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BWRVIP-18, Revision 2, Core Spray Inspection and Flaw Evaluation Guidelines

Open Session

EPRI BWRVIP / NRC Meeting

May 27, 2015

Agenda

- Meeting Objectives
- BWRVIP Perspective on Use of Topical Reports
- Optimization of BWRVIP Inspection and Flaw Evaluation Guidelines
- History and Status of Core Spray Internals Inspection and Flaw Evaluation Guidance (BWRVIP-18)
- BWRVIP Concerns Regarding NRC SE for BWRVIP-18, Rev. 2
- Conclusions

Meeting Objectives

- Communicate the BWRVIP's concerns with the conditions contained in the draft SE for the optimized version of the BWRVIP Core Spray Inspection and Evaluation Guidelines (BWRVIP-18, Rev. 2)
- Request that the NRC consider the BWRVIP's technical input regarding those concerns when finalizing the SE for BWRVIP-18, Rev. 2

BWRVIP Perspective on Use of Topical Reports

Historical Perspective

- The Boiling Water Reactor Vessel and Internals Project (BWRVIP) is a voluntary initiative first formed in 1994.
- The initial purpose of the BWRVIP was to address stress corrosion cracking (SCC) in BWR core shrouds, but was expanded to address SCC and other age related damage mechanisms for all the safety related BWR vessel internals (and some non-safety components).
- In the absence of Regulatory or ASME Code requirements that addressed these issues, the BWRVIP developed inspection and evaluation guidelines for the vessel internal components and submitted these "topical reports" to the NRC for review and approval.

Benefits for Both Industry and NRC

- Proactively addresses BWR vessel internals material degradation issues not covered by Regulation or Code
- Ensures adequate safety margins are maintained and provide for asset protection
- Robust and effective aging management tool
- Generic solutions with fleet-wide applicability

Intended to be Generic

- The BWRVIP Inspection and Evaluation Guidelines (I&EGs) are developed such that they can be generically applied to the entire U.S. BWR fleet
- In accordance with 10CFR170.11 (a)(1)(iii), the I&EGs are submitted to the NRC as a means of exchanging information for the purpose of supporting generic regulatory improvements
- Generically applicable guidance optimizes the use of NRC and Industry resources
  - NRC approval of BWRVIP flaw evaluation guidance precludes the need for plant-specific flaw evaluation submittals

Optimization of BWRVIP Inspection and Flaw Evaluation Guidelines

Background

- BWRVIP I&E Guidelines were developed from 1994 to 1999 and largely based on safety considerations and potential degradation mechanisms including limited inspection results
  - Program based on normal water chemistry, thus no credit taken for or consideration of SCC mitigation via improved water chemistry (MHWC/NMCA)
- Post-implementation of I&E Guidelines
  - Significant inspection data generated which provides insight regarding component degradation trends and mitigation effectiveness
  - Widespread implementation of MHWC / NMCA and desire to obtain credit for SCC mitigation
  - EPRI/BWRVIP R&D efforts have improved knowledge of degradation mechanisms
  - NDE improvements both in UT and VT

Objective

- Optimize inspection programs based on:
  - Field inspection data and fleet operating experience
  - Evaluation of mitigation credit for benefits of HWC / NMCA
  - Current NDE capabilities
- Primary considerations:
  - Inspection results
  - Crack growth studies
  - Structural evaluations

Approach

- Phase 1: Component Prioritization
  - Prioritize order for optimizing inspection of components addressed by BWRVIP
- Phase 2: Inspection Optimization
  - Develop revised inspection recommendations for each component:
    - Technical basis report
    - Revision to inspection guidelines
    - Submit reports to NRC for approval
- Approach presented to NRC at 6/11/2011 public meeting

Phase 1 Prioritization Process

- Systematic process established for screening & prioritizing I&E Guidelines
- Prioritization approach
  - Relevant attributes identified
    - Available inspection data
    - Effectiveness of mitigation
    - Applicable NDE techniques
    - Structural margin
    - Other factors (e.g., fluence, fatigue cycling)
    - Utility value
  - Ranking and weighting of attributes
  - Final ranking by consensus

Phase 1 Results

No.	I&E Guideline	Priority
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2	Jet Pump (BWRVIP-41)	
3	Shroud (BWRVIP-76)	
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5	CRD Guide Tubes (BWRVIP-47)	
6	Vessel ID Brackets (BWRVIP-48)	Medium
7	Top Guide Rims / Pins (BWRVIP-26)	
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Resultant Changes to I&E Guidelines

