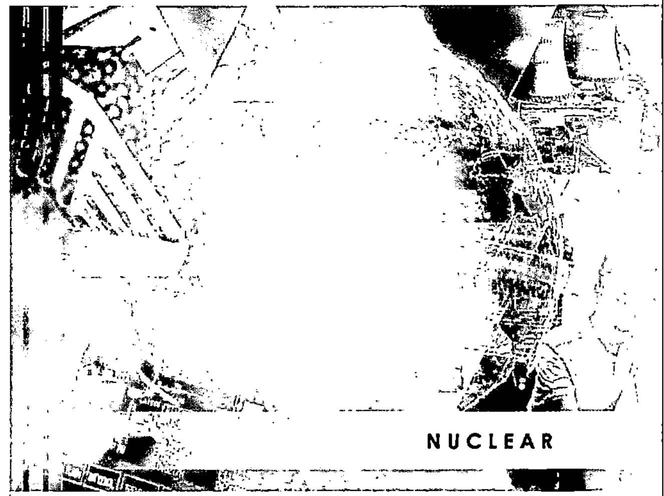
EPRI | ELECTRIC POWER RESEARCH INSTITUTE

BWRVIP-316: BWR Internals Aging Management for Extended Operations

(CLOSED SESSION)



Wayne Lunceford, P.E.
Technical Executive, EPRI BWRVIP

NRC Public Meeting
March 25, 2020

Agenda (Closed Session)

- BWRVIP-74-A Background and Relationship to BWRVIP-316
- Scope of Components Evaluated
- Degradation Assessment
- Aging Management Review for Extended Operations
- AMP Attribute Assessment for Extended Operations
- Upper Shelf Energy (USE) Evaluations
  - RPV Plates and Welds
  - RPV Nozzle Forgings
- Status & Plans for Submittal

BWRVIP-74-A Background

- BWRVIP-74-A, RPV I&E Guidelines for License Renewal, provides a demonstration that aging effects applicable to RPV components will be adequately managed for an initial license renewal period
  - Although identified as an "I&E Guideline", the report does not specify inspection requirements
  - Documents that adequate aging management of RPV components is accomplished through an "integrated" approach that relies on Regulation, ASME B&PVC requirements, and supplemental inspections specified within existing BWRVIP I&E guidelines
  - No new inspections were determined to be needed
- Initial version of BWRVIP-74 developed prior to the initial GALL Report (NUREG-1801) and provided a basis that NRC could use to assess LRAs
  - NUREG-1801 references BWRVIP-74 in addressing aging management of RPV neutron embrittlement and recommends aging management of RPV components using an approach consistent with that in BWRVIP-74-A

BWRVIP-316 Key Elements

- Revisits the conclusions presented in BWRVIP-74-A regarding RPV aging management
  - Focuses on BWRVIP aging management guidance
  - Assesses guidance to identify time-dependent factors
  - Assesses the applicability of BWRVIP guidance for extended operations
- Provides a high level "roadmap" of BWRVIP guidance relevant to RPV aging management
- Provides generic evaluations that can be used by licensees to address select RPV TLAAs

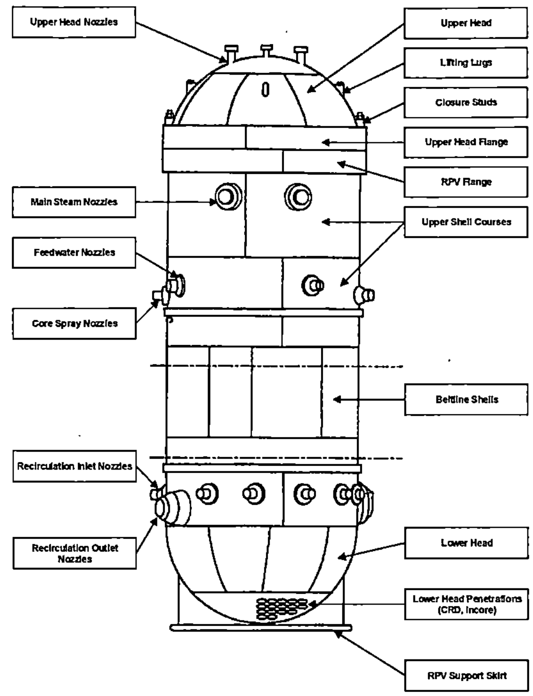
Relationship Between BWRVIP-74-A and BWRVIP-316

