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ELECTRIC POWER RESEARCH INSTITUTE

2010-190 BWR Vessel & Internals Project (BWRVIP)

August 25, 2010

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Subject: Revised BWR Issue Management Tables

Enclosed for your information are five (5) copies of the report "BWRVIP-167NP, Revision 2: BWR Vessel and Internals Project, BWR Issue Management Tables," EPRI Technical Report 1020995, August 2010. This report is being transmitted to the NRC for information only to keep the NRC informed of industry efforts to manage BWR material degradation issues.

The enclosed report is a revision to BWRVIP-167 to incorporate changes reflecting industry progress in addressing LWR materials issues. The BWR Issue Management Tables (IMT) provide a tool to assist utility personnel in identification, prioritization, and resolution of BWR degradation issues. The IMTs identify all of the major BWR nuclear steam supply system subcomponents. For each subcomponent, the applicable degradation mechanisms, consequences of failure, mitigation techniques, repair/replacement approaches and inspection & evaluation guidance is summarized. Where open issues exist, these issues are identified as "R&D gaps."

The R&D Gaps resulting from the IMT development process are listed in Section 3 of this report. Gaps are divided into functional areas based on the type of gap (e.g., assessment, mitigation, inspection and evaluation). Each gap includes a summary of the open issue and supporting basis documentation. Failure consequence information, along with probability of failure by a given degradation mechanism, is used to establish gap priorities which represent the technical bases and funding priorities for additional R&D. Where work is currently underway that will eliminate a gap, the responsible industry program is identified. If no work is underway but is needed, a responsible industry program is recommended as the responsible group to manage the R&D necessary to eliminate the gap. The prioritization of the gaps shown in Table 3-1 is based on input from the BWRVIP participants.

Current plans are to review the IMTs and related gaps annually. The IMTs and related gaps may also be updated at other times to reflect emerging issues as well as other industry events or needs.

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NRR

Please note that the enclosed report is non-proprietary and is available to the public. The report can be downloaded from www.epri.com.

If you have any questions on this subject please call Chuck Wirtz (FirstEnergy, BWRVIP Integration Committee Technical Chairman) at 440.280.7665.

Sincerely,

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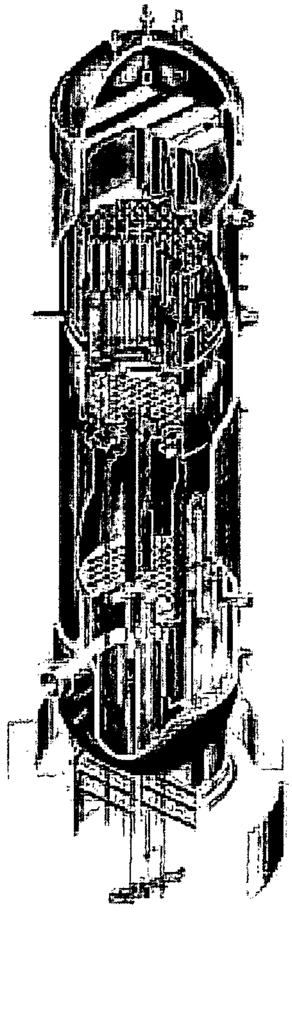
BWRVIP-167NP, Revision 2: BWR Vessel and Internals Project

Boiling Water Reactor Issue Management Tables



BWRVIP-167NP, Revision 2: BWR Vessel and Internals Project

Boiling Water Reactor Issue Management Tables

1020995

Final Report, August 2010

EPRI Project Manager
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Work to develop this product was completed under the EPRI Nuclear Quality Assurance Program in compliance with 10 CFR 50, Appendix B and 10 CFR 21,

YES (NO) ✓

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REPORT SUMMARY

Nuclear utilities face numerous ongoing issues related to degradation of boiling water reactor (BWR) pressure vessels, reactor internals, and American Society of Mechanical Engineers (ASME) Class 1 piping components. These issues have resulted in the need for a summary tool to assist in prioritizing and addressing research and development (R&D) issues and BWR Vessel and Internals Project (BWRVIP) requirements. The BWR Issue Management Tables (IMTs) in the report are living documents that summarize the state of industry knowledge regarding degradation and management of BWR nuclear steam supply system subcomponents.

Background
The rate of materials degradation and, consequently, plant component or system availability are strongly affected by a plant's operating environment, including temperatures, radiation types and fluxes, and water chemistry. Accordingly, the anticipated operating environment is a critical element of materials selection for new and replacement components. For materials in service, understanding how the operating environment may be practically modified is essential to mitigating degradation and associated problems. Thus, a comprehensive, integrated understanding of materials issues and management options is a fundamental consideration in the development of overall plant business and operating strategies. IMTs represent an important step in achieving such understanding for BWRs. This second revision of the BWR IMTs represents an updated presentation of current materials issues and management options for BWRs.

Objective
To provide a tool to assist utility personnel in the identification, prioritization, and resolution of BWR degradation issues.

Approach
Investigators reviewed information from a variety of industry sources — including the Nuclear Regulatory Commission (NRC), Nuclear Energy Institute (NEI), and EPRI — in developing IMTs for BWR nuclear steam supply system subcomponents. The IMTs include information regarding degradation mechanisms, construction materials, consequences of failure, mitigation techniques, repair / replacement approaches, and inspection and evaluation guidance for each subcomponent.

Based on this review, investigators identified a number of R&D gaps and program requirement items. The R&D gaps represent research needs to ensure that components will continue to perform their intended functions for the remainder of the license period. Prioritization of gaps is based on input from the BWRVIP Integration Committee and EPRI BWRVIP task managers.

The BWRVIP requirement items represent areas where ongoing funding is necessary to ensure that degradation issues continue to be managed effectively and that closed gaps remain closed in

the future. Identification of requirement items is confirmed by consensus opinion of the BWRVIP Integration Committee and EPRI BWRVIP task managers.

Results

This BWRVIP report identifies, describes, and prioritizes 45 currently open R&D gaps where additional R&D is needed to resolve issues related to degradation of BWR components. Revision 1 of the BWR IMTs originally identified 48 R&D gaps. The breakdown is as follows:

- Nine new R&D gaps were identified in this revision.
- One new R&D gap was identified in an interim revision in 2009.
- Seven R&D gaps were categorized as closed, based on new data or combination with another gap.
- Six R&D gaps were categorized as closed in an interim revision in 2009.
- The net result is that there are three fewer R&D gaps in this Revision 2 report than were identified previously in Revision 1.

A majority of the new gaps identified and a substantial number of changes to existing gaps result from specific consideration of 80-year service lives, commonly termed long term operation (LTO) by industry. A series of tables describes the R&D gaps, identifies impacted components, provides references to existing research, and presents gap prioritization data. Gaps are divided into functional areas based on the type of gap. For each open R&D gap, an EPRI issue program group is recommended as the responsible group to manage the R&D necessary to eliminate the gap. Additionally, this report documents eight BWRVIP requirement items. An appendix contains the full IMTs for all BWR nuclear steam supply system subcomponents addressed in this project.

EPRI Perspective

EPRI plans to review and update the IMTs and related R&D gaps and program requirements yearly. The IMTs may also be updated at other times to reflect emerging issues as well as other industry events or needs.

Keywords

BWR Vessel and Internals Project (BWRVIP)
BWR
Degradation mechanisms
Issue management tables
R&D gaps
Reactor pressure vessel
Vessel and internals
Piping

ABSTRACT

This document contains Boiling Water Reactor Issue Management Tables (IMTs) that identify, prioritize, and describe R&D gaps and issue program requirements related to BWR degradation issues. An R&D "Gap" is identified whenever there are needs in the areas of degradation mechanism understanding, mitigation techniques, repair / replacement techniques, or inspection & evaluation technologies to provide reasonable assurance that a component will continue to perform its intended function for the remainder of the licensed period. Additionally, this report documents BWRVIP Requirement Items. Requirement items represent ongoing issue program projects necessary to ensure that degradation issues continue to be managed effectively and closed gaps remain closed in the future. The IMT tables included in the report summarize information on materials of construction, degradation mechanisms, consequences of failure, mitigation approaches, repair and replacement technologies, and inspection and evaluation of components.

