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# Development of Guidance for Aging Management During Subsequent License Renewal

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Office of Nuclear Reactor Regulation

June 4, 2015

# OUTLINE

- Background on License Renewal
- Activities for Subsequent License Renewal
- Technical Issue Areas for SLR
- Mechanical AMPs for SLR

# Nuclear Power Plant Licensing

- Atomic Energy Act
  - Plants licensed to operate for 40 years
  - Allows for license renewal up to 20 years each (e.g., 40 to 60 years)
  - No restrictions on number of subsequent renewals
- License Renewal Rule – 10 CFR Part 54
  - Focus is on managing the effects of aging of long-lived, passive structures and components important to plant safety
  - Active structures and components are covered by Maintenance Rule (10 CFR 50.62)
  - Other aspects of original license are not reconsidered
  - Detecting failures is not aging management

# License Renewal Safety Principles

- The ongoing regulatory process is adequate to ensure the safety of currently operating plants
- The same plant operating rules apply during the renewal term (plant CLB to be maintained)
  - Requires additional actions for aging management of passive, long-lived plant structures and components for license renewal

# License Renewal Process

- Submittal of Application - Integrated Plant Assessment
  - Aging management review (identify materials, environments and aging effects)
  - Aging management programs
  - Time-limited aging analyses (e.g., fatigue evaluations)
- Safety Review
  - Regional Inspection
  - Advisory Committee on Reactor Safeguards
- Environmental Review (10 CFR 51) – Environmental Impact Statement
- Hearing Opportunity
- Agency Decision
- Regional Inspection before end of each operating period

# NRC Guidance for License Renewal

- Generic Aging Lessons Learned (GALL) Report
  - NUREG-1801, Revision 2 issued 2010
  - Provides assessments for aging management review, including identification of materials, environments and aging effects that require management)
  - Identifies acceptable Aging Management Programs (AMPs)

- Safety Review Plan for License Renewal (SRP-LR)
  - NUREG-1800, Revision 2 issued 2010
  - Guidance for NRC staff review of
    - Scoping and Screening
    - Aging Management Review
    - Time-limited Aging Analyses (TLAAs)
      - e.g., metal fatigue, reactor pressure vessel (RPV) neutron embrittlement, environmental qualification

# License Renewal Status

- 99 operating reactors in the U.S.
  - 65 PWRs
  - 34 BWRs
- Renewed licenses issued for 76 units at 39 sites (2 have ceased operations)
- Reviewing applications for 18 units at 11 sites
  - Application scheduled for 6 units (1 unit unscheduled)
- 38 units have entered their 41st year of operation; first was in April 2009

# Subsequent License Renewal

- Anticipate first submittal(s) in 2018 to 2019 ??
- Industry has lead role to submit applications and identify resolution of technical issues
- NRC proposing changes to regulatory guidance to address aging issues for 80 years of operation

# Concerns for Aging

- Activities looking at identification of potential new aging phenomena – locations, forms, severity
  - Known mechanisms that could become more active – incubation times, activation energies, late blooming phases
  - New phenomena
- Approaches for identifying potential aging phenomena
  - Expanded materials degradation assessment (EMDA)
  - Results from 1st renewal aging management programs
    - Both “one-time” and periodic programs
  - Relevant domestic and international operating experience

It is difficult to simulate 80 years of aging when oldest plants are just over 40 years old

# NRC Actions on Subsequent Renewal

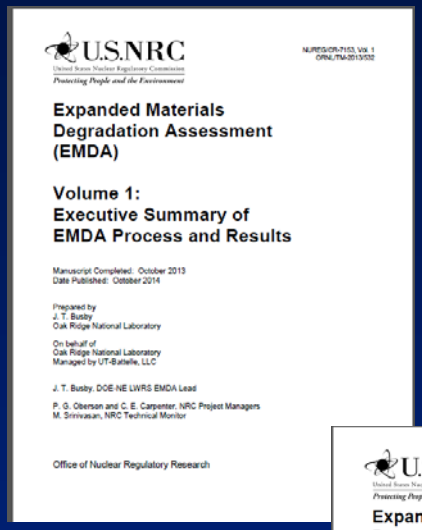
- Used an expert panel process to identify potential materials degradation issues for 80 years of operation
- Audits to assess results from implementation of AMPs at three plants with renewed licenses
- Public meetings with industry on technical issues, including operating experience and industry research activities
- NRC staff review information and propose aging management approaches for 80 years of operation