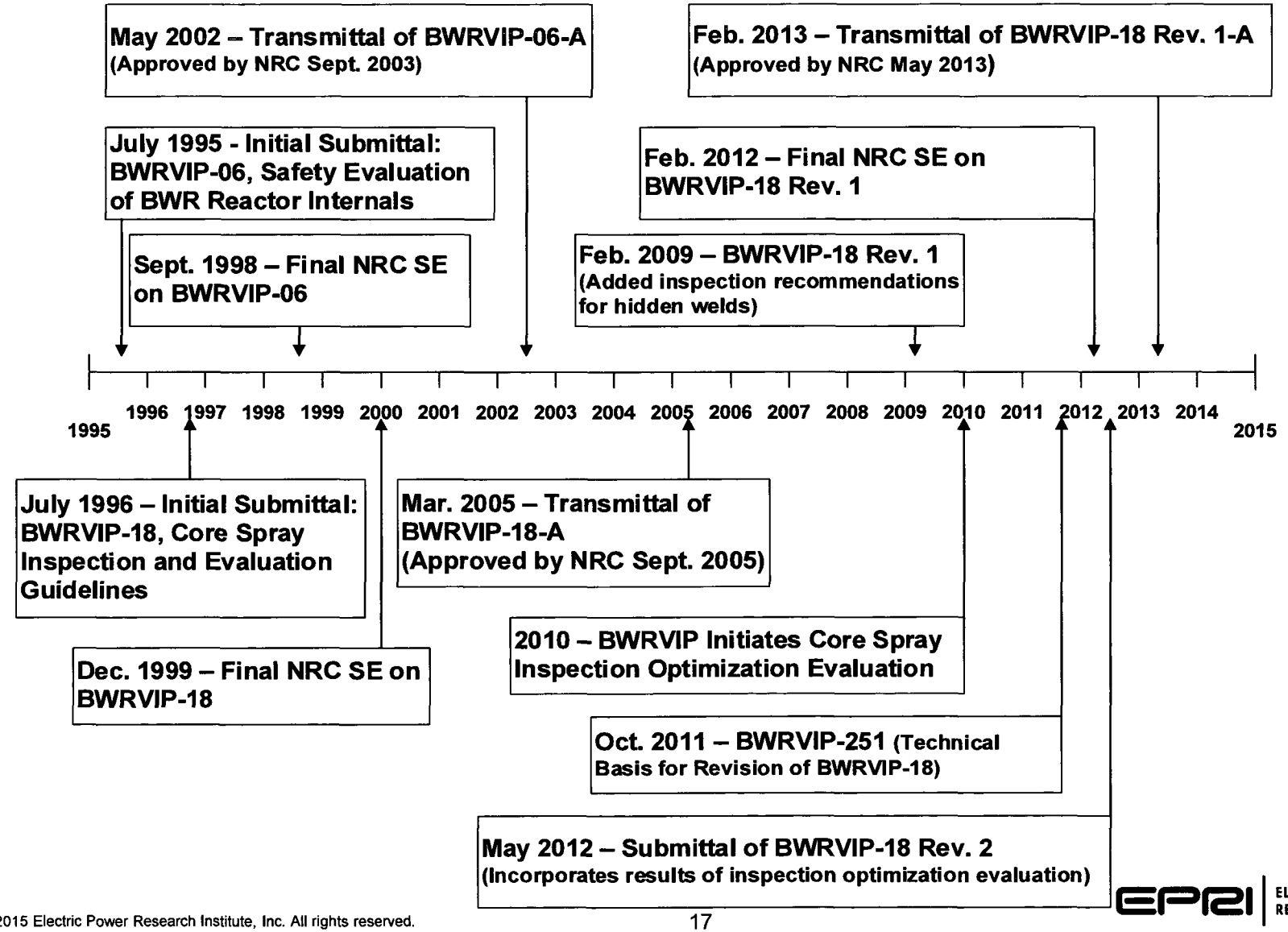
- What is changed
  - Incremental changes to the inspection requirements
  - In general, inspection frequency and/or sample size requirements are relaxed, but some are increased
  - More credit for volumetric exams (incentivize its use)
- What is not changed
  - Safety bases
  - Flaw evaluation methodologies
  - Leakage analysis requirements
  - Hidden weld guidance

Status of I&E Guidelines Optimization

- Results of ranking published in BWRVIP-236: Inspection Optimization Program Roadmap
- Core Spray (BWRVIP-18, Revision 2)
  - Revision 2 submitted to the NRC for review and approval on 05/09/2012 (Basis document BWRVIP-251)
- Jet Pump Assembly (BWRVIP-41, Revision 4)
  - Revision 4 submitted to the NRC for review and approval on 09/24/2014 (Basis document, BWRVIP-266)
  - Acceptance review complete, now in technical review
- Core Shroud (BWRVIP-76, Revision 2)
  - Revision 2 is published, but not yet submitted to the NRC (Basis document, BWRVIP-278)

