“High”)
- GALL Elements:
  - 1. Scope of Program (selection of components)
  - 2. Preventive Actions (assumption of controlled PWR water chemistry in screening criteria)
  - 3. Parameters Monitored or Inspected (degradation mechanisms and degradation effects)

Engineering Evaluation

- Documented in MRP-229, Revision 4 for B&W units
  - Appendix added in Rev. 4 to consider the results of MRP-189, Revision 3 and evaluate impacts of:
    - IE
    - ISR/IC
    - IASCC
    - VS
  - Items considered:
    - Core barrel cylinder, including welds
    - Former plates
    - Baffle plates
    - Baffle-to-Former Bolts/Screws
    - Core Barrel-to-Former Plate Cap Screws
    - Baffle-to-Baffle Bolts/Cap Screws
  - Process
    - Estimate fluence
    - Preform assessment based on fluence
    - Perform structural assessment to project relative change in stress
    - Summarize the engineering assessment and provide recommended Primary, Expansion, and No Additional Measures Categories
- GALL Elements:
  - 3. Parameters Monitored or Inspected (degradation mechanisms and degradation effects)
  - 4. Detection of Aging Effects
  - 5. Monitoring and Trending

Aging Management Strategy Development

- Documented in MRP-231, Revision 4 for B&W units
  - Combined inputs from previous steps to develop aging management strategies
  - Contains details of each component or assembly and applicable degradation mechanism
  - Focused on Category B and C items (Category A are generally no additional measures)
  - Implemented a “waterfall” strategy, with Primary and Expansion components
- Aging management strategy results are the key summary input to MRP-227
- GALL Elements:
  - 3. Parameters Monitored or Inspected (degradation mechanisms and degradation effects)
  - 4. Detection of Aging Effects
  - 5. Monitoring and Trending
  - 6. Acceptance criteria

B&W Primary Item Changes Rev. 1-A to 2-A (Table 4-1)

Component	Changes	Basis
B1. Plenum Cover Assembly and Core Support Shield Assembly a. Plenum Cover Weldment Rib Pads b. Plenum Cover Support Flange c. Plenum Cover Support Ring d. CSS top flange	Noted that all one-time physical measurements required by previous revisions of the guidance is complete Keep remaining VT-3 examinations	Editorial only as physical measurements are complete, VT-3 exams are ongoing
B4. Vent Valve Assembly Original locking devices (pressure plates, spring retainers, springs, U-covers)	Updated applicability from specific units to more general wording	Allows for vent valve replacements
B5. Vent Valve Assembly Original locking devices (key rings, pins)	Updated applicability from specific units to more general wording Addition of Note 5	Allows for vent valve replacements Clarification
B7. Core Support Shield Assembly Upper core barrel (UCB) bolts	Removed locking devices Updated applicability to separate 40-60, 60-80 years Added ISR/IC/wear/fatigue for 60-80 years Removed SSHT bolts as Expansion item for 60-80 years	Previously only included due to concern of wear or fatigue damage by failed bolt, but screened as Category A for age-related degradation mechanisms Editorial Fluence increases over additional time SSHT bolts become Primary for 60-80 years
B8. Core Barrel Assembly Lower core barrel (LCB) bolts	Removed locking devices Updated applicability to separate 40-60, 60-80 years Removed SSHT bolts as Expansion item for 60-80 years Addition of note that compression collars are Primary	Previously only included due to concern of wear or fatigue damage by failed bolt, but screened as Category A for age-related degradation mechanisms Editorial SSHT bolts become Primary for 60-80 years Editorial

B&W Primary Item Changes Rev. 1-A to 2-A (Table 4-1)

Component	Changes	Basis
B9. Core Barrel Assembly Baffle-to-former bolts	Updated applicability to separate 40-60, 60-80 years Added note about void swelling applicability for 60-80 years New note to state assumption that all units have completed baseline examinations, removed requirement for this examination	Editorial Clarification Editorial
B10. Core Barrel Assembly Baffle plates	Updated applicability to separate 40-60, 60-80 years Removed former plates and core barrel as Expansion items for 40-60 years Removed lower grid rib section as Expansion item for 60-80 years Included void swelling as age-related degradation mechanism for 60-80 years	Editorial Core barrel now included as Primary item, former plate removed due to response to Action Item 6 from MRP-227-A Lower grid rib section now included as Primary item Fluence increases over additional time
B12. Flow Distributor Assembly Flow distributor (FD) bolts	Removed locking devices Updated applicability to separate 40-60, 60-80 years Removed SSHT bolts as Expansion item for 60-80 years Addition of note that compression collars are Primary	Previously only included due to concern of wear or fatigue damage by failed bolt, but screened as Category A for age-related degradation mechanisms Editorial SSHT bolts become Primary for 60-80 years Editorial
B13. Lower Grid Assembly Alloy X-750 dowel-to-guide block weld	Separation of Expansion items (numbered) Removal of applicability note	Editorial Addition of unit-specific entry

B&W Primary Item Changes Rev. 1-A to 2-A (Table 4-1)