# AMP Effectiveness Audits

- Three plants – Ginna, Nine Mile Point and HB Robinson
- Reviewed all AMPs (one-time and periodic)
- Assess findings – unanticipated or expected degradation found, or confirm no degradation
- Accessibility issues, adequacy of methods
- Trending information (mainly existing programs)

Purpose – Evaluate effectiveness of AMPs and enable an assessment of the need for new or enhanced AMPs to address subsequent renewal

# Expert Panel Reports – Expanded Materials Degradation Assessment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NUREG/CR-7153, Vol. 1
ORNL/TM-2013/532

Expanded Materials Degradation Assessment (EMDA)

Volume 1:
Executive Summary of EMDA Process and Results

Manuscript Completed: October 2013
Date Published: October 2014

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Office of Nuclear Regulatory Research

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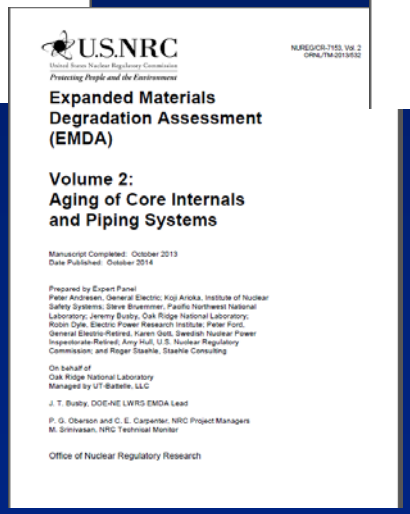
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NUREG/CR-7153, Vol. 2
ORNL/TM-2013/532

Expanded Materials Degradation Assessment (EMDA)

Volume 2:
Aging of Core Internals and Piping Systems

Manuscript Completed: October 2013
Date Published: October 2014

Prepared by Expert Panel
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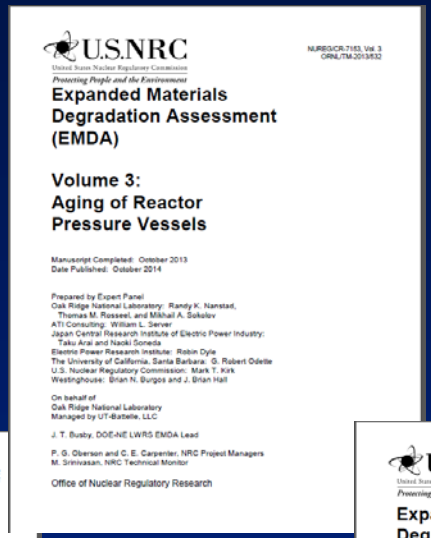
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NUREG/CR-7153, Vol. 3
ORNL/TM-2013/532

Expanded Materials Degradation Assessment (EMDA)

Volume 3:
Aging of Reactor Pressure Vessels

Manuscript Completed: October 2013
Date Published: October 2014

Prepared by Expert Panel
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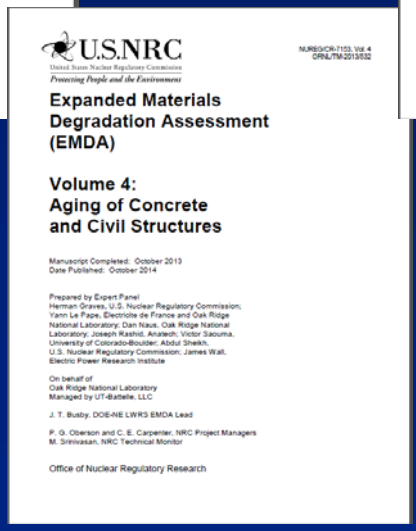
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NUREG/CR-7153, Vol. 4
ORNL/TM-2013/532

Expanded Materials Degradation Assessment (EMDA)

Volume 4:
Aging of Concrete and Civil Structures

Manuscript Completed: October 2013
Date Published: October 2014

Prepared by Expert Panel
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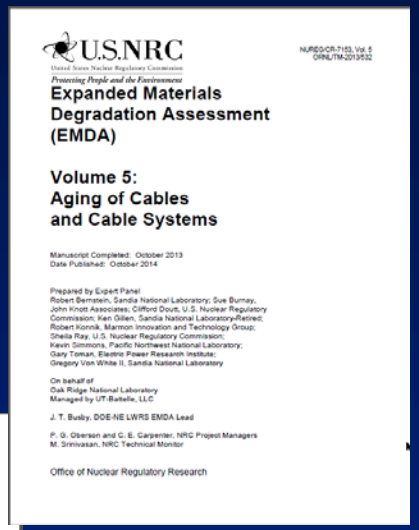
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NUREG/CR-7153, Vol. 5
ORNL/TM-2013/532