History of Core Spray Internals Inspection Guidance (BWRVIP-18 Background)

BWRVIP-18 Timeline



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BWRVIP-06, Internals Safety Evaluation

- Developed to proactively address the continuing observations of IGSCC in BWR reactor internals
- Evaluated component function and potential failure modes and locations
- Identified short and long-term actions needed for management of reactor internals
- Core spray evaluation concluded that the periodic inspections performed every outage since the early 1980s (NRC Bulletin 80-13) were adequate to address short-term needs
- A long-term action was identified to develop generic guidance to assure the capability of core spray systems to perform their intended safety functions

BWRVIP-18-A

- Replaced the guidance provided by NRC IE Bulletin 80-13
- Reinspection criteria conservative, based on the cracking observed in early vintage plants
  - Joint configuration (creviced vs. uncreviced welds)
  - Material of construction (304SS vs. L-Grade)
  - Uncreviced 304SS welds inspected at the same frequency as creviced welds
- Provided conservative methods for flaw and leakage evaluations
  - Conservative CGRs assumed
  - Uninspected regions assumed to be fully cracked
- "-A" version addressed issues identified in the NRC SE and was accepted by NRC
- Subsequently accepted by NRC for referencing in LRAs

BWRVIP-18, Rev. 1-A

- Limited revision defining the conditions under which inaccessible welds must be inspected or preemptively repaired or replaced
- Considers redundant load carrying capabilities and the condition of similar accessible welds
- Provides reasonable assurance that structural and leakage margins are maintained, while avoiding excessive cost and personnel dose that would result from unnecessary repair of inaccessible welds
- Provides a conservative method for considering leakage associated with inaccessible welds
- "Rev. 1-A" version accepted by NRC without condition

BWRVIP-18, Rev. 2

- First revision of the inspection program provided by BWRVIP-18 since initial publication in 1996
- Inspection program optimized based on a comprehensive data collection and evaluation effort
  - In the case of core spray, includes approximately 15 years of inspection data resulting from examinations performed consistent with the original BWRVIP-18 program – **multiple inspections over many years**

BWRVIP-18, Rev. 2 (continued)

- Revision **NOT** focused solely on inspection reductions. Program focus altered as appropriate based on evaluation of the available data
  - Reinspection intervals increased for some weld categories but decreased for others
- Revision did **NOT** alter any of the safety bases supporting the program, nor the guidance provided for structural and leakage evaluations which had been previously reviewed and accepted by NRC

Core Spray Internals Optimization Results

- Data provided by all U.S. plants
  - Location, number and length of all flaws remaining in service
  - Timeline data - when flaws first observed, changes identified by subsequent inspections
  - NDE methods and coverages attained
- Resulting database provides comprehensive status of every core spray internals weld in the U.S. fleet
  - A significant percentage of core spray internals welds inspected every outage or every other outage since initial implementation of BWRVIP-18
  - Large database of baseline and reinspection data available for evaluation
- Results summarized in Section 3 of BWRVIP-251

Core Spray Internals Results – Piping Welds

- All large flaws detected during baseline inspections performed as a result of BWRVIP-18 or even earlier (no new flaws ≥ 5 inches detected since 1998)
- Little evidence of significant new cracking
  - Between 2001 and 2010, more than 3,000 piping weld inspections performed with 8 new indications reported (some locations from rotating sample and were not inspected before 2001)
  - Declining trend in crack growth, many flaws show no growth at all
- Performance of L-Grade welds similar to that of uncreviced 304SS – and no propensity for development of large flaws in L-Grade piping welds (either creviced or uncreviced joint designs)

Core Spray Internals Results – Sparger Welds

- Significant flaws in major sparger welds detected very early in fleet service life, generally prior to implementation of BWRVIP-18
- Overall, very few flaws reported and a majority of repairs were installed preemptively
- Numerous repeat examinations have not identified any new flaws in the past 20+ years (*last S1 / S2 sparger weld flaw reported in 1993*)
- Since 2001, over 1,200 major sparger weld exams performed with no new indications identified
- New initiation occurrences or periods of high crack growth are improbable given the large number of inspections performed over many years with no new cracking identified

BWRVIP Questions and Concerns Regarding the Safety Evaluation for BWRVIP-18 Rev. 2

NRC's Regulatory Requirements Basis

- In the Section 2.0 of draft SE, the NRC references the ECCS evaluation model requirements of 10 CFR 50, Appendix K as the regulatory requirements applicable to the safety evaluation.
- The BWRVIP believes the more appropriate requirements are the general design requirements of 10 CFR 50, Appendix A; in particular Criteria 36, which states, "The emergency core cooling system shall be designed to permit appropriate periodic inspection."
- In fact, SE's for previous versions of BWRVIP-18 referenced 10 CFR 50 Appendix A rather than Appendix K. The following slide shows the regulatory requirements section of the SE for BWRVIP-18, Revision 1-A.