ACRONYMS AND ABBREVIATIONS

Acronym / Abbreviation	Definition
AHC	Access Hole Cover
ALARA	As Low As Reasonably Achievable
ART	Adjusted Reference Temperature
AS Gap	Assessment R&D Gap
ASME	American Society of Mechanical Engineers
B&PVC	Boiler & Pressure Vessel Code
BWR	Boiling Water Reactor
BWROG	BWR Owners' Group
BWRVIA	BWR Vessel and Internals Application
BWRVIP	Boiling Water Reactor Vessel and Internals Project
CASS	Cast Austenitic Stainless Steel
CFD	Computational Fluid Dynamics
CGR	Crack Growth Rate
C&LAS	Carbon and Low Alloy Steel
CRD	Control Rod Drive
CS	Carbon Steel
CUF	Cumulative Usage Factor
C&W	Corrosion & Wear
DH	Down Horizontal
DMW	Dissimilar Metal Weld
DM Gap	Degradation Mechanism Understanding R&D Gap
ECP	Electrochemical Corrosion Potential
Emb	Embrittlement
Env	Environmental

Acronym / Abbreviation	Definition
EOL	End-of-Life
EPRI	Electric Power Research Institute
EVT	Enhanced Visual Test
Ext.	External
FAC	Flow Accelerated Corrosion
Fat	Fatigue
FIV	Flow Induced Vibration
GALL Report	Generic Aging Lessons Learned Report
GE	General Electric Company
GEH	GE Hitachi
GE-NE	GE Nuclear Energy
GE SIL	GE Services Information Letter
HC	High-Cycle
HWC	Hydrogen Water Chemistry
HWC-M	Hydrogen Water Chemistry - Moderate
I&E	Inspection & Evaluation
IASCC (IA)	Irradiation Assisted Stress Corrosion Cracking
ICMH	In-Core Monitor Housing
IE	Irradiation Effects
IGSCC (IG)	Intergranular Stress Corrosion Cracking
IHSI	Induction Heating Stress Improvement
ISP	Integrated Surveillance Program
IMT	Issue Management Table
KSCC	Stress Intensity Factor, SCC Threshold
LAS	Low Alloy Steel
LC	Low-Cycle
LPCI	Low Pressure Coolant Injection
LPRM	Local Power Range Monitor
LTCP	Low Temperature Crack Propagation
LTO	Long Term Operation
MDM	Materials Degradation Matrix

Acronym / Abbreviation	Definition
MRP	Materials Reliability Program
MSIP	Mechanical Stress Improvement Process
MT Gap	Mitigation R&D Gap
NBS	Nuclear Boiler System
NDE	Nondestructive Examination (or Evaluation)
NDEC	Nondestructive Evaluation Center
NEI	Nuclear Energy Institute
Ni-Alloy	Nickel Alloy
NMCA	Noble Metal Chemical Application
NPS	Nominal Pipe Size
NRC	Nuclear Regulatory Commission
NWC	Normal Water Chemistry
OLNC	On-line NobleChemTM
PDI	Performance Demonstration Initiative
PNNL	Pacific Northwest National Laboratory
PSCR	Primary Systems Corrosion Research Program
PWR	Pressurized Water Reactor
R&D	Research and Development
RAMA	Radiation Analysis Modeling Application
RDC	Repair Design Criteria
R.G.	Regulatory Guide
RG Gap	Regulatory Issue R&D Gap
RHR	Residual Heat Removal
RiFP	Reduction in Fracture Properties
RMS	Root Mean Square
RPV	Reactor Pressure Vessel
RQMT	Requirement
RR Gap	Repair / Replacement R&D Gap
RTNDT	Reference Temperature – Nil Ductility Transition
SBP	Small Bore Piping
SCC	Stress Corrosion Cracking

Acronym / Abbreviation	Definition
SE	Safety Evaluation
SIL	Services Information Letter
SLC	Standby Liquid Control
SR	Stress Relaxation
SS	Stainless Steel
SSP	Supplemental Surveillance Program
TGSCC (TG)	Transgranular Stress Corrosion Cracking
UT	Ultrasonic Testing
VT	Visual Test
WOSI	Weld Overlay Stress Improvement

DEFINITIONS

The following set of definitions are provided to clarify some of the terminology used within the gap descriptions and the IMTs. This listing is not intended to be a comprehensive glossary of technical terms, but rather a key listing of terms which are helpful to the user in understanding the IMTs.

Alloy 600 is a common abbreviation used by industry, the regulatory authority, and research organizations for UNS N06600 base metal.

Alloy 52 and ***Alloy 152***, and Alloy 52M (also includes Alloy 52MS) are common abbreviations used by industry, the regulatory authority, and research organizations for UNS N06052 (SFA-5.14, ERNiCrFe-7), UNS W86152 (SFA 5.11, ENiCrFe-7), or UNS N06054 (SFA-5.14, ERNiCrFe-7A), respectively.

Alloy 82 and ***Alloy 182*** are common abbreviations used by industry, the regulatory authority, and research organizations for UNS N06082 (SFA-5.14, ERNiCr-3) and UNS W86182 (SFA- 5.11, ENiCrFe-3), respectively.

Beltline, as defined in 10 CFR 50.61(a)(3), is the region of the reactor vessel (shell material including welds, heat affected zones, and plates or forgings) that directly surrounds the effective height of the active core and adjacent regions of the reactor vessel that are predicted to experience sufficient neutron radiation damage to be considered in the selection for the most limiting material with regard to radiation damage.

Branch connections are fittings that merge a smaller fluid line into or with a larger one. Instrumentation connections within piping (such as pressure tap connections and resistance temperature element mounting bosses) are also referred to as branch connections. Fittings are generally included within the "piping component" IMT line items and are not shown as separate IMT line items.

A ***Casting*** is an item at or near finished shape obtained by solidification of a substance in a mold.

Cladding (clad) is a thin layer of stainless steel or nickel-base alloy material applied to the interior surfaces of a carbon or low-alloy steel component in contact with reactor coolant.

Class 1 is the ASME Class 1 primary coolant pressure-retaining boundary.

Consequences of Failure describes the operational results that occur when a component item ceases to perform its intended function.

Degradation Mechanism is a term describing the degradation processes that are applicable to NSSS materials.

A ***Dissimilar Metal Weld (DMW)*** is a weld between (a) carbon or low-alloy steels to high alloy steels, (b) carbon or low-alloy steels to high nickel alloys, or (c) high alloy steels to high nickel alloys.

A ***Fitting*** is a manufactured component used in a piping system to effect a change in fluid flow direction, pipeline size, or a special connection. Such components may be manufactured by processes similar to those used in manufacturing pipe. Fittings are generally included within the "piping component" IMT line items and are not shown as separate IMT line items.

Fluence is the time-integrated neutron flux. Neutron flux is the product of neutron density times neutron speed. Units of fluence are neutrons/cm^2 (n/cm^2).

Forging is plastically deforming metal, usually hot, into a desired shape by means of localized compressive forces exerted by presses, special forging machines, or by manual or power hammers.

Fracture Resistance is a generic term for measures of a material's resistance to extension of a crack.

Full Structural Weld Overlay describes the deposition of weld reinforcement on the outside diameter surface of the piping, component, or associated weld such that the weld reinforcement is capable of supporting the design loads without the piping, component, or associated weld lying beneath the weld reinforcement.