Expanded Materials Degradation Assessment (EMDA)

Volume 5:
Aging of Cables and Cable Systems

Manuscript Completed: October 2013
Date Published: October 2014

Prepared by Expert Panel
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# SLR Technical Issues

- Reactor pressure vessel – neutron embrittlement
  - Trends for high fluence levels
  - Surveillance programs
- Reactor vessel internals - high fluence effects
  - Irradiation-assisted stress corrosion cracking
  - Loss of fracture toughness
  - Void swelling
- Concrete and containment performance
  - Long-term radiation and high temperature exposure
  - Alkali-silica reaction (ASR)
- Electrical cables
  - Environmental qualification
  - In-service testing of cables
  - Long-term submersion of low and medium voltage cables

# Information Meeting

# GALL-SLR REPORT
# Mechanical – AMPS AND TLAAS

Office of Nuclear Reactor Regulation (NRR)
Division of License Renewal
Division of Engineering

Office of  Nuclear Regulatory Research (RES)
Division of Engineering

May 7, 2015
9:00 AM- 4:00 PM
3WFN 1C03 & 1C05

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# *Schedule*

| Milestone | Date |
|---|---|
| **Additional Discussion of Three** SLR Mechanical AMPs | **June 11, 2015** |
| ACRS Technical Meeting | **November 2015** |
| Draft GALL-SLR and SRP-SLR Publication | December 2015 |
| Public Meetings | January-February 2016 |
| ACRS Sub-Committee Meeting | February 2016 |
| Public Comment Period Ends | February 2016 |
| ACRS Full-Committee | February 2017 |
| Final GALL-SLR, SRP-SLR and Technical Basis/Response to Public Comments Publication | May 2017 |
| First SLR applications | 2018-2019 |

# GALL-SLR AMPS

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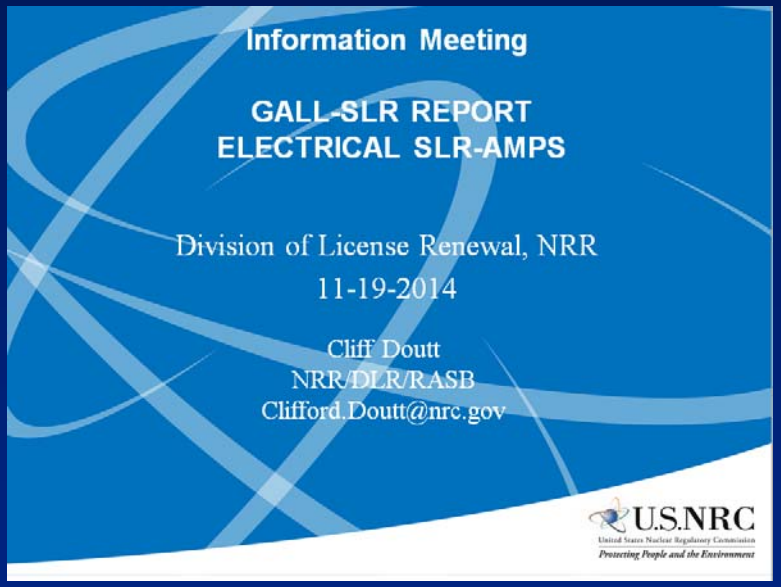
- **Basis for Changes**
  - To reflect expected aging differences for increased operating time from 60 to 80 years
  - New plant operating experience since GALL Rev 2
  - Gaps identified in current guidance
  - Improvements in efficiency and effectiveness of applications and NRC reviews
  - Errors in GALL and SRP
  - Incorporate Interim Staff Guidance since GALL Rev 2