NRC's Regulatory Requirements Basis

- Section 2.0, Regulatory Evaluation, of the SE for BWRVIP-18, Revision 1-A states:

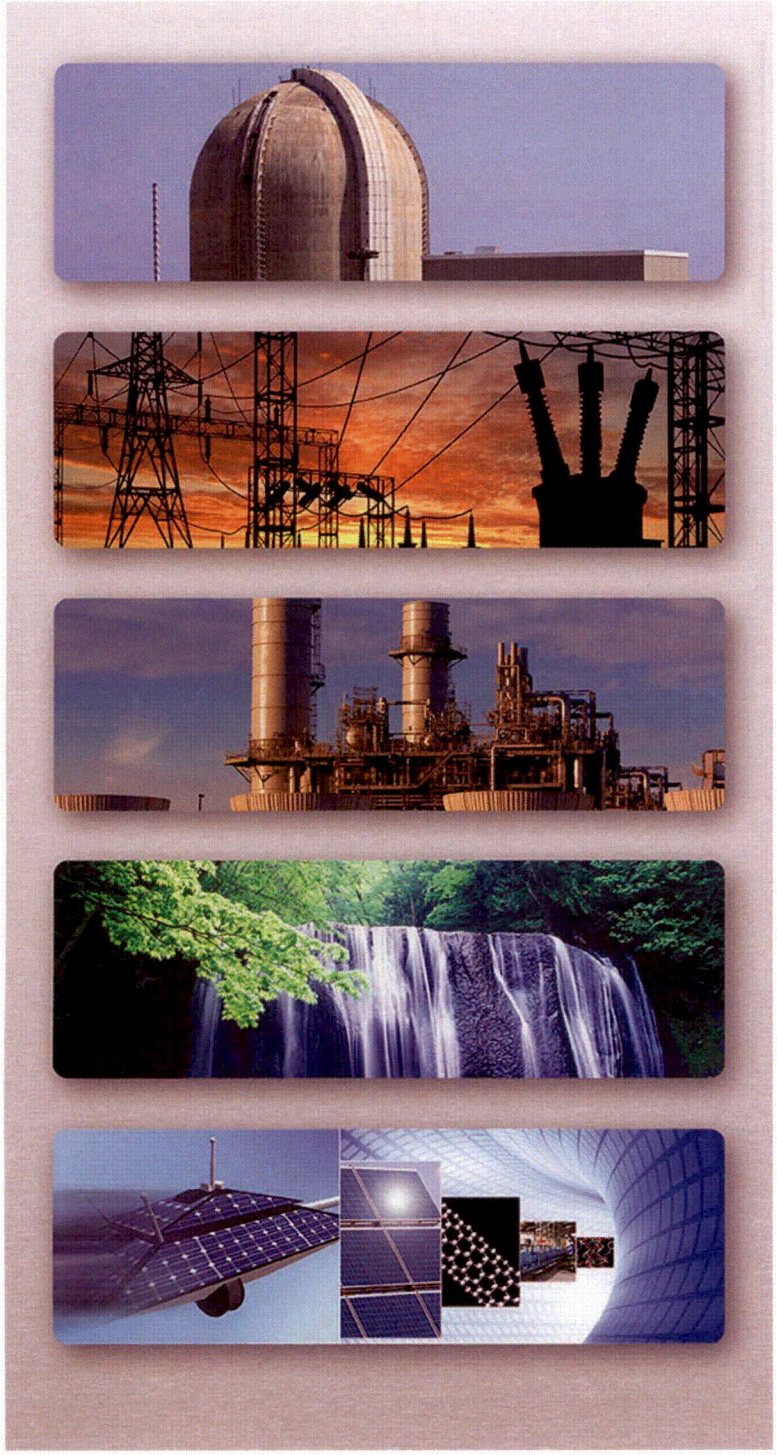
"The BWRVIP guidance regarding core spray internals inspections is a voluntary program pursued by industry in order to address aging management issues in BWR units. At a high level, the general design criteria of Title 10 of the *Code of Federal Regulations* Part 50 Appendix A, 'General Design Criteria for Nuclear Power Plants,' apply. Pertinently, Criteria 36 states that 'the emergency core cooling system shall be designed to permit appropriate periodic inspection,' with BWRVIP-18 providing details regarding the inspection of the core spray internals portion of such a system. The creation of BWRVIP was, at least in part, motivated by a desire to demonstrate that no increased specificity in NRC regulation for BWR internals aging management would be necessary."