- BWRVIP-316 does not replace BWRVIP-74-A
  - Licensees may still credit the NRC-approved conclusions and apply the NRC-approved evaluation methods contained in BWRVIP-74-A in SLRAs
- Instead, BWRVIP-316:
  - Confirms that the integrated set of inspection and flaw evaluation requirements identified in BWRVIP-74-A remain adequate to address operation beyond 60 years
  - Recognizes the extension of the integrated surveillance program (ISP) to address 80-year operations
  - Summarizes alternative methods that may be applied by licensees to address generic TLAAs

Scope (BWRVIP-316, Section 2)

Scope

- RPV components addressed by BWRVIP aging management guidance (*similar to BWRVIP-74-A*)
  - RPV shells, heads, flanges
  - Nozzles, safe ends & dissimilar metal welds
  - Bottom head penetrations (CRD, incore)
  - RPV instrument penetrations
  - Internal attachment welds (shroud support, ID attachment brackets)
  - Closure head studs
  - RPV Supports
- Additional relevant scope includes permanently installed "replacement" materials
  - Weld Overlays of RPV nozzle to safe end welds
  - RPV half nozzle repairs
  - Results in the addition of Alloy 690 and Alloy 52/152 weld metals
- Excludes components not addressed by BWRVIP guidance
  - Non-pressure retaining components (e.g., support skirt, lifting lugs, closure studs)



Typical BWR RPV Illustrating Shell Courses and Nozzle Locations

Degradation Assessment (BWRVIP-316, Section 3)

BWR RPV Materials of Construction

Material	Applicable Material Grades
Structural Materials	
Carbon and Low-Alloy Steels	A-302, Gr. B, SA-533, Gr. B, Cl. 1, SA-336, SA-508, Cl. 1, SA-508, Cl. 2
Stainless Steel (and weld filler materials)	Types 304, 304L, 316, and 316L (weld materials: 308, 308L, 309, 309L, 316, 316L)
Ni-base Alloys	Alloys 600, 690 (Weld materials: Alloys 82, 182, 52, 152)
Fasteners & Hardware	
Low Alloy Steels	ASME SA-193 or SA-540/540M, Grade B23 or B24

Applicable Aging Effects and Associated Degradation Mechanisms

Aging Effect	Age-Related Degradation Mechanisms
Loss of Material	General Corrosion
	Crevice Corrosion
	Wear
Cracking	Stress Corrosion Cracking (SCC, IGSCC)
	Low-Cycle Fatigue (LCF) / Environmentally-Assisted Fatigue (EAF)
Loss of Fracture Toughness	Neutron Embrittlement

Extended Operations Aging Management Impact Evaluation

- Identify those aging effects and associated age-related degradation mechanisms that require additional review to assess the impact of operation beyond 60 years (extended operations) on the adequacy of existing BWRVIP aging management guidance
- Where the potential for new occurrences of age-related degradation (*e.g., initiation of new cracks*) or for progression of degradation (*e.g., crack growth rates*) does NOT correlate with operating time, there is no reason to revisit prior conclusions regarding the adequacy of existing BWRVIP aging management guidance
- For degradation mechanisms not impacted by consideration of extended operations, continued implementation of existing aging management guidance is adequate, regardless of accumulated service time

Extended Operations Impact Review Results

Aging Effect	Age-Related Degradation Mechanisms
Loss of Material	General Corrosion
	Crevice Corrosion
	Wear
Cracking	Stress Corrosion Cracking (SCC, IGSCC)
	Low-Cycle Fatigue (LCF) / Environmentally-Assisted Fatigue (EAF)
Loss of Fracture Toughness	Neutron Embrittlement

Potential Impact

No Impact

Degradation Mechanisms Not Impacted by Extended Operations (1 of 2)