# Meetings on Structural and Electrical AMPs

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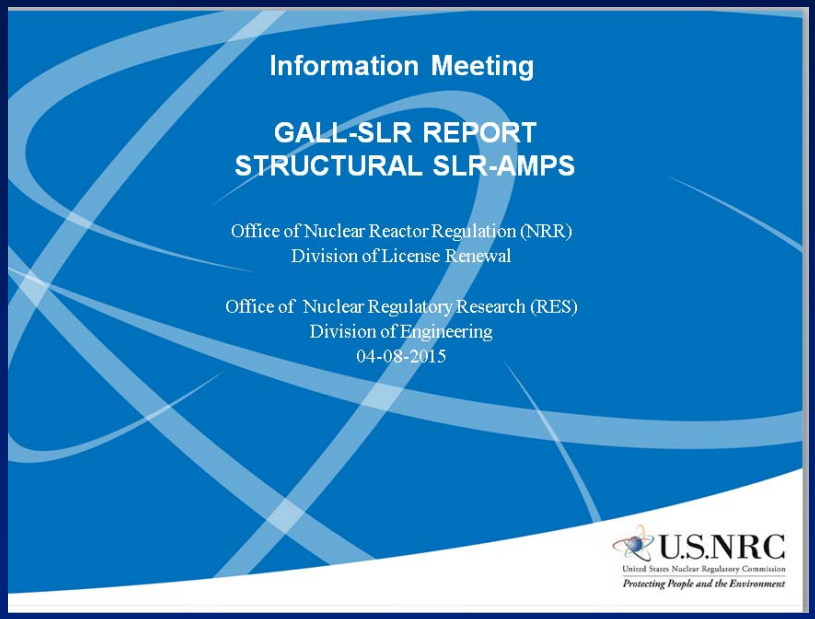


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# DISCLAIMER

Items discussed on following slides are conceptual changes and may change prior to issuance for public comment

# AMP XI.M6 – Control Rod Drive Return Line Nozzle

*Basis for No AMP in GALL-SLR*

- AMP in GALL 2 used to manage cracking in BWR control rod drive (CRD) return lines
- Previously renewed BWRs, Nine Mile Pt., Unit 2 (NMP-2) and Oyster Creek (OC) established procedures to perform UT examinations of the CRD return lines
- Aging in all other BWRs managed by other AMPs
- AMP XI.M6 is no longer needed to manage cracking in the CRD return lines
- Appropriate AMR line items and SRP-SLR further evaluation sections have been added or modified to account for the revised basis

# AMP XI.M16A – PWR Vessel Internals

*Basis for No AMP in GALL-SLR*

- AMP in GALL 2 used to manage PWR reactor vessel internals (RVIs)
- AMP based on methodology in EPRI Technical Report MRP-227-A
- Scope of MRP-227-A  does not cover 80-year operating basis
- New AMR further evaluation (FE) section addresses aging management
- New FE section will request plant-specific AMP for PWR RVIs
- AMP XI.M16A will not be included in the GALL-SLR report

# AMP X.M1 – Cyclic Load Monitoring

*(Previously Named "Fatigue Monitoring Program")*

- Program Description (PD), Scope of Program, Detection of Aging Effects, and Monitoring and Trending: Elements renamed and amended to clarify that AMP X.M1 is a "condition monitoring" program
  - May be used to accept cycle-based TLAAs accordance with §54.21(c)(1)(iii)
  - Includes all types of cycle-related TLAAs in SRP-SLR 4.2
  - Monitoring to cover number of cycles and severity of design transient occurrences
  - States that technical specification requirements may apply
- Acceptance Criteria: Appropriate thresholds to be established for each type of fatigue analysis monitored by the AMP

# AMP XI.M31, Reactor Vessel Material Surveillance

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- Program Description:
  - Based on requirements in 10 CFR Part 50, Appendix H
  - Adjusted to provide adequate reactor vessel (RV) surveillance program criteria to cover plant operations through a 80-year period of licensed operation
  - Updated to differentiate between plant-specific RV material surveillance programs and RV material integrated surveillance programs (ISPs)
- Scope of Program, Detection of Aging Effects, and Monitoring and Trending Elements: Improved element criteria defined for implementation of both plant-specific RV material surveillance programs and RV material ISPs
- Parameters Monitored: Updated capsule removal schedule and RG 1.190 conformance criteria

# AMP XI.M31, Reactor Vessel Material Surveillance (cont.)

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- Detection of Aging Effects and Monitoring and Trending Elements: Withdrawal and testing of additional capsule during the subsequent period of extended operation that achieves a capsule fluence that is between 1 and 2 times the maximum ID fluence that is projected for the RV through 80 years of licensed operation
  - Program element criteria includes alternative management activities if no surveillance capsules are available for withdrawal and testing during a subsequent license renewal period