Component	Changes	Basis
B14.Lower Grid Assembly Shock pad bolts and their locking devices	Removed due to cessation of unit	Removed due to cessation of unit
B15. In-Core Monitoring Instrumentation (IMI) Guide Tube Assembly a. IMI guide tube spiders b. IMI guide tube spiders-to-lower grid rib section welds	Updated applicability to separate 40-60, 60-80 years Added note to address the basis for removing TE Adding Expansion Item B15.2 (upper grid fuel assembly support pad items) for 60-80 years	Editorial To address basis for removing TE Fluence increases over additional time
B16. Core Barrel Assembly Details contained in ML24150A093	New Primary entry for 40-80 years (SCC)	Industry operating experience Details contained in ML24150A093 and ML23095A050
B17. Core Barrel Assembly Details contained in ML24150A093	New Primary entry for 60-80 years (IASCC)	Fluence increases over additional time Details contained in ML24150A093 and ML23095A050
B18. Lower Grid Assembly Lower grid rib section	New Primary entry for 60-80 years (from Expansion)	Fluence increases over additional time
B19. Core Barrel Assembly Surveillance specimen holder tube (SSHT) bolts and their locking devices	New Primary entry for 60-80 years (from Expansion)	Fluence increases over additional time
B20. Core Barrel Assembly Core barrel cylinder top flange circumferential weld regions	New Primary entry for 60-80 years	Updated fluence ranking process for 60-80 years Details contained in ML24150A093 and ML23095A050
B21. Lower Grid Assembly Alloy X-750 dowels-to-lower grid fuel assembly support pad welds	New entry for one unit	Unit-specific difference, previously addressed outside of MRP-227

B&W Expansion Item Changes Rev. 1-A to 2-A (Table 4-4)

Component	Changes	Basis
Upper Grid Assembly B13.1. Alloy X-750 dowels-to-upper grid fuel assembly support pad welds	Update to address unit-specific difference (see Item B13, B21 in Primary table)	Addition of unit-specific entry
B2.1. Vent Valve Assembly Vent valve bodies	Removed after evaluation of ferrite content	Removed after evaluation of ferrite content
Core Barrel Assembly B7.1. Upper thermal shield (UTS) bolts	Removed locking devices Removed link to Primary Item B14	Previously only included due to concern of wear or fatigue damage by failed bolt, but screened as Category A for age-related degradation mechanisms Removed due to cessation of unit
Core Barrel Assembly B7.2. Surveillance specimen holder tube (SSHT) bolts	Applicability of 40-60 years (see Item B19 in Primary table)	Move from Expansion to Primary for 60-80 years due to fluence increases over additional time
Core Barrel Assembly B10.2. Former plates	Included void swelling as age-related degradation mechanism for 60-80 years	Fluence increases over additional time

B&W Expansion Item Changes Rev. 1-A to 2-A (Table 4-4)

Component	Changes	Basis
Core Barrel Assembly B11.1. Locking devices, including locking welds, for the external baffle-to-baffle bolts and core barrel-to-former bolts	Included IASCC as age-related degradation mechanism for 60-80 years	Fluence increases over additional time
Lower Grid Assembly B8.1. Lower thermal shield (LTS) bolts (ANO-1, DB) or studs and nuts (ONS-1, ONS-2 and ONS-3)	Removed locking devices Removed link to Primary Item B14	Previously only included due to concern of wear or fatigue damage by failed bolt, but screened as Category A for age-related degradation mechanisms Removed due to cessation of unit
Upper Grid Assembly B15.2. Upper grid fuel assembly support pad items: pad, Alloy X-750 dowels, cap screw, and their locking welds	New Expansion Item for 60-80 years	Fluence increases over additional time
Core Barrel Assembly B20.1, B20.2, B20.3, B20.4, B20.5, B20.6 Details contained in ML24150A093	New Expansion entries for 60-80 years	Updated fatigue ranking process for 60-80 years Details contained in ML24150A093
Core Barrel Assembly B16.1, B16.2, B16.3 Details contained in ML23095A050	New Expansion entries for 40-80 years	Industry operating experience Details contained in ML23095A050
Core Barrel Assembly B17.1, B17.2, B17.3 Details contained in ML23095A050	New Expansion entries for 60-80 years	Fluence increases over additional time Details contained in ML23095A050

B&W Components with no Changes Rev. 1-A to Rev. 2-A

- All items have been updated, some only editorial or clarifications
- Significant technical changes are detailed in the previous slides

Conclusions

Conclusions

- MRP-227, Rev. 2 developed using the same methodology as previous revisions
  - Process linked directly to a gap analysis from previous approved version (Rev. 1-A)
    - *Interim guidance for SLR "lead plants" published in MRP 2018-022* [ML19081A061]
  - Guidelines continue to support meeting the GALL elements
- Changes created by additional operating time were addressed
  - Increases in exposure time, fatigue, fluence, etc.
  - Updated screening parameter inputs were developed and the full aging management strategy development process revised based on the updated screening results
  - Finite element models updated for SLR operation
- Guideline changes have been implemented to manage the expected aging
  - Interim guidance documents to address OE were incorporated
  - Additional components and requirements were added to address components with anticipated increased risk for SLR
- Overall, the changes were limited and fit within the same guidance framework developed for previous revisions of MRP-227

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