- Loss of Material
  - General corrosion rates are not significant for RPV components
    - Corrosion allowances far exceed anticipated service lives
    - Excessive crevice corrosion of stainless steels and nickel alloys will not occur irrespective of exposure time provided that water chemistry controls are maintained
    - Managed by water chemistry program
  - Wear
    - No basis for postulating time-dependent acceleration or significant adverse trends with extended operating periods
    - Although an adverse trend could potentially occur if a plant undergoes significant changes in operation (*such as a power uprate or flexible operations*), changes in trends are not truly time-dependent, but are a result of the change in operating conditions

Degradation Mechanisms Not Impacted by Extended Operations (2 of 2)

- SCC / IGSCC
  - For austenitic materials, the results of a review of RPV OE indicates a declining or flat trend
  - Two occurrences associated with RPV water level instrumentation
  - Limited instances of IGSCC identified in nozzle to safe end welds (*many of which are likely not new indications, but newly identified through implementation of improved UT techniques*)
  - No reason to anticipate any significant change in IGSCC occurrence or growth trends
- CONCLUSION – AGING MANAGEMENT GUIDANCE ADDRESSING IGSCC REMAINS ADEQUATE FOR EXTENDED OPERATIONS

Aging Management Review For Extended Operations (BWRVIP-316, Section 4)

BWRVIP I&E Guidance

Document	RPV Component(s) Addressed	Augmented Exam Reqd?
BWRVIP-27	Standby Liquid Control (SLC) Nozzles and Safe Ends	Y [1]
BWRVIP-38	Shroud Support	Y [2]
BWRVIP-47	Bottom Head Penetrations	N [3]
BWRVIP-48	ID Attachment Bracket Welds	Y [4]
BWRVIP-49	Penetrations	N [3]

[1] Volumetric examination or enhanced leakage inspection of nozzle to safe end dissimilar metal welds and heavily cold worked safe end extensions.

[2] UT / EVT-1 of shroud support plate to RPV welds and gusset to RPV welds (some designs)

[3] Existing ASME Section XI activities are adequate.

[4] EVT-1 examination of core spray piping bracket welds, jet pump riser brace bracket welds, steam dryer support and feedwater bracket attachments which use furnace-sensitized stainless steel or Alloy 182 weld metal.

Relevant Operating Experience

- Operating experience includes very few instances of cracking in these locations, including:
  - Two instances of RPV instrument penetration cracking
  - Several instances of Alloy 600 / 182 stub tube cracking in a BWR/2 (no further instances for many years now)
  - Limited cases of steam dryer support bracket weld cracking (furnace sensitized stainless steel material)
- There is no time dependent trend observed and therefore, no basis to conclude that existing guidance should be modified to address extended operations

Time Dependent Inputs / Limitations Associated with BWRVIP I&E Guidance

- Comprehensive review of BWRVIP reports and correspondence performed
- Two potentially relevant time-dependent evaluations for the shroud support:
  - BWRVIP 2006-334 includes a fracture mechanics evaluation for the shroud support, including the H9 support plate to RPV weld. The evaluation is not time-dependent because the result is used only to demonstrate that proposed inspection intervals are conservative.
  - BWRVIP-104: PFM analysis assuming a 40-year plant life. The evaluation is not credited as a basis for the inspection intervals specified in BWRVIP-38.
- Inspection requirements are interval-based (independent of plant service time)
- Therefore, no changes to BWRVIP I&E guidance were determined to be needed to address extended operations
- Minor clarifications may be made, but are not required

BWRVIP Evaluations Supporting RPV TLAAs

- Inservice Inspection of RPV Circumferential Welds
  - Evaluation documented in BWRVIP-329, Updated Probabilistic Fracture Mechanics Analyses for BWR RPV Welds to Address Extended Operations
- USE Evaluation for RPV Plates and Welds
  - A 60-year equivalent margins analysis (EMA) is included in Appendix B of BWRVIP-74-A
  - Review of the EMA in BWRVIP-74-A determined that sufficient conservatism exists to address extended operations
  - Verification forms were restructured to maximize use of the existing EMA results
- USE Evaluation for RPV Nozzle Forgings
  - Reduction in nozzle forging USE is a TLAA for some plants
  - In cases, there may be limited data indicative of true upper shelf properties
  - Evaluations of available nozzle forging data included in BWRVIP-316 conclude that there is no evidence of a safety concern associated with nozzle forging USE reduction