NRC Not Accepting Inspection Program for Creviced Welds

- In reaching a conclusion that the proposed inspection program for creviced piping and major sparger welds is unacceptable, the staff did not appear to consider the extensive OE presented in BWRVIP-251, relying instead on theories based on incomplete understanding of IGSCC in BWRs
- SE acknowledges improved data provided by UT examination, but effectively discourages use of UT since BWRVIP-18 Rev. 2 program encourages use of UT

NRC Conditions Placed on Use of BWRVIP-18, Rev. 2

- The proposed NRC conditions on the use of BWRVIP-18, Rev. 2 essentially ensure that no utility would choose to adopt this guidance because:
  - Regardless of inspection results, each licensee would be required to submit a plant-specific leakage assessment for staff review and approval
  - Requires submittal of flaw evaluations for staff review and approval
  - Allows only more conservative inspection program attributes - and, even in this case requires staff approval
  - Requires plants to revert to BWRVIP-18 Rev. 1-A if any flaw or defect is observed in the unflawed welds in the rotating sample of welds
- BWRVIP-18 Rev. 2 was developed with the construct of encouraging use of volumetric NDE and ensuring a focus on the most susceptible welds – these staff conditions will encourage continued reliance on less costly EVT-1 and redundant inspection of low susceptibility welds



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Chuck Wirtz, EPRI

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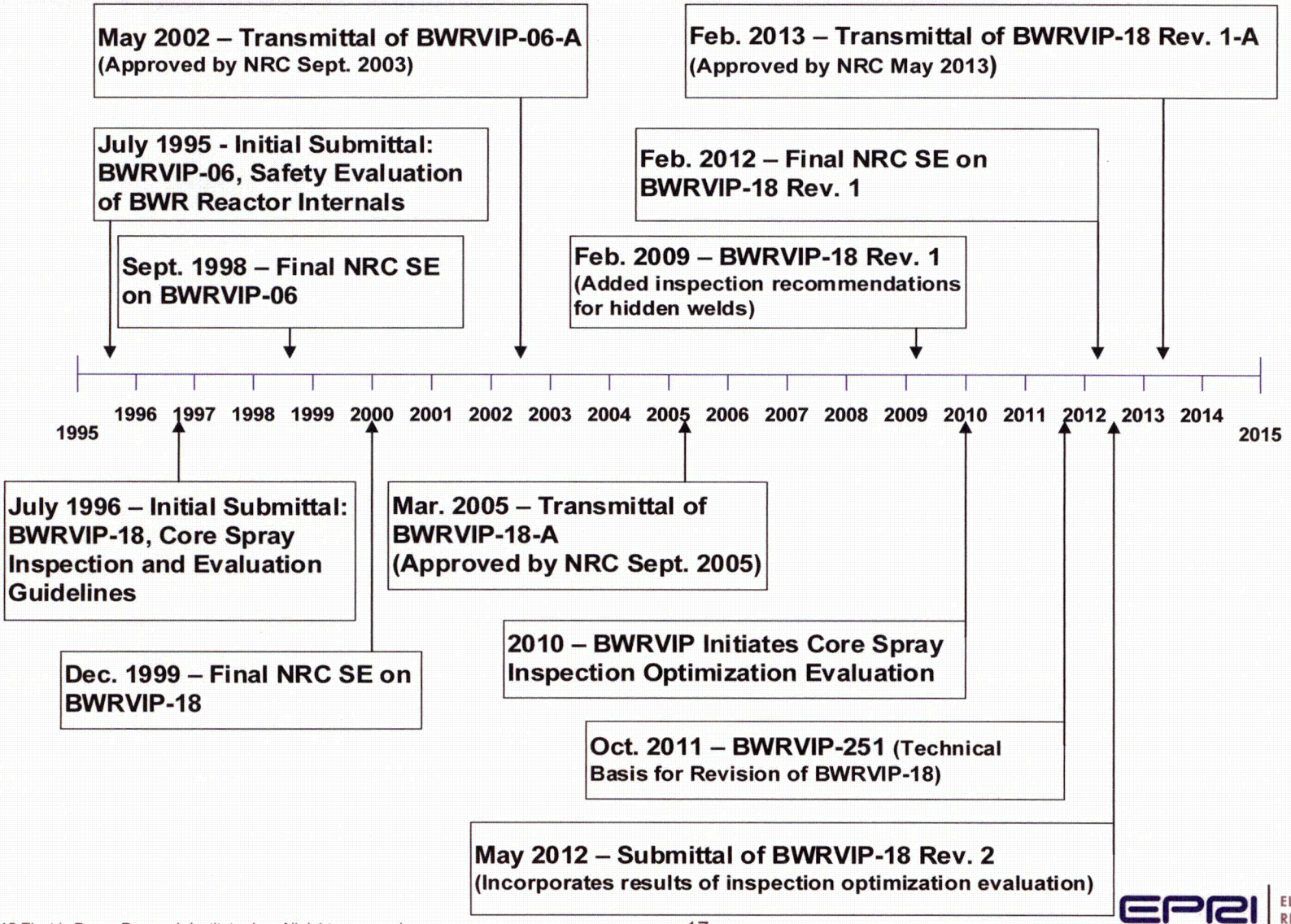