A ***Gap*** is an identified area where additional research & development is considered warranted to improve the fundamental understanding of degradation mechanisms or to develop improved solutions for prevention of materials degradation or detection of degraded conditions.

Intended Functions are those functions of a system, structure or component which satisfy the requirements established in 10 CFR 54 for functions within the scope of license renewal.

The ***Nominal Pipe Size (NPS)*** system is a classification system published in ANSI/ASME B36.10 and B36.19 setting standard dimensions for pipes of various sizes.

Non-Process Piping Components is a generic term used in the IMTs to describe NBS connected piping segments that do not directly support the NBS functions, but rather function only to provide operator feedback, support automated actions, or support outage / maintenance activities.

Nozzles are defined in the IMTs to include full penetration welded vessel penetrations, sometimes with thermal sleeves or other features. The IMTs distinguish between full penetration welded nozzles and other vessel penetrations using partial penetration welds. See "penetrations" below. Examples of nozzles include reactor vessel feedwater and main steam nozzles.

Passive describes components that perform their intended function(s) without moving parts or without a change in configuration of properties.

Penetrations are defined to include vessel connections which use tube inserts and partial penetration welds (e.g. are not full penetration welded nozzles).

The term ***Piping Component*** is generally used in the IMTs to describe pipe segments, pipe fittings, branch connections, welded attachments, thermowell bosses and thermowells.

The term ***Qualification*** is used generally in the IMTs to describe performance demonstrations for NDE technologies, procedure qualification, and NDE personnel certification.

A ***Safe End*** is a transition piece welded to the terminal end of a "nozzle" or "branch connection" prior to connection with the external piping.

The term ***Shells and Heads*** is generally used in the IMTs for forged or welded alloy steel plate components comprising pressure vessels.

Small Bore Piping (SBP) is a generic term used to describe piping with nominal pipe size (NPS) less than 4". NPS 4" is a pipe size commonly used in ASME Section XI to differentiate between inspection techniques for larger pipe sizes (typically including volumetric examination requirements) and inspection techniques for smaller pipe sizes (typically limited to visual and surface examination requirements).

Stress Improvement is a process that produces sufficient compressive stress on the inside diameter wetted surface to inhibit initiation and propagation of stress corrosion cracks.

Thermal Sleeve is a thin sleeve provided inside a nozzle or branch connection to mitigate sudden large thermal shocks at a physical junction when fluids of highly dissimilar temperatures are mixed.

The term ***Tube*** is generally used in the IMTs to describe tubular products used in heat exchangers.

The term ***Welded Attachment*** is generally used in the IMTs to describe groups of components which are welded to the interior or exterior surfaces of primary pressure-retaining components.

A ***Wrought*** alloy is a metal alloy that has been mechanically worked following an initial casting step.

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INTRODUCTION

1.1 Objective

The BWR IMTs provide a tool to assist utility personnel in identification, prioritization, and resolution of BWR degradation issues. The IMTs identify all of the major BWR nuclear steam supply system subcomponents. For each subcomponent, the applicable degradation mechanisms, consequences of failure, mitigation techniques, repair / replacement approaches and inspection & evaluation guidance is summarized. Where open issues exist, these issues are identified as "R&D gaps." Gaps are used to collect and identify areas where the allocation of additional resources is needed to resolve a materials degradation issue.

Currently open R&D gaps resulting from the IMT development process are listed in Section 3 of this report. Gaps are divided into functional areas based on the type of gap (e.g., assessment, mitigation, inspection & evaluation). Each gap includes a summary discussion of the open issue and supporting basis documentation. Failure consequence information, along with probability of failure by a given degradation mechanism, is used to establish gap priorities which represent the technical bases and funding priorities for additional R&D.

Section 3 also lists BWRVIP Requirement Items. Requirement items represent ongoing issue program projects necessary to ensure that degradation issues continue to be managed effectively and closed gaps remain closed in the future.

Appendix A contains the BWR Issue Management Tables.

Appendix B contains additional information related to R&D gaps closed by this revision of the IMT report.

1.2 Implementation Requirements

This report is provided for information only. Therefore, the implementation requirements of Nuclear Energy Institute (NEI) 03-08, Guideline for the Management of Materials Issues, are not applicable.

2 METHODOLOGY

This chapter outlines the content and methodology used to develop the issue management tables, R&D gaps, and program requirements. In preparing revision 2 to this document, a review of applicable references was performed covering the time period since development of Revision 1 (March 2008) through January 2010.

2.1 Issue Management Table Structure

2.1.1 Components

The component column identifies the set of components evaluated by the IMT process. Component identification for the RPV and the Reactor Internals is primarily obtained from the BWRVIP safety evaluation, BWRVIP-06, Revision 1-A, and any applicable Inspection & Evaluation (I&E) documents. The level of detail is at the major sub-component level as described in BWRVIP-06, Revision 1-A and the I&E documents. For components not addressed by BWRVIP-06, Revision 1-A or I&E documents, review of recent license renewal applications (LRAs) and NUREG-1801 (Generic Aging Lessons Learned Report) is used as an aid in identification of sub-components.

To reduce the number of IMT line items, the component list does not address welds as separate line items, even though SCC is associated with weld locations. Using this approach, IMT attributes (degradation mechanisms, mitigation techniques, I&E guidance, repair / replacement techniques) applicable to either the base metal component or any associated welds are shown together in one line item. An exception to this methodology is dissimilar metal Ni-Alloy welds, which are called out specifically either within the component line item or as a separate item.

For some non-safety related assemblies such as the steam dryer assembly and the shroud head assembly, sub-components are not specifically called out. Determination of which assemblies were "consolidated" is based on the similarity of the applicable degradation mechanisms, management strategies, and R&D Gaps. Identical line items are combined.

Each component line item included in the IMTs is assigned a unique numerical identifier having three aspects.

The ***Major Assembly*** identifier is the same for all component items in each IMT table / major assembly (e.g. upper reactor internals).

The ***sub-assembly*** identifier is the same for all component in a sub-assembly (e.g. control rod guide tube assembly).

The ***component item*** identifier is specific to the component level of detail (e.g. control rod guide tube support tubes). Note that when multiple materials are in service for a single component item (e.g. X-750 and 316CW guide tube support pins), separate line items and component identification numbers are assigned to each different material used. However, effort has not been made to distinguish between various treatments of the same material class, such as differences in heat treatment.

Figure 2-1 below illustrates the component identification number.

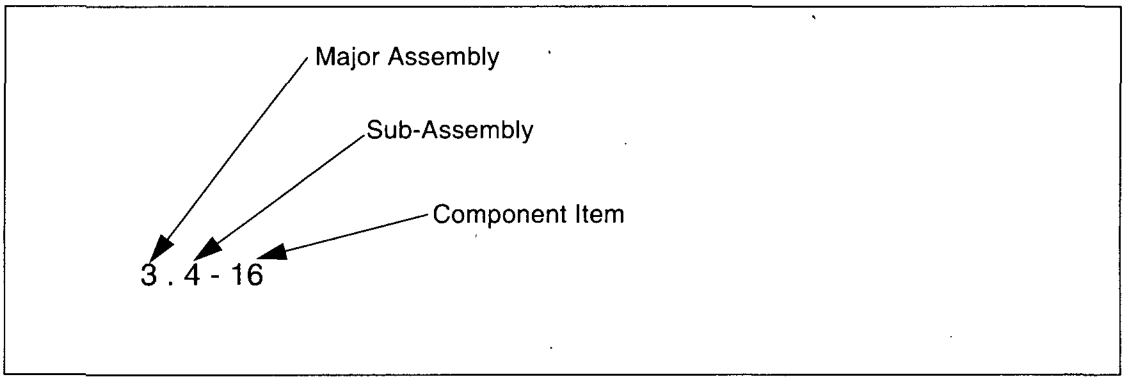

Figure 2-1 IMT Component Identification Number

2.1.2 Material

The material of construction column provides general information on the materials of construction for each component line item. The materials of construction are identified from applicable I&E documents, LRAs, and other resources as needed. The materials are categorized at the same level of detail as the Materials Degradation Matrix (MDM), with the exception that welds are not shown as a separate material category (for example, a stainless steel component including both base metal and welds is shown only as "SS"). For welded components, the presence of weld heat affected zones is also implied. The intent is to consistently specify material classes and facilitate electronic searching of the IMTs. IMT users are encouraged to refer to the MDM for definitions of the material classes used and for detailed discussion regarding materials of construction.