# New AMP X.M2, Neutron Fluence Monitoring

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- Program Description (PD) and Scope of Program: Added to provide a method for accepting reactor pressure vessel (RV) neutron embrittlement TLAAs in accordance with §54.21(c)(1)(iii).
  - May be used for other non-TLAA assessments
  - AMP to be used in conjunction with GALL-SLR AMP XI.M31
  - Use of X.M2 is analogous to use of AMP X.M1 for fatigue TLAAs
- Detection of Aging Effects and Monitoring and Trending Element Clarifications:
  - Monitoring methods for components in the RV beltline to be consistent with RG 1.190.
  - Methodology for monitoring RVI components or RV components away from the beltline may need additional justification, on a plant-specific basis
  - Monitoring to be performed in comparison to the neutron fluence methods, assumptions, and results used in the TLAAs or aging management assessments
- Acceptance Criteria and Corrective Action Elements: When monitoring is applied to NRC mandated analyses, regulatory requirements for updating the analyses and for submitting the analyses to the NRC must be adhered to, as defined in the applicable regulations or Technical Specification requirements

# SRP-SLR Section 4.1, Identification of Time-Limited Aging Analyses (TLAAs) and Exemptions

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- Added that TLAAs may be applicable to the assessment of in-scope, active components
- Clarified that some analyses not qualifying as TLAAs before could qualify as TLAAs for a proposed subsequent period of extended operation
- Added examples of regulatory exemptions in past LRAs that were granted in accordance with 10 CFR 50.12 and are based on a TLAA

# SRP-SLR Section 4.2, Reactor Vessel Neutron Embrittlement Analysis and SRP-SLR Section 3.1.2.2.3 Subsection 1

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- Added “acceptance criteria” and “review procedure” criteria for neutron fluence methodology TLAAs
- PTS TLAAs for SLR may be based on either §50.61 or §50.61a (depending on CLB)
- AMP, when used in conjunction with XI.M31, provides one way to accept under §54.21(c)(1)(iii)
- BWR RV girth and axial weld probability of failure analyses for SLR to be reviewed on a case-by-case basis

# SRP-SLR Section 4.3, Metal Fatigue

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- Section expanded to include all cycle-based TLAAs in previous LRAs
- Prior environmentally-assisted fatigue analyses will be TLAAs for SLR
- Subsections regrouped by those for: (a) environmentally-assisted fatigue analyses, and (b) other types of cycle-based analyses
- Additional clarifications for accepting TLAAs per §54.21(c)(1)(iii):
  - AMP X.M1, Cyclic Load Monitoring, a way to accept under (iii)
  - Other bases for (iii) to be reviewed on a case-by-case basis
  - If an inspection-based AMP is used for (iii), AMP must inspect the specific components during the subsequent PEO

# XI.M32 One-Time Inspection

- Scope of Program
  - Results of prior one-time inspections when acceptance criteria not met, industry OE, or environment not equivalent excludes use
  - Steel components exposed to environments without corrosion inhibitors
- Parameters Monitored or Inspected
  - One-time inspections for SLR
  - Inspection quantity is unit-based
- Acceptance Criteria
  - Acceptance criteria for individual and compiled results
- Corrective Actions
  - Expanded scope of inspections

# XI.M33 Selective Leaching

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- Detection of Aging Effects
  - Periodic inspections dependent on environment
  - One-time inspections dependent on environment
  - Destructive examinations are conducted
  - Internal and external coatings, cathodic protection
  - Visual inspections for copper based
  - Mechanical inspections for gray cast iron
  - Inspection quantity is unit-based
- Acceptance Criteria
  - Components meet design criteria until end of subsequent PEO
- Corrective Actions
  - Expanded scope of inspections

# *Further Evaluation: PVC Exposed to Outdoor Air*

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- Long-term (2 years or longer) exposure of PVC to sunlight can result in a reduction in impact strength
- JM Eagle™ Technical Bulletin, “The Effects of Sunlight Exposure on PVC Pipe and Conduit,” JM Manufacturing Company Inc., January 2009
- Opaque wrap or paint can eliminate aging effect
- Manage loss of coating integrity or reduction in impact strength

# *Further Evaluation: Underground Stainless Steel Components Exposed to Raw Water*

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- SRP-LR further evaluation addresses stainless steel components exposed to outdoor air
- Cracking due to stress corrosion cracking is the current aging effect
- Underground stainless steel components can be exposed to raw water due to vault in-leakage