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- The BWRVIP believes the more appropriate requirements are the general design requirements of 10 CFR 50, Appendix A; in particular Criteria 36, which states, "the emergency core cooling system shall be designed to permit appropriate periodic inspection."
- In fact, SE's for previous versions of BWRVIP-18 referenced 10 CFR 50 Appendix A rather than Appendix K. The following slide shows the regulatory requirements section of the SE for BWRVIP-18, Revision 1-A.

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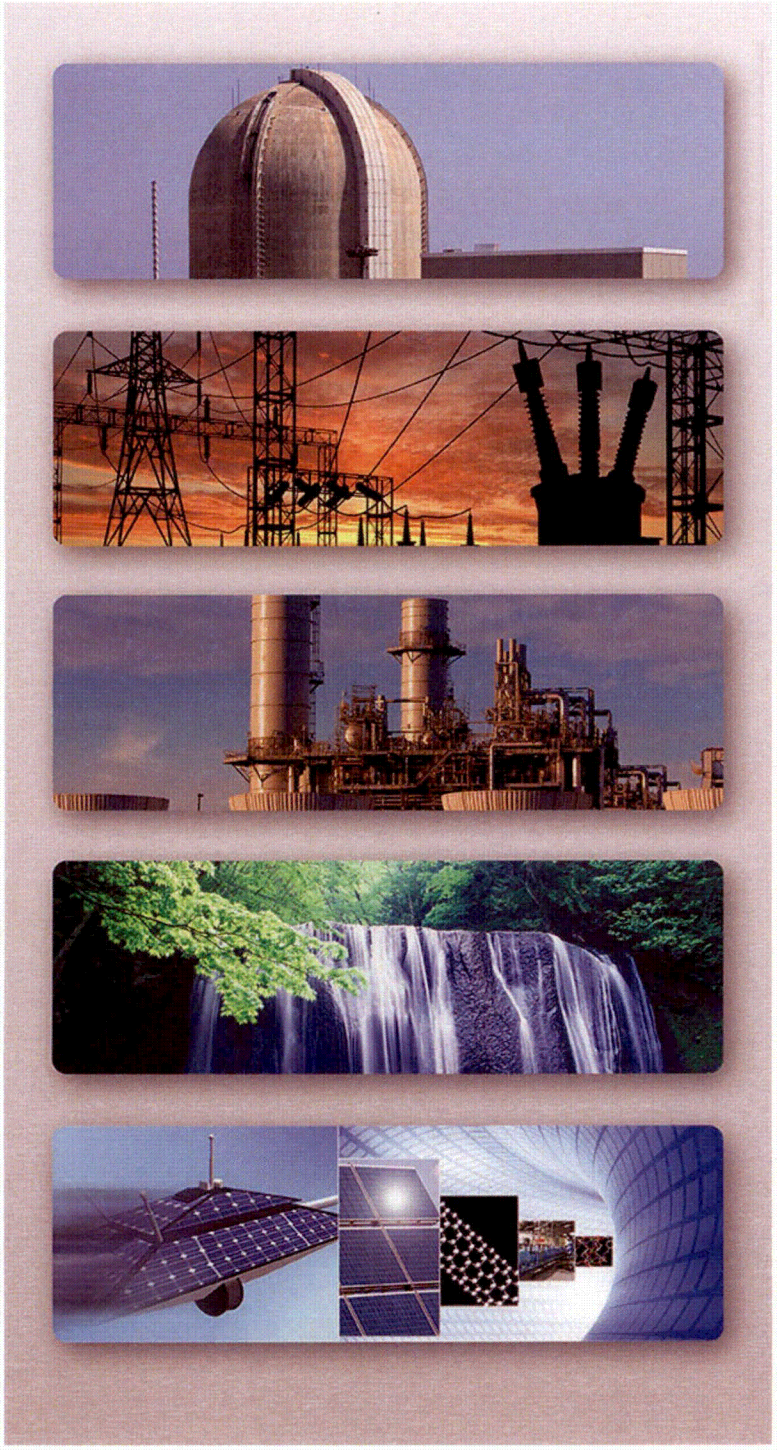