Initial lists of materials of construction for each component were identified by review of BWRVIP reports. Input from member utilities is used to refine the materials listings.

In addition to the material class, material grades (e.g., 304, 304L, etc.) are, when available, shown in parentheses below the material category. In all cases, the material grade information should be considered typical, and not all-inclusive. Stainless steel and carbon & low alloy steel weld metal grades are not included since these were not typically specified in the documents reviewed. For stainless steels, the weld metal used is less important than the associated base metal grades since the location of greatest IGSCC susceptibility is the base metal heat affected zone and not the weld. Where Ni-Alloy weld metal is present, effort was made to identify the applicable grades, typically Alloy 82 and / or Alloy 182.

2.1.3 Degradation Mechanisms

The Degradation Mechanism column contains the applicable degradation mechanisms for each component location. The current version of the EPRI MDM forms the basis for the degradation mechanism results contained in the BWR IMTs. Definitions for degradation mechanisms generally follow the definitions provided in the current revision of the MDM. IMT users are encouraged to refer to the MDM for definitions of degradation mechanisms and for detailed discussion regarding degradation mechanisms.

Application of the MDM results for specific component locations is accomplished by review of the MDM notations and by review of other relevant documentation. BWRVIP documents and other industry references were also reviewed to gain an improved interpretation of degradation mechanism applicability for BWR reactor vessel, internals, and ASME Class 1 piping components. As a result of these reviews, some degradation mechanisms were limited to specific locations based on factors such as the nature of the MDM notations associated with a degradation mechanism, fluence thresholds, or operating experience. Where the MDM results leave some ambiguity, a conservative approach is taken.

2.1.4 Consequences of Failure

Applicable BWRVIP I&E documents and recent LRAs were reviewed to identify component functions and consequences of failure. A short list of common terms is used to simplify the presentation of results. BWRVIP-06, Revision 1-A and BWRVIP I&E documents provide detailed discussions regarding the component consequences of failure. No effort was made to duplicate this level of detail in the BWR IMTs. The intent of the IMT categories used is to generally describe the subcomponent's primary function and to distinguish safety-related components from those components having no safety-related function. Interested readers are directed to BWRVIP-06, Revision 1-A and the applicable BWRVIP I&E guidelines for discussion regarding consequences of failure.

The following consequences of failure key is used throughout the IMTs:

A - Loss of reactor coolant pressure boundary integrity

B - Loss of component support

C - Loss of component constraint
(This consequence includes the potential for crack extension into the RPV alloy steel base material.)

D - Loss of Integrity
(This consequence is applied to the steam dryers where recent operating experience with loose part generation indicates that maintaining the integrity of steam dryer components is important to safety due to the potential for generation of loose parts and the impact of these loose parts on safety-related components.)

E - Loss of core flow distribution
(This consequence is specifically related to flow distribution within the reactor vessel to ensure adequate cooling of fuel assemblies.)

F - Loss of core support and / or orientation
(This consequence is related to support and / or orientation of the reactor core, internals components, or control rod assemblies, or incore instrumentation.)

G - Loss of two-thirds core height coverage

H - Loss of Flow restriction capability

None - There are no safety-related consequences of failure
(This function indicates that there is no safety consequence directly associated with failure of the component location. Economic or non-safety related operational consequences may exist for these component locations.)

When no safety consequences exist for a component, no R&D gaps are associated with the component.

2.1.5 Mitigation

The Mitigation column provides a general description of the currently available mitigation technologies, primarily chemistry controls. Operating changes and stress improvement may also be viewed as mitigation methods. The mitigation methods may or may not be in full use in the fleet, and may or may not be "qualified" as to their relative effectiveness. The column attempts to capture all of the possible techniques, with gaps identified where further research & development is needed to mature a mitigation technology. Reference documents are provided when applicable to the mitigation technique.

Water Chemistry

In this version of the BWR IMT, water mitigation technologies include normal water chemistry (ALARA) and hydrogen water chemistry technologies:

- Moderate Hydrogen Water Chemistry (HWC-M)
- Nobel Metal Chemical Application (NMCA)
- On-line NobleChem^{TM} (OLNC)

Stress Improvement

Weld Overlay Stress Improvement (WOSI), Induction Heating Stress Improvement (IHSI), Peening, and Mechanical Stress Improvement Process (MSIP) are existing technologies available to reduce tensile stresses in piping butt welds to levels below K_{SCC}. This mitigation category is applicable to line items related to large bore Alloy 82 / 182 butt welds and SS butt welds.

Mechanical Fatigue Management

This mitigation technique describes mitigation approaches for management of high cycle fatigue issues related to the steam dryers and to cantilevered small bore piping vents and drains.

Recent operating history with steam dryers indicates that significant unanticipated loadings due to power uprates have resulted in flow-induced high cycle fatigue damage. In response, one available mitigation technology is to strengthen certain susceptible weld locations to reduce operating stresses or to reconfigure steam dryer geometry in an effort to reduce the acoustic loads present during operating conditions. An additional method that can be employed is the use of acoustic load mitigation devices.

For small bore piping, high cycle fatigue failures can occur due to vibratory oscillation in excess of the ultimate fatigue threshold. Effective mitigation of this degradation mode can be accomplished through strengthening of susceptible welds or through reduction in the cantilevered piping segment moment arm.

High-Cycle Thermal Fatigue Management

PWRs have experienced fatigue cracking of stagnant lines connected to the reactor coolant loop due to cyclic penetration of thermal eddies into the stagnant branch line. A similar situation could occur at a BWR unit if the appropriate conditions exist. The BWRVIP sponsored work to assess these conditions and provide member utilities with screening criteria. BWRVIP-155 contains specific screening criteria that can be implemented to minimize the risk of this specific manifestation of high-cycle thermal fatigue.

Bolting Integrity (Maintenance Practices)

Proper application of fastener preload significantly reduces the probability of either SCC (due to excessive preload) or joint leakage (due to under-loading).

2.1.6 Repair / Replace

The Repair / Replace column includes reference to the ASME Boiler and Pressure Vessel Code repair criteria or to applicable BWRVIP Repair Design Criteria or Replacement Design Criteria. For some component locations where repair techniques are known to exist or improved design replacement components exist, these additional repair / replacement options are listed.

Replacement is always considered to be an option for either component repair or to mitigate the potential for occurrence of a degradation mechanism. Only industry standard replacements are listed.

2.1.7 Inspection & Evaluation Guidance

The Inspection & Evaluation column provides information relating to existing inspection and evaluation guidelines and the associated inspection technologies and techniques. Data contained in this column typically includes:

- Reference to the applicable I&E guidance documents (such as BWRVIP I&E guidance, ASME Section XI, and GE SILs), or other current and established guidance.
- A description of examination technologies / techniques when no applicable I&E guidance document exists. Where applicable I&E guidance documents exist, users are referred to cited documents for details related to specific inspection and evaluation requirements for a given component item.

Due to the limitations of the IMT development process, it is noted that the IMTs do not include vendor controlled I&E guidance.

Inspection techniques and requirements for each component location are not listed in the IMTs since the implementation of inspection requirements for BWR reactor internals components is often plant specific and below the level of detail appropriate for the IMTs. Users are referred to the references cited in the I&E column for details on applicable I&E requirements. One caveat is that where evaluation concludes that no inspection is required for a component location, this result is shown in the I&E column.