RPV Plate and Weld Equivalent Margin Analysis to address Upper Shelf Energy

Issue Summary

- BWRVIP-74-A, Appendix B contains criteria for demonstrating adequate material toughness
- Based on equivalent margin analyses (EMA) developed in the context of 60-year operation
- Review of this analysis indicates sufficient conservatism exists in the "60-year" evaluation in BWRVIP-74-A to address extended operations
- BWRVIP-74-A results arbitrarily limited by maximum predicted USE % drop in fleet based on Reg. Guide 1.99
- BWRVIP-316 results reflect maximum allowable % USE drop to reach EMA limit. Either:
  - Minimum value from U.S. fleet database
  - Lower bound value based on 95% confidence
- Verification form removes use of "54 EFPY", now simply states "fluence"
- Results are presented on the following slides

BWR/2 Plates – BWRVIP-74-A

[[

Content Deleted
EPRI Proprietary Information

]]

BWR/2 Plates – BWRVIP-316

[[

Content Deleted
EPRI Proprietary Information

]]

BWR/3-6 Plates – BWRVIP-74-A

[[

Content Deleted
EPRI Proprietary Information

]]

BWR/3-6 Plates – BWRVIP-316

[[

Content Deleted
EPRI Proprietary Information

]]

  EPRI ELECTRIC POWER RESEARCH INSTITUTE

Weld Materials SMAW & ESW – BWRVIP-74-A

[[

Content Deleted
EPRI Proprietary Information

]]

  EPRI ELECTRIC POWER RESEARCH INSTITUTE

Weld Materials SMAW & ESW – BWRVIP-316

[[

Content Deleted
EPRI Proprietary Information

]]

Weld Materials SAW – BWRVIP-74-A

[[

Content Deleted
EPRI Proprietary Information

]]

Weld Materials SMAW & ESW – BWRVIP-316

[[

Content Deleted
EPRI Proprietary Information

]]

  EPRI ELECTRIC POWER RESEARCH INSTITUTE

Results – Maximum Allowable % USE Drop

[[

Content Deleted
EPRI Proprietary Information

]]

  EPRI ELECTRIC POWER RESEARCH INSTITUTE

Verification Form Comparison - Example

[[

Content Deleted
EPRI Proprietary Information

]]

Upper Shelf Energy Evaluation for RPV Nozzles

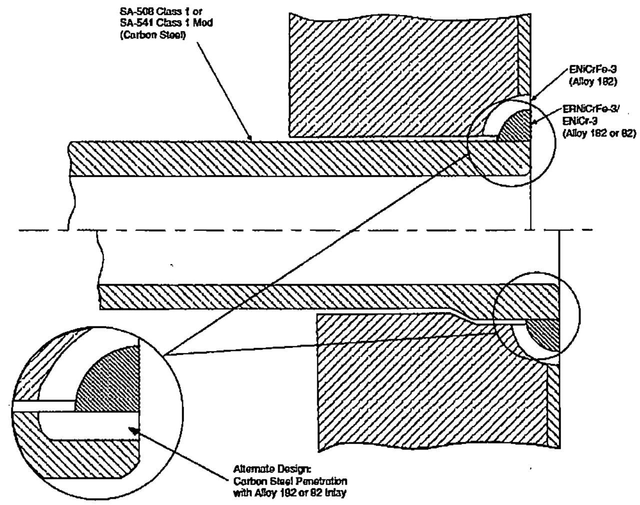
RPV Nozzle Upper Shelf Energy (USE)

- TLAA that has been previously identified for initial LR
- 10CFR50 Appendix G requires EOL USE ≥ 50 ft-lbs
- Consideration of SLR results in a need for plants to revisit this issue
- Two nozzle types need to be considered:
  - SA-508 Cl. 1 instrument nozzles
  - SA-508 Cl. 2 nozzles

Upper Shelf Energy Evaluation for SA-508, Cl. 1 Nozzles

SA-508 Cl. 1 Nozzle Forging USE

- Applies to instrument penetration configuration
  - Configuration applicable to limited number of plants (Columbia, Fermi 2, Hope Creek, Laguna Verde 1, Laguna Verde 2, and Nine Mile Point 2) [see BWRVIP-49-A]
- GEH database of SA-508, Cl. 1 initial USE data compiled to assess
  - Charpy data with ≥95% shear, conservatively assuming longitudinal orientation
  - Component types represented include nozzles, safe ends, pipe, flanges