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BWRVIP-18, Revision 2, Core Spray Inspection and Flaw Evaluation Guidelines

Closed Session – Non-Proprietary Version

Wayne Lunceford, Structural Integrity Associates

EPRI BWRVIP / NRC Meeting

May 27, 2015

BWRVIP Concerns Regarding Draft SE on BWRVIP-18, Rev. 2

- BWRVIP concerns related to the technical bases for NRC not accepting the proposed inspection schedule for unflawed creviced piping and sparger welds can be grouped into three main areas:
  - Lack of consideration of the significant amount of field inspection data / OE compiled and evaluated with regard to weld performance (SE Section 4.2.2, items b, c, g)
  - Assumptions regarding NDE capability and the potential for long part-thru wall flaw to exist in core spray piping weld regions (SE Section 4.2.2, items a, d, e, h/i)
  - Consideration of leakage from flaws in uninspected regions of core spray piping welds (SE Section 4.2.2, items e, f, j)

Item (a) Inspection Technology

- The draft SE states: "*Some of the creviced welds in core spray piping system are not inspected with UT technique, and the inspection coverage for some creviced welds is less than 50%. Therefore, some welds could potentially have a through-wall crack which would not be detected until the next inspection period*"

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EPRI Proprietary Information

Item (b) HWC protection

- The draft SE states: "*core spray piping and sparger welds are not protected by hydrogen water chemistry which reduces the IGSCC growth rates. Higher IGSCC crack growth rates were observed when hydrogen is not added*"

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EPRI Proprietary Information

Item (c) Influence of Cold Work

- The draft SE states: "*It is likely that some core spray piping and sparger welds could have been exposed to cold work during the initial fabrication which could potentially increase the occurrence of IGSCC in the weld joints. The severity of cold work is difficult to quantify and, therefore, the licensees may not be able to accurately assess the severity of the cold work and its effects on IGSCC.*"
- The SE statement is based on a historical consideration. The BWRVIP agrees that cold work can potentially increase the occurrence of IGSCC. However:
  - The effect of cold work is anticipated to be manifested early in service life – likely evidenced by the significant number of early life IGSCC flaws identified
  - There is no evidence that cold work affects long-term initiation or crack growth trends

Item (d) Application of UT

- The Draft SE states: "*As of 2006, the BWRVIP's inspection strategy is to perform two sided UT of the weld joint to identify indications in heat affected zone (HAZ) on both sides of the weld. IGSCC generally occurs in HAZ area due to sensitization of this area during welding. Therefore, a significant portion of previous (prior to 2006) UT examination results may not represent the severity of subsurface cracking in HAZ areas on both sides of the weld joint. Because the inspections were performed from one side of the weld joint, the licensees would not be able to effectively monitor the extent of IGSCC in a given weld joint*"

Item (d) Application of UT (continued)

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Items (e) and (f) Inability to Detect Leakage During Operation

- The draft SE states:
  - "(e) *The licensee would not be alerted of any leak in core spray piping or sparger piping during normal operation because any leak in this system would not provide signs that would prompt the licensee to take proper corrective actions*"
  - "*(f) Potential undetected leakage would compromise the functionality of the core spray systems during the emergency situations. This is particularly true for the welds located outside the core shroud in the annulus region*"

Items (e) and (f) Inability to Detect Leakage During Operation (continued)

- The safety significance of the core spray system was recognized in BWRVIP-06
- BWRVIP-06 Rev. 1-A, Section 2.4.2 addresses monitoring of core spray piping integrity:

  "During normal plant operation, the core spray piping integrity is monitored by a leak detection system which monitors the differential pressure across the core shroud during full power operation. If the differential pressure reaches the setpoint, due to gross core spray pipe cracking, an alarm alerts operators of the condition"

- Thus, BWRVIP-06 Rev. 1-A directly addresses the staff's concerns presented in items (e) and (f)

Item (g) Creviced L-Grade Stainless Steel Weld Performance

- In item (g) of the draft SE, the staff revisits several of the prior items as a basis for not accepting the reduced inspections proposed for creviced L-Grade piping welds – sub-items (1) and (2)
- In addition to the generic BWRVIP positions associated with those items presented in the preceding slides, there are additional observations that can be made specific to creviced L-Grade piping welds
- These observations, documented in BWRVIP-251 and summarized in the following slide, appear not to have been directly considered by the staff in making its determination

Item (g) Creviced L-Grade Stainless Steel Weld Performance (continued)