2.2 R&D Gaps

The "Gaps" column in the IMTs contains a reference to the associated R&D gaps for each component. Note that gaps are not assigned to components where no consequences of failure have been identified or where existing management techniques are considered adequate to manage applicable degradation mechanisms. An exception to this convention is gap B-AS-20 which is related to an assessment of non-safety locations. R&D gap tables are included in the results section (Section 3) to describe the gap and identify applicable references.

An R&D "Gap" is identified whenever there are needs in the areas of degradation mechanism understanding, mitigation techniques, repair / replacement techniques, or inspection & evaluation technologies to provide reasonable assurance that a component will continue to perform its intended function for the remainder of the licensed period. When any column of the IMT cannot be adequately populated (e.g., adequate I&E techniques are not available for a degradation mechanism that is not fully mitigated by available mitigation technologies), a gap is identified.

R&D gaps are identified by investigators through review of selected EPRI reports and correspondence (including the MDM and BWRVIP documents), NEI documents, and NRC documents (such as NUREG-1801 and NUREG/CR-6923). R&D Gaps are also identified based on interviews with and input from EPRI personnel, utility advisors, and industry experts.

After R&D gap identification, data mining is performed to identify additional content for the identified gaps. References applicable to each R&D gap are listed at the bottom of the gap description.

R&D gaps are prioritized by the BWRVIP Integration Committee with input from EPRI BWRVIP task managers.

2.2.1 Gap Identification Numbers

Each gap ID number includes three aspects:

- ***Design Type***: BWR IMT gaps are prefixed with "B-" to associate them with the BWR IMTs and prevent confusion with PWR IMT gaps in documentation linking IMT gaps to ongoing research projects, planned research projects, and research proposals. This may occur for IPs with responsibilities bridging both BWR and PWR designs, such as the EPRI NDE Center or Water Chemistry Program.
- ***Gap Type***: Each gap includes an identifier for the type of gap, as discussed in section 2.2.2.
- ***Sequential Numbering:*** Within each gap type, gaps are sequentially numbered. It is significant to note that these sequential numbers are never re-assigned, even if the gap is closed. This approach reduces confusion when referring to gaps by ID number only.

Figure 2-2 illustrates the R&D Gap identification number.

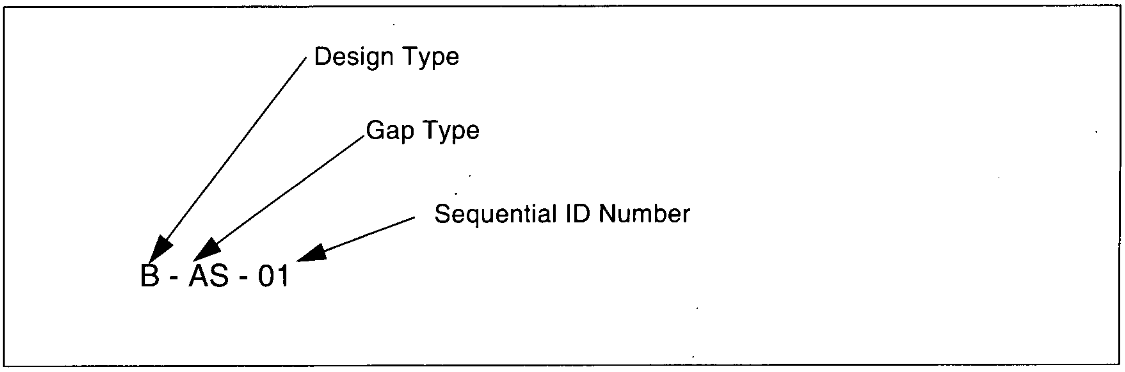

Figure 2-2 R&D Gap Identification Number

2.2.2 Gap Types

Degradation Mechanism Understanding (DM) Gaps

Degradation Mechanism understanding gaps are identified using data obtained from the MDM. These degradation mechanisms are shown as "?" and highlighted in blue in the MDM. An example of a degradation mechanism understanding gap is the development of an understanding of the applicability of low temperature crack propagation for BWR operating conditions.

Assessment (AS) Gaps

Assessment gaps are identified when additional resources are needed to characterize the potential impact of a degradation mechanism shown to be applicable to the BWR operating environment. Additionally, assessment may be needed to determine the proper approach for management of a degradation mode or to develop additional data to better characterize and manage a known degradation issue. An example of an assessment gap is development of additional crack growth rate data for irradiated stainless steels.

Mitigation (MT) Gaps

Mitigation gaps are associated with R&D needs in the area of new technology development or verification of technique effectiveness for preventing degradation mechanism initiation or limiting degradation mechanism progression. An example of a mitigation gap is development of an effective alternative to hydrogen water chemistry technologies.

Inspection & Evaluation (I&E) Gaps

Inspection & evaluation gaps are typically associated with component inspection guidance, NDE qualification, or development of new NDE technology to effectively detect and size indications in degraded components. An example of an I&E gap is development of NDE tools to effectively detect thinning of RPV bottom head drain lines.

Repair / Replacement (RR) Gaps

Repair / Replacement gaps are typically associated with the need for further development or verification of the effectiveness of certain repair techniques. An example of an RR gap is development of weld repair techniques for highly irradiated stainless steels.

Regulatory (RG) Gaps

Regulatory gaps relate to differences between an industry position and the NRC staff position. Regulatory gaps can also relate to technology needs to ensure compliance with regulations. Gap closure typically requires research and development of submittals intended to result in relaxation or alteration of the NRC position or to result in conformance with a regulatory requirement.

Gap Status

Each gap is identified by a status in the IMTs:

- ***Closed***: Applies to previous revision IMT gaps which are no longer considered to be open gaps in this IMT Revision. Gaps may be classified as Closed based on the availability of new data, by obsolescence of the issue, or by incorporation of the issue into another open R&D gap. Gaps closed in this revision of the PWR IMTs are shown in Appendix B, which includes brief discussion regarding the basis for closure of the gap.
- ***Open***: Applies to open gaps from previous revisions of the IMTs which remain open in this IMT Revision.
- ***New***: Applies to gaps which are newly identified in this IMT Revision.

2.3 Program Requirements

The Program Requirement category represents an effort to capture ongoing issue program activities which do not meet the definition of an R&D gap, but are necessary to manage materials degradation issues. These activities are necessary to ensure that materials issues continue to be adequately managed in the future and to ensure that previously closed R&D gaps remain closed. Requirements items are not listed against components in the IMTs. Examples of program requirements items include maintenance of the BWR Integrated Surveillance Program (ISP) and maintenance of the BWRVIP NDE program.

Program requirements are limited to BWRVIP requirements, the primary issue program supporting the BWR IMTs. The list does include program requirements for other issue programs.

Program requirements are confirmed by the consensus opinion of the BWRVIP Integration Committee.

Similar to the R&D gaps, each program requirement is assigned an ID number that includes three aspects:

1. ***Issue Program***: BWRVIP program requirements gaps are prefixed with "B-".
2. ***Requirement Identifier***: Each program requirement includes the "RQ" identifier to differentiate the number from gaps and to enable fast searching for all references to specific program requirements.
3. ***Sequential Numbering***

Figure 2-3 below illustrates the Program Requirement identification number used in the IMTs.