Typical SA-508 Cl. 1 Nozzle
(from BWRVIP-49-A)

SA-508 Class 1 Initial USE Data

- Atypical distribution of results
- Many high USE data points truncated by machine test capability
- All of the low initial USE test results associated with two heats of material used for safe end forgings
- All of the nozzle and pipe data have high initial USE

[[

Content Deleted
EPRI Proprietary Information

]]

SA-508 Cl. 1 Forging Initial USE Data

- Safe end forging data are clearly different than other distributions
- All of the data from two low initial USE heats contained in the red box
- Data are distinct from other safe end data – no overlapping data points

[[

Content Deleted
EPRI Proprietary Information

]]

  EPRI ELECTRIC POWER RESEARCH INSTITUTE

SA-508 Class 1 Initial USE Data

- Considering all data ([[ ]] data points)
  - Mean = [[ ]]
  - Min measurement = [[ ]]
  - Mean-2σ = [[ ]]
- Considering only data for nozzles and pipe ([[ ]] data points)
  - Mean = [[ ]]
  - Min measurement = [[ ]]
  - Mean- 3σ = [[ ]]
- Considering only data from two low USE heats (safe ends) ([[ ]] data points)
  - Mean = [[ ]]
  - Min measurement = [[ ]]
  - Mean- 2σ = [[ ]]
- Nonparametric statistical test concludes safe end data are from a different population than nozzle and pipe data

Content Deleted
EPRI Proprietary Information

  EPRI ELECTRIC POWER RESEARCH INSTITUTE

Discussion

- An investigation into the low toughness heats was performed to identify any characteristics that would explain the differences. No such evidence was identified. However, these two heats are clearly different than the remaining 26 heats in the database.
- Resources likely not expended to investigate low initial USE values, so long as the result obtained was acceptable
- Minimum initial USE needed to satisfy a bounding assessment is only 65 ft-lbs
  - Assuming Cu content at upper end of specification allowable (0.35%) and a conservative upper-end fluence associated with 80-yr operations
- The consequence of low upper shelf toughness is not the same for these penetrations as for RPV shells and large diameter nozzles
  - In the very unlikely event that the penetration or extension/safe end cracked 360° and separated, the resulting small break would be immediately detected by drywell pressure, temperature or leakage detection instrumentation and a safe reactor shutdown would be achieved
  - This assessment is included within BWRVIP-49-A

  EPRI ELECTRIC POWER RESEARCH INSTITUTE

BWRVIP Position on SA-508, Cl. 1 Nozzles

- No evidence of a safety concern associated with SA-508, Cl. 1 nozzle forging low initial USE
  - High USE values are generally anticipated
  - Conservative assessment shows that initial USE values need be only [[ ]] (more realistic estimates would place initial USE values needed at less than [[ ]])
  - Although not anticipated, failure of a small bore nozzle is accommodated within the plant design basis and is a part of the rationale associated with NRC acceptance of the conclusions related to aging management of RPV penetrations in BWRVIP-49-A
- Many plants have initial USE values that meet the requirement of 50 ft-lbs, but are based on low shear data
  - Efforts made to "justify" end of life USE values associated with these data are not needed to assure safe operation

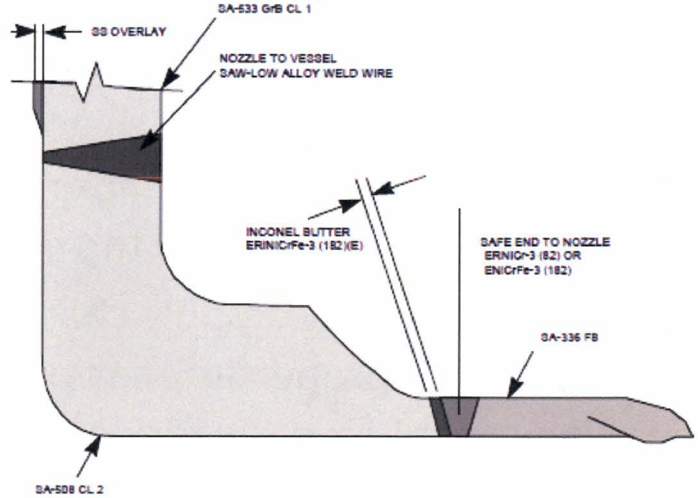
Content Deleted
EPRI Proprietary Information