# *Further Evaluation: Cracking due to Stress Corrosion Cracking in Aluminum Alloys*

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- Added a Further Evaluation (FE) to the SRP-SLR for determining if cracking of aluminum alloys is adequately managed during SLR
  - Added GALL Report AMR line items to recommend further evaluation for aluminum piping, piping components, & tanks exposed to potentially aggressive environments
  - AMPs have been revised to allow for surface examinations and inspections to manage cracking of aluminum when applicable
- Contents of FE:
  - Material Susceptibility
  - Potentially Aggressive Environment
  - Sustained Tensile Stress

# XI.M27 Fire Water System

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- Preventive Actions
  - Acknowledged flushing as a means to mitigate or prevent flow blockage
- Parameters Monitored or Inspected
  - Corrected misstatement associated with detecting changes in nominal wall thickness
- Detection of Aging Effects
  - Clarified the potential of corrosion in sprinkler systems
  - Added deluge testing every 3 years unless design flow not met due to nozzle blockage
  - Addressed portions of fire water systems with only an (a)(2) intended function
- Monitoring and Trending
  - Added trend rates of degradation

# XI.M9 BWR Vessel Internals

- Scope of Program:
  - Added: Loss of preload due to thermal or irradiation-enhanced stress relaxation (for core plate rim holddown bolts and jet pump assembly holddown beam bolts)
  - Clarified: Cracking due to cyclic loading includes cracking due to flow-induced vibration (for steam dryers)

# XI.M9 BWR Vessel Internals (cont'd)

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- Detection of Aging Effects: Added evaluations to determine need for supplemental inspections
  - The SLR term increases neutron fluence levels and operational periods, which can promote (a) loss of fracture toughness due to neutron irradiation or thermal aging embrittlement and (b) cracking due to IASCC in nickel alloy and stainless steel internal components
  - Applicants should evaluate the need for supplemental inspections in addition to the existing BWRVIP examination guidelines
  - Evaluations should consider neutron fluence, cracking susceptibility (i.e., applied stress, operating temperature, and environmental conditions), thermal aging susceptibility, and fracture toughness
  - Supplemental inspections based on evaluations
  - Accordingly, further evaluation sections added to SRP-SLR

## *XI.M11B Cracking of Nickel-Alloy Components and Loss of Material Due To Boric Acid-Induced Corrosion in Reactor Coolant Pressure Boundary Components*

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- Scope of Program (clarified)
  - Nickel alloy components and welds identified in ASME Code Cases N-770, N-729, and N-722, as incorporated by reference in 10 CFR 50.55a
  - All nickel alloy components and welds which are identified at the plant in accordance with the guidelines of EPRI MRP-126
  - Components that are susceptible to boric-acid corrosion and may be impacted by leakage of boric acid from adjacent nickel alloy components described above

## *XI.M11B Cracking of Nickel-Alloy Components and Loss of Material Due To Boric Acid-Induced Corrosion in Reactor Coolant Pressure Boundary Components (cont'd)*

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- Detection of Aging Effects:
  - Inspections are conducted in accordance with 10 CFR 50.55a
  - Other nickel alloy components and welds not addressed by 10 CFR 50.55a are inspected in accordance with the guidance in MRP-126
  - Added: A baseline inspection of all susceptible nickel alloy bottom-mounted instrumentation nozzles is performed using a volumetric method prior to the subsequent period of extended operation. Alternatively, applicant-proposed and staff-approved mitigation methods may be used to manage PWSCC
  - Added: Baseline inspection provisions are added for branch line connections, control rod drive mechanism housings, and associated welds that are fabricated with nickel alloys susceptible to PWSCC

# GALL XI.M41 Buried and Underground Piping and Tanks

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- Preventive Actions
  - Limiting critical potential (-1200mV) moved to Preventive Actions
- Parameters Monitored or Inspected
  - Loss of material due to wear for polymeric materials
  - Change in material properties for cementitious materials
- Detection of Aging Effects
  - Annual fire water system leakage testing
  - Table 4a extent of inspections for buried piping
  - Polymeric material – physical manipulation
  - Transitioning to a higher number of inspections late in interval
- Acceptance criteria
  - Cathodic protection acceptance criteria

# Conclusions

- Licenses have been renewed for 3/4 of plants
- Challenges for subsequent license renewal
  - Resolution of technical issues by industry is critical
    - Adequate understanding of degradation mechanisms
    - Sufficiency of aging management approaches
  - NRC will evaluate acceptability of proposed resolutions
- NRC is preparing guidance on aging management for plant operation up to 80 years
  - Draft guidance to be issued December 2015
  - Final guidance to be issued May 2017