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Item (g) Creviced L-Grade Stainless Steel Weld Performance (continued)

- In addition, the draft SE presents two additional bases for not accepting the proposed change to the inspection program for creviced L-Grade piping welds:
  - "*(3) undetected embedded flaws could still exist in these welds because UT examinations were not used for all the welds*"
  - "*(4) inspection coverage for some un-creviced welds is less than 50%*"
- Although the topic is creviced welds, item (4) cites un-creviced welds

Item (g) Creviced L-Grade Stainless Steel Weld Performance (continued)

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Item (h / i) Cracking in Uninspected Regions

- Items (h) and (i) present staff concerns related to NDE coverage and the potential for cracking to exist in uninspected regions
  - In item (h) the draft SE states: "*The extent of an inspection coverage that was implemented thus far, for any given category of welds i.e., creviced or non-creviced welds, may not be sufficient to assess the severity of IGSCC in these welds…*"
  - In item (i) the draft SE states: *"For any given weld joint, if the inspection coverage is 50% or less of the surface area, IGSCC may not be detected in a timely manner."*
- The BWRVIP agrees that some potential for undetected cracking will exist for any weld not inspected from both sides by a high coverage volumetric technique
- However, BWRVIP-251 considered such scenarios in developing revised inspection requirements

Item (h / i) Cracking in Uninspected Regions (continued)

- The evaluations documented in Section 4.2 of BWRVIP-251 recognized that limited coverage conditions could exist

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Item (h / i) Cracking in Uninspected Regions (continued)

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Revised Inspection Program (Piping)

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BWRVIP Concerns Associated with NRC Bases for Not Accepting Creviced Weld Inspection Intervals

1. The staff evaluations appear to not include appropriate consideration of the significant review of OE documented in BWRVIP-251

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2. Although the staff recognizes the value in application of UT methods in assessing the integrity of core spray piping welds, appropriate credit for UT is not being granted

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BWRVIP Concerns Associated with NRC Conditions Placed on Use of the Revised Inspection Program

- Condition 1 parts (a) and (b) require that licensees *"should submit a plant-specific leakage assessment for NRC staff review and approval"* and "*develop a technical justification for implementing the BWRVIP's proposed inspection plan for uncreviced welds along the five attributes as described in Section 4.1.3 of this SE*"
  (Note: Section 4.1.3 is incorrect, the reference should be to draft SE Section 4.2.3)
- The BWRVIP maintains that the requirements of this condition are not relevant to making a safety determination
  - BWRVIP-18 provides a methodology for performing leakage assessments, thus plants performing such assessments consistent with BWRVIP guidance and obtaining acceptable results are in compliance. NRC review and approval is not necessary.
  - The technical basis for BWRVIP-251, Rev. 2 provides a sound generic technical basis for the revised inspection plan proposed. The guidance considers inspection data from the entire fleet and is intended to be implemented generically.

Conditions Placed on Use of the Revised Inspection Program

- Condition 1 part (c) requires that, "*if any cracking or a defect is observed during future inspections of the unflawed welds that are categorized under 'rotating sample of welds,' the inspection frequency addressed in the BWRVIP-18, Revision 1-A shall be implemented*"
- The BWRVIP maintains that such a condition is unnecessary
  - The inspection program includes provision for inspection of flawed welds on a different interval than unflawed welds
  - The inspection program includes scope expansion requirements

Conditions Placed on Use of the Revised Inspection Program

- Condition 2 requires that licensees "*submit a flaw evaluation to demonstrate that adequate structural margin is maintained for the cracked core spray internal components for continued operation to the next inspection date.*"
- The BWRVIP maintains that this condition represents a new and burdensome requirement not relevant to ensuring safe operation
  - BWRVIP-18 includes NRC approved methodologies for performing structural evaluations and for evaluating inaccessible welds
  - Plants performing such assessments consistent with BWRVIP guidance and obtaining acceptable results are in compliance. NRC review and approval is not necessary.

Conclusions

- The BWRVIP commitment has always been to evaluate operating experience and make appropriate adjustments to the program. BWRVIP-18, Rev. 2 does this.
- The inspection program has been very effective in detection and monitoring of degradation (IGSCC).
- BWRVIP-18 (Rev. 0, 1 and 2) is an aging management program. It does not change or alter the design bases of the core spray system.

Conclusions

- The draft SE on BWRVIP-18, Rev. 2 appears to not recognize the substantial amount of field inspection data that forms the basis for the revised inspection program.
- The draft SE provides no incentive for plants to adopt BWRVIP-18, Rev. 2.
- Plants performing evaluations in accordance with BWRVIP-18, Rev. 2 should not be required to submit those evaluations for NRC review and approval.

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