  EPRI ELECTRIC POWER RESEARCH INSTITUTE

Upper Shelf Energy Evaluation for SA-508, Cl. 2 Nozzles

SA-508 Cl. 2 Nozzle Forgings

- Full penetration welded nozzle forgings
- Many BWRs have SA-508, Cl. 2 nozzles in the extended beltline
- Documented in LRAs



Typical SA-508 Cl. 2 Nozzle
(from BWRVIP-74-A)

SA-508 Class 2 Initial USE Data

- Data analyzed from SA-508 Class 2 BWR forgings database. Charpy data for transverse and longitudinal specimens with high % shear.
- Transverse USE ([[ ]])
  - Mean = [[ ]], St Dev (σ) = [[ ]]
  - Min measurement = [[ ]]
  - Mean-2σ = [[ ]]
  - Mean-3σ = [[ ]]

Content Deleted
EPRI Proprietary Information

- Minimum required initial USE = [[ ]] to attain EOL USE of 50 ft-lb, assuming a conservative upper-end fluence associated with 80-yr operations and best estimate %Cu (based on BWRVIP-173-A).
- If plant-specific fluence is lower than assumed in this analysis, likelihood of low EOL USE is very small, and no additional evaluation is needed
- Some plants have limited charpy data that does not include data indicative of upper shelf properties. These plants may need to rely on this evaluation as a basis for disposition.

Discussion

- No evidence of a safety concern associated with SA-508, Cl. 2 nozzle forging low initial USE
- Statistically improbable that nozzle end-of-life USE is less than 50 ft-lbs so long as nozzle end-of-life fluence is less than the upper end fluence assumed in the evaluation ([[Content Deleted EPRI Proprietary Information]])
- Some plants having only charpy data that are not indicative of upper shelf properties may potentially need to rely on this evaluation as a basis for disposition of nozzle forging TLAAs

Status / Schedule

BWRVIP-316 – Status & Future Plans

- *EPRI Report 3002012536, BWRVIP-316: BWR Vessel and Internals Project - Reactor Pressure Vessel Aging Management Evaluation for Extended Operations*
  - To be published July 2020
  - BWRVIP intends to submit BWRVIP-316 to NRC for review and approval in September 2020

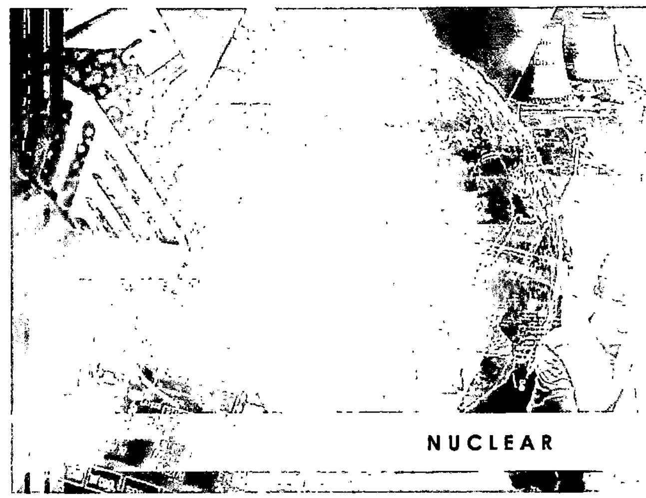
Together...Shaping the Future of Electricity

ELECTRIC POWER RESEARCH INSTITUTE

BWRVIP-316: BWR Reactor Pressure Vessel Aging Management for Extended Operations
(OPEN SESSION)