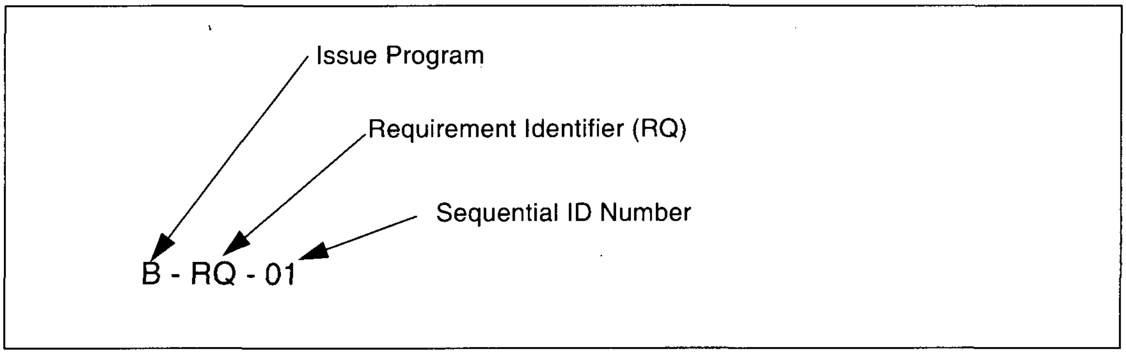

Figure 2-3 Issue Program Requirement Identification Number

3 RESULTS

3.1 Discussion

The following sections outline some of the significant and noteworthy results from identification and prioritization of R&D gaps in this Revision 2 of the BWR IMTs.

3.1.1 Presentation Of Results

The primary results of the BWR IMTs are the final set of open R&D gaps identified. In this revision of the BWR IMTs, there are forty-five currently open R&D gaps identified where additional R&D is needed to resolve issues related to degradation of BWR components. There were forty-eight R&D gaps identified in the previous revision of the BWR IMTs. The breakdown is as follows:

- 9 new R&D gaps were identified in this revision.
- 1 new R&D gap was identified in an interim revision in 2009.
- 7 R&D gaps were categorized as closed based on issue resolution, issue restructuring within gaps, or gap merging.
- 6 R&D gaps were categorized as closed by an interim gap review performed in 2009.

The net result is that there are three fewer R&D gaps in this Revision 2 report than were identified previously in Revision 1.

A series of tables describe the R&D gaps, identify impacted components, provide references to existing research, and present gap prioritization data. Gaps are divided into functional areas based on the type of gap, e.g., assessment, mitigation. For each open R&D Gap, an EPRI issue program group is recommended as the responsible group to manage the R&D necessary to eliminate the gap. Table 3-1 contains a master list of the currently open R&D gaps, along with the associated gap priorities from IMT Report Revision 1 (2008), Revision 1.1 (interim 2009 revision)[1], and Revision 2 (2010). This report is Revision 2 of the BWR IMTs. Tables 3-2 through 3-7 contain R&D gap descriptions by category:

[1] Revision 1.1 of the BWR IMTs refers to *BWRVIP Correspondence 2009-216, "Interim Revision to BWR Issue Management Tables to Include New, Revised, and Re-Ranked R&D Gaps."* This correspondence added new R&D Gaps, re-ranked some R&D Gaps, and revised the content of some R&D Gaps. The BWR IMT Report was not re-published in 2009 to reflect these changes.

Table 3-2 - "Degradation Mechanism Understanding Gaps"

Table 3-3 - "Assessment Gaps"

Table 3-4 - "Mitigation Gaps"

Table 3-5 - "Inspection & Evaluation Gaps"

Table 3-6 - "Repair / Replacement Gaps"

Table 3-7 - "Regulatory Issue Gaps"

Table 3-8 documents eight BWRVIP Requirement Items. BWRVIP Requirement items represent ongoing issue program projects necessary to ensure that degradation issues continue to be managed effectively and closed gaps remain closed in the future.

3.1.2 Strategic Issues

3.1.2.1 Long-Term Operation

A majority of the new gaps identified and a substantial number of changes to existing gaps result from specific consideration of 80-year service lives, commonly termed long term operation (LTO) by industry. Long-term operation of light water reactors generates a number of materials performance concerns for the primary systems. In most cases, longer operation simply aggravates known degradation mechanisms. These degradation processes are reasonably well understood and methods to monitor and manage the degradation are in place. Nevertheless, contemplation of 80-year operation introduces some uncertainty on how severe the degradation will become and whether the rate of degradation follows the projected path. In some areas, extended operating periods raise the potential for new degradation mechanisms to become active that were generally not expected in shorter operating intervals. BWR related LTO issues include neutron fluence effects, fatigue usage, and late-life SCC initiation.

Neutron Fluence Effects:

An additional 20 years of operation substantially increases end of life neutron fluence for many core support structure components and expands the scope of components exceeding neutron fluence thresholds for onset of degradation phenomena. While neutron fluence accumulation is generally linear with increasing operating time (subject to changes in core design and management), the effect on both scope of components affected and the severity of degradation phenomena occurring may not be. Issues identified or aggravated by consideration of LTO include:

- Reactor vessel embrittlement correlations, Pressure-Temperature Limitations, and 80-Year material surveillance programs (Gaps B-AS-28, B-AS-30, and B-RG-08)

- Irradiation effects on cracking of low alloy reactor vessel steels:
  The 2010 MDM panel identified concerns regarding the potential for radiation hardening of the material to reduce resistance to environmentally assisted cracking (Gap B-DM-08).
- Stainless steel irradiated materials data:
  There are concerns that with higher levels of irradiation and long exposure of the surface to the environment, the threshold stress for IASCC initiation could be reduced to relatively low stress levels. This could result in cracking in welds and components where none has previously occurred. A parallel concern is that, at some level of irradiation damage to the microstructure, reduced electrochemical potential (as produced by HWC in BWRs) will cease to be effective at preventing crack initiation and slowing crack growth (Gaps B-AS-09, B-AS-10, and B-AS-11).
- Assessment of irradiation effects for CASS reactor internals:
  BWRVIP-234 documents screening of BWR reactor internals for the effects of thermal and irradiation embrittlement. This study concludes that there are no concerns for 60-year operation. However, the associated gap remains open based on a need to re-perform the screening assessment to address 80-year operation (Gap B-AS-12).
- Irradiation effects on nickel alloys:
  Previously, few nickel alloy reactor internals were projected to exceed neutron fluence screening criteria. Eighty year service lives result in irradiation effects for materials whose irradiated materials properties have not been extensively studied, e.g. Alloy 182 and X-750 (Gaps B-AS-26 and B-AS-27).
- Irradiated materials welding:
  Higher End-of-Life (EOL) neutron fluence expands the scope of components where neutron fluence may limit welding process that can be applied and increases the need for development of field ready laser welding technologies capable of implementing welded repairs for components subject to high neutron fluence (Gaps B-RR-02 and B-RR-08).

Fatigue Usage:

Environmental effects on fatigue usage becomes a significant concern for LTO. Application of NRC guidance for application of fatigue environmental factors to licensing for 60 year operation requires that only a few components be evaluated as defined in NUREG/CR-6260. These evaluations have been generally successful, but not without some difficulty with respect to obtaining historical thermal cycle data. In some cases commitments to fatigue monitoring have been necessary. For 80 year operation, it is likely these evaluations could be extended to a broader selection of components. In any case, it is quite probable that some component locations will have calculated fatigue usage factors exceeding 1.0 when environmental factors are applied, even when stress-based fatigue monitoring and advanced calculation algorithms are employed. See Gaps B-AS-07 and B-AS-14.

Late-life SCC Initiation

Cracking in unsensitized low carbon stainless steels has been attributed to accelerated oxidation of the cold worked surface layer and oxide penetrations into the surface layer. Longer times for oxide formation could lead to more cracking events, or cracking of less severely cold worked layers. Even for surfaces that are not cold worked, or that have had the cold worked layer removed, it is currently unknown if long exposure to the environment can lead to crack initiation in the strained material of heat affected zones. For nickel alloys there is also concern for long term exposure to the environment. Surface cold work has specifically been seen to promote SCC initiation and could be a factor at increasingly long exposure times. Additionally, there is concern that long term deterioration of the surface condition by oxidation, specifically of grain boundaries, could lead to crack initiation at progressively lower stress levels. This could lead to cracking in locations or components not previously known to experience SCC. See gap B-DM-09 and B-DM-10.

3.1.2.2 Mitigation Technologies

Prevention and mitigation of SCC in stainless steels and nickel alloys by means of water chemistry mitigation remains a high priority area for BWR issue management. Mitigation of SCC by chemical means could substantially reduce inspection and repair costs, more so with consideration of 80-year operations. Three of four open mitigation gaps are high priority, with the fourth gap having a medium priority. High priority mitigation gaps associated with prevention or mitigation of SCC include improved ECP modeling (B-MT-02), development of start-up and shutdown chemistry guidance to mitigate SCC crack growth during periods when HWC is unavailable (B-MT-05), and improved methods for distribution of noble metal coatings to prevent SCC during off-hydrogen operation (B-MT-04). Development of alternatives to hydrogen water chemistry technologies that can mitigate cracking in above core components is a medium priority gap.

3.1.2.3 Nondestructive Examination Issues

There are a number of high and medium priority gaps associated with the inability to adequately inspect components. Component areas where either improved NDE technologies or alternate assessment approaches are needed include core plate rim hold down bolts (Gaps B-AS-32 and B-I&E-01), selected shroud and shroud support welds (Gap B-I&E-03), and the RPV bottom head drain nozzle and drain line (Gaps B-AS-07).

Separate from these technical issues, there is ongoing NRC concern that EVT-1 has not been well characterized and may need to be subject to a demonstration program (Gap B-RG-05). While the consensus of the industry is that EVT-1 is generally effective as currently implemented and no significant technical gap exists, the gap prioritization results indicate that the possible impact on in-vessel examinations in terms of increased in-vessel inspection costs and outage time is a significant issue for the BWRVIP membership.

Incorporation of a dimensionless flaw sizing criteria into ASME Section XI Appendix VIII (B-RG-07) is a second gap viewed to be significant by the BWRVIP Integration Committee. As with evaluation of EVT-1, no significant technical gap is associated with the issue, the primary obstacle is codification of this approach.

3.1.2.4 Environmental Reductions in Fracture Properties

The 2010 MDM indicates that reductions in fracture properties due to exposure to the coolant environment remain a significant issue for the industry. There is a growing body of data available to characterize elements of the phenomena, but the broad nature and extent of potential concerns as a function of loading, temperature, material microstructure, and environment chemistry remain poorly defined. At present, there is consensus that a hydrogen mechanism is most likely involved, but there is often insufficient information to quantitatively predict the effects. Laboratory observations include degradation of both fracture resistance (J-R tearing response) and apparent fracture toughness properties (K_{IC} for rapid fracture). These fracture property responses to environment have been observed, mainly at low temperatures (< 150 °C) but can be seen also in high temperature regimes. In general, hydrogen effects are expected to be a more significant in PWRs, since PWR primary water hydrogen concentration is roughly one to two orders of magnitude higher than BWR coolant hydrogen concentrations (even for HWC). However, it is possible that a sufficient hydrogen absorption by BWR components will occur, especially in crevices, when operating under either NWC or HWC and promote environmental effects on fracture behavior. Based on the currently available information, the associated gap, B-DM-06, is assigned a high priority by the BWRVIP Integration Committee.

3.2 R&D Gap Results

Table 3-1 R&D Gap Priority Results

Gap ID No.	Gap Description	Priority		
		R1 (2008)	R1.1[1] (2009)	R2 (2010)
Degradation Mechanism Understanding Gaps (Table 3-2)				
B-DM-03	Low Temperature Crack Propagation	Low	Low	Low
B-DM-06	Environmental Effects on Fracture Resistance	Med	High	High
B-DM-07	Chloride Transient Effects on Low Alloy Steel Crack Growth Rates [2]	N/A	N/A	Med
B-DM-08	Long Term Neutron Fluence Effect on Low Alloy Steel Cracking Susceptibility [2], [3]	N/A	N/A	Low
B-DM-09	Long Term SCC Susceptibility (Late Life SCC Initiation) [2], [3]	N/A	N/A	Low
B-DM-10	Long Term Stress Stability [2], [3]	N/A	N/A	Low
Assessment Gaps (Table 3-3)				
B-AS-05	Assess Neutron Dose Rate Effects on Embrittlement of C&LAS [3]	Med	Med	Med
B-AS-07	Environmental Effects on Fatigue Life: Pressure Boundary Components [3]	Med	Med	High
B-AS-09	Assess the Impact of High Fluence on Fracture Toughness [3]	High	High	High
B-AS-10	Assess the Impact of High Fluence and HWC Mitigation Technologies on SCC Crack Growth Rates [3]	High	High	High
B-AS-11	Assess Non BWR Reactor Irradiated Materials Data Applicability to the BWR Environment [3]	Low	Low	Low
B-AS-12	Thermal & Irradiation Embrittlement: Synergistic Effects (on CASS BWR Reactor Internals) [3]	Low	Low	Low
B-AS-14	Environmental Effects on the Fatigue Life of Reactor Internals [3]	Low	Low	Low

Table 3-1 R&D Gap Priority Results (Continued)

Gap ID No.	Gap Description	Priority		
		R1 (2008)	R1.1[1] (2009)	R2 (2010)
B-AS-15	FIV and High Cycle Fatigue Assessment: Reactor Internals	Med	Med	Med
B-AS-17	Evaluate Hidden Weld Locations	High	High	High
B-AS-18	Jet Pump Degradation Management	High	High	High
B-AS-19	Assess In-Vessel Fastener Loosening	Low	Low	Low
B-AS-20	Assess Non-Safety Locations	Low	Med	Low
B-AS-22	High-Cycle Thermal Fatigue: Piping Locations	Low	Low	Low
B-AS-26	High Strength Alloys [3]	High	High	High
B-AS-27	Alloy 182 / Creviced Alloy 600 SCC Susceptibility & Irradiation Effects [3]	High	Med	Med
B-AS-28	Impact of BWR Nozzle Penetrations on Pressure-Temperature Limit Curves [3]	High	Med	Med
B-AS-29	Steam Dryer Evaluation Methodology [2]	N/A	High	High
B-AS-30	Material Surveillance Program Implementation for 80-Year Service Lives [2], [3]	N/A	N/A	Med
B-AS-31	BWRVIP-47-A (CRGT) Re-Inspection Requirements [2]	N/A	N/A	Med
B-AS-32	Assessment of Core Plate Rim Hold Down Bolts [2]	N/A	N/A	High
Mitigation Gaps (Table 3-4)				
B-MT-01	Alternative Mitigation Technologies	Med	Med	Med
B-MT-02	Demonstrate Improved ECP Model	High	High	High
B-MT-04	Noble Metal Catalyst-Based Mitigation Technology Improvement	Med	Med	High
B-MT-05	Startup & Shutdown Chemistry	High	High	High
Inspection & Evaluation Gaps (Table 3-5)				
B-I&E-01	Inspection of Core Plate Rim Hold Down Bolts	Med	Med	Med

Table 3-1 R&D Gap Priority Results (Continued)