Wayne Lunceford, P.E.
Technical Executive, EPRI BWRVIP

NRC Public Meeting
March 25, 2020



BWRVIP History

- Program created in 1994
- Initial objective to address IGSCC identified in BWR core shrouds
- Expanded to encompass all materials issues associated with BWR RPVs and internals
- Large body of knowledge - currently, there are well over 300 BWRVIP reports, many of which have been revised one or more times
- Inspection and Flaw Evaluation (I&E) Guidance exists for all safety-related BWR RPV & internals components
- Consistent tracking, trending and evaluation of field inspection data for over 20 years
- Key involvement in development and deployment of IGSCC mitigation technologies
- History of proactive engagement with NRC to address aging management concerns associated with BWRs

BWRVIP Guidelines to Manage Degradation

Component	Assessment (I&E) Guidelines	Inspection Guidelines	Repair/Replace Design Criteria	Mitigation Recommendations
Core shroud	BWRVIP-76	BWRVIP-03	BWRVIP-02/-04	BWRVIP-62/-190
Core spray	BWRVIP-18	BWRVIP-03	BWRVIP-16/-19/-34	N/A
Shroud support	BWRVIP-38	BWRVIP-03	BWRVIP-52	BWRVIP-62/-190
Top Guide	BWRVIP-26	BWRVIP-03	BWRVIP-50	N/A
Core Plate	BWRVIP-25	BWRVIP-03	BWRVIP-50	BWRVIP-62/-190
SLC	BWRVIP-27	BWRVIP-03	BWRVIP-53	BWRVIP-62/-190
Jet pump assembly	BWRVIP-41	BWRVIP-03	BWRVIP-51	BWRVIP-62/-190
CRD guide/stub tube	BWRVIP-47	BWRVIP-03	BWRVIP-17/-55/-58	BWRVIP-62/-190
In-core housing/dry tube	BWRVIP-47	BWRVIP-03	BWRVIP-17/-55	BWRVIP-62/-190
Instrument penetrations	BWRVIP-49	BWRVIP-03	BWRVIP-57	BWRVIP-62/-190
LPCI coupling	BWRVIP-42	BWRVIP-03	BWRVIP-56	N/A
Vessel ID brackets	BWRVIP-48	BWRVIP-03	BWRVIP-52	BWRVIP-62/-190
Reactor pressure vessel	BWRVIP-74	N/A	N/A	BWRVIP-62/-190
Primary system piping	BWRVIP-75	N/A	N/A	BWRVIP-62/-190
Steam dryer	BWRVIP-139	BWRVIP-03	BWRVIP-181	N/A
Access hole cover	BWRVIP-180	BWRVIP-03	TBD	BWRVIP-62/-190
Top guide grid beam	BWRVIP-183	BWRVIP-03	BWRVIP-50	N/A
Bottom head drain line	BWRVIP-205	N/A	BWRVIP-208	N/A

Utility Participation & Commitment

- On May 30, 1997 BWRVIP issued a letter to NRC, committing all BWR U.S. utilities to full support in the development, maintenance and implementation of the BWRVIP program
- This commitment stayed in place until superseded by NEI 03-08, Guideline for the Management of Materials Issues
  - NEI 03-08 Materials Initiative Policy Statement:

    "... the industry will ensure that its management of materials degradation and aging is ***forward-looking and coordinated*** to the maximum extent practical. Additionally, the industry will ***continue to*** rapidly identify, react and ***effectively respond to emerging issues***. The associated work will be managed to emphasize safety and operational risk significance as the first priority, appropriately balancing long term aging management and cost as additional considerations. To that end, as issues are identified and as work is planned, the groups involved in funding, managing and providing program oversight will ensure that the ***safety and operational risk significance of each issue is fully established prior to final disposition***."

BWRVIP Approach to SLR

BWRVIP Approach to SLR (1 of 2)

- Existing aging management guidance is robust and, unless impacted by time-dependent factors, remains adequate to manage the effects of aging
  - Although unanticipated adverse trends are possible, the BWRVIP program already includes activities to assess operating experience and new R&D results.
  - Field performance data are continually evaluated and aging management guidance updated as appropriate
- Time-Dependent Factors:
  - Factors associated with age-related degradation that directly or indirectly correlate with total accumulated operating time
  - Examples – neutron fluence, fatigue cycles
- Many of the elements of an effective AMP are clearly independent of operating time (e.g., program scope, administrative controls, corrective actions, operating experience evaluation)
  - No need to revisit these program elements for SLR

BWRVIP Approach to SLR (2 of 2)

- Aging management guidance implementation should be linked to engineering-based parameters
  - Contained in the underlying analytical work forming the technical basis for AMP implementation
  - Limitations on guidance applicability tied to parameters related to onset / progression of age-related degradation (*not operating period*)
- Applicability can be confirmed on a plant-specific basis (*results need not be "bounding" for the entire fleet*)
  - Each owner / licensee confirms that their plant satisfies the conditions for use of the guidance
  - BWRVIP focus placed on technical aspects of aging management
  - Decisions regarding plant operating period and licensing approach are the responsibility of the owner / licensee

BWRVIP-316, Reactor Pressure Vessel Aging Management Evaluation for Extended Operations

BWRVIP-316, RPV Aging Management Evaluation for Extended Operations

- Comprehensive review of the technical bases for conclusions regarding the impact of aging effects and associated degradation mechanisms on aging management of BWR RPV components for extended operations
- Review of operating experience relevant to aging management of BWR RPVs
- BWRVIP Evaluations Addressing RPV TLAAs
  - Fluence calculations
  - RPV Material Surveillance / Integrated Surveillance Program (ISP)
  - Upper shelf energy (USE)
- Represents an augmentation of BWRVIP-74-A, BWR RPV Inspection and Flaw Evaluation Guidelines for License Renewal

BWRVIP-316 - Contents

1. Introduction
2. Evaluation Scope
3. Degradation Assessment
4. Aging Management Review For Extended Operations
5. BWRVIP Evaluations Supporting RPV TLAAs
   - Inservice Inspection of RPV Circumferential Welds
   - USE Evaluation for RPV Plates and Welds
   - USE Evaluation for RPV Nozzle Forgings
6. AMP Attribute Assessment
   - Reviews the applicability of AMPs based on BWRVIP guidance that are credited by NUREG 2191 to manage aging of RPV components:
     - XI.M4, "BWR Vessel ID Attachment Welds"
     - XI.M7, "BWR Stress Corrosion Cracking"
     - XI.M8, "BWR Penetrations"
     - XI.M31, "Reactor Vessel Material Surveillance"
7. Summary of Results

BWRVIP-316 – Contents (continued)

Appendix A – BWRVIP Guidance Applicable to Aging Management of RPV Components

Appendix B – RPV Plate and Weld Upper Shelf Energy (USE) Evaluation

Appendix C – RPV Nozzle Forging USE Evaluation

Appendix D – BWR RPV Operating Experience Review

Appendix E – Degradation Mechanism Summaries

BWRVIP-316 – Summary of Conclusions (1 of 2)

- Neutron fluence and fatigue are the primary time-dependent factors affecting aging management of BWR RPV components
- Management of SCC is not time-dependent
  - Detailed review of BWR RPV fleet operating experience does not show an adverse trend in performance
  - Existing AMPs (ASME Section XI, relevant BWRVIP I&E Guidelines) remain adequate to address cracking due to SCC
- BWRVIP-06 Rev. 1-A safety assessment conclusions and BWRVIP inspection and flaw evaluation (I&E) guidance relevant to RPV aging management are not impacted by consideration of extended operations

BWRVIP-316 – Summary of Conclusions (2 of 2)

- BWRVIP evaluations that generically support neutron embrittlement TLAA dispositions should be re-evaluated to address extended operations
  - RPV circumferential weld inservice inspection TLAAs are addressed by demonstrating that the acceptance criteria in BWRVIP-329 remain satisfied through plant EOL
  - RPV plate and weld upper shelf energy TLAAs are addressed by demonstrating that the acceptance criteria Appendix B of BWRVIP-316 are met
  - RPV nozzle upper shelf energy TLAAs are addressed by Appendix C of BWRVIP-316

BWRVIP-316 – Status & Future Plans

- *EPRI Report 3002012536, BWRVIP-316: BWR Vessel and Internals Project - Reactor Pressure Vessel Aging Management Evaluation for Extended Operations*
  - To be published July 2020
  - BWRVIP intends to submit BWRVIP-316 to NRC for review and approval in September 2020

Together...Shaping the Future of Electricity