Gap ID No.	Gap Description	Priority		
		R1 (2008)	R1.1[1] (2009)	R2 (2010)
B-I&E-02	Inspection of Hidden Weld Locations (Thermal Sleeves & Piping)	Med	Med	Med
B-I&E-03	Inspection of Shroud & Shroud Support Weld Locations	High	High	High
B-I&E-05	Appendix VIII Compliance	Med	Low	Low
B-I&E-06	NDE Capability: CASS Components	Low	Low	Low
B-I&E-07	NDE Capability: RPV Bottom Head Drain Line	High	High	High
B-I&E-08	Inspection and Evaluation Guidance for Repairs	Low	Low	Low
B-I&E-09	Examination Techniques for Detection of Loss of Preload in Reactor Internals Components	Low	Low	Low
Repair / Replacement Gaps (Table 3-6)				
B-RR-02	Welding Processes for Repair of Irradiated Material [3]	Med	High	High
B-RR-05	Alternate High-Strength Materials	Med	Med	Med
B-RR-06	Repair Solutions for Bottom Head Drain Line Locations	High	High	High
B-RR-08	Availability of Laser Welding for Repairs to Highly Irradiated Components [3]	Low	Med	Med
Regulatory Issue Gaps (Table 3-7)				
B-RG-05	Evaluation of EVT-1	High	Med	High
B-RG-08	Reactor Pressure Vessel Material Surveillance Program Implementation for 80-Year Service Lives [2], [3]	N/A	N/A	Med
B-RG-09	Management of License Renewal Issues [2]	N/A	N/A	High

Notes:

[1] Revision 1.1 refers to *BWRVIP Correspondence 2009-216, "Interim Revision to BWR Issue Management Tables to Include New, Revised, and Re-Ranked R&D Gaps."* This correspondence added new R&D Gaps, re-ranked some R&D Gaps, and revised the content of some R&D Gaps. The BWR IMT Report was not re-published in 2009 to reflect these changes.

[2] Indicates a new R&D gap added since Revision 1 of the BWR IMT Report.

[3] Gaps are created by or affected by consideration of long-term operation (LTO).

Table 3-2 Degradation Mechanism Understanding Gaps

R&D Gap Description	Results Data
B-DM-01 - Environmentally Assisted Cracking: LAS **Gap closed** – See Table B-2 for Gap Description and Closure Basis.	**Status:** Closed
B-DM-02 - SCC of "Resistant" Stainless Steel Materials **Gap closed** – See Table B-2 for Gap Description and Closure Basis.	**Status:** Closed

Table 3-2 Degradation Mechanism Understanding Gaps (Continued)

R&D Gap Description	Results Data
B-DM-03 - Low Temperature Crack Propagation **Issue:** Low Temperature Crack Propagation (LTCP) is a form of hydrogen embrittlement, which has yet to be identified in commercial nuclear reactors, but which can cause significant degradation of the fracture resistance of certain nickel-base alloys in laboratory tests performed under specific test conditions. **Description:** While LTCP is regarded as a result of H_2 embrittlement, the effect of coolant H_2 concentrations is not consistently observed and reductions in fracture tearing resistance can be severe, even at low H_2 concentrations. It is not yet clear whether it represents a genuine reduction in fracture properties of the material, or rather a form of rapid, subcritical crack growth due to the environment. From an operational perspective, it is not known if actual service stresses are sufficient to induce this degradation mechanism. Primary pressure stresses are significantly reduced at the low temperatures where LTCP is observed and only secondary, deflection controlled stresses remain. As a result, there is currently insufficient data to determine if LTCP is a significant concern for BWR commercial operations. Recently completed testing did not identify significant loss of fracture toughness for Alloy 182 exposed to a BWR HWC environment. In another recent EPRI funded study, large reductions in fracture resistance were identified for CASS material in a PWR environment. Reductions in fracture toughness were severe for low temperature (< 150 °C) and inadvertent testing at PWR operating temperature yielded a substantial reduction in fracture resistance as well. Given this information, it is likely that some degradation of CASS fracture properties will occur for CASS components in BWRs, although the magnitude and significance of any reduced fracture properties are likely less substantial than for PWRs. Additionally, the identification of degraded fracture properties in CASS materials is cause for some concern for stainless steel welds, which have similar material composition and microstructural properties. Higher strength alloys (i.e. X-750 and XM-19), heavily cold worked, and highly irradiated components must be considered to be potentially subject to some low temperature effects until testing is performed. Resolution of this gap involves development of an improved understanding regarding the potential applicability and significance of low temperature crack propagation in commercial BWRs and characterization of the parameters influencing LTCP such that, if necessary, guidance for eliminating or minimizing LTCP concerns can be provided in water chemistry guidelines. (Continued on next page.)	**Priority:** R2(2010): Low R1.1(2009): Low R1(2008): Low **Status:** Open **Responsibility:** BWRVIP: Assessment Other: PSCR Program **Affected by LTO?** No

Table 3-2 Degradation Mechanism Understanding Gaps (Continued)

R&D Gap Description	Results Data
B-DM-03 (continued) [*NOTE: This gap is focused only on specific LTCP concerns. Broader concern regarding reduced fracture resistance in materials exposed to reactor coolant across the range of normal operating temperatures is described in gap B-DM-06.*] **References:** 2010 MDM (Appendix A, Section A.6.2) MRP-108, MRP-145, MRP-209, MRP-247, 1019030	See previous page
B-DM-04 - NMCA Plant Corrosion Products **Gap closed** in Revision 1 (2008) – See EPRI BWRVIP-167NP, Revision 1 (EPRI 1018111) for Gap Description and Closure Basis.	**Status:** Closed
B-DM-05 - Thermal Embrittlement of Nickel Alloys **Gap closed** in Revision 1 (2008) – See EPRI BWRVIP-167NP, Revision 1 (EPRI 1018111) for Gap Description and Closure Basis.	**Status:** Closed

Table 3-2 Degradation Mechanism Understanding Gaps (Continued)

R&D Gap Description	Results Data
B-DM-06 - Environmental Effects on Fracture Resistance **Issue:** There is growing evidence that the fracture properties of some structural materials can be degraded significantly by stressing in water, especially after long-term exposure to hydrogenated high temperature water. There is a growing body of data available to characterize elements of the phenomena, but the broad nature and extent of potential concerns as a function of loading, temperature, material/ microstructure, and environment are not well defined. At present, there is consensus that a hydrogen mechanism is involved, but insufficient information to quantitatively predict the effects. **Description:** There have been a number of unintentional observations of very rapid crack growth (and in most cases complete specimen fracture) in specimens tested in high temperature water. These observations suggest that hydrogen presence can affect fracture toughness properties and that environmental effects are not limited to lower temperature operations or J-R tearing conditions. These effects have been observed in high temperature BWR water chemistry for both cold worked stainless steels and Alloy 182. It is likely that similar or more substantial effects would be observed if the materials were cooled to low temperature (< 150 °C), where hydrogen effects are known to be larger. To date, there has been no effort to specifically investigate these observations, either through data review or new testing. While historical plant operation provides confirmation of degradation predictions for SCC and corrosion fatigue, there is no plant experience to characterize the nature and magnitude of environmental effects on fracture behavior and their potential impact on component structural margins. If significant, the impact of this issue could be broad in nature, affecting numerous plant evaluations. The most significant effects are expected for higher yield strength material (where elevated yield strengths may occur by fabrication induced cold work, shrinkage strain in the weld HAZ, precipitation hardening, or by irradiation) and in inhomogeneous materials (e.g., nickel alloy weld metals). As a result, there are concerns for pressure vessel steels, X-750, Alloys 82/182, and cold worked stainless steels, and irradiated materials. Additionally, recent testing of CASS in PWR environments has increased concerns for that material (see gap B-DM-03). Presently, this issue is presumed to possibly impact all primary system and reactor internals materials of construction. Until an improved understanding of this phenomenon is achieved, this gap is applied to all IMT component line items. (continued on next page)	**Priority:** R2(2010): High R1.1(2009): High R1(2008): Medium **Status:** Open **Responsibility:** BWRVIP: Assessment Other: PSCR Program **Affected by LTO?** No

Table 3-2 Degradation Mechanism Understanding Gaps (Continued)

R&D Gap Description	Results Data
B-DM-06 (continued) Closure of this gap involves characterization of this environmental fracture issue and the relative consequences on reactor operation and plant analyses. **References:** 2010 MDM (Notes b1-9a, b2-9a, b2-9f and Appendix A Section 6.2) MRP-108, MRP-145, MRP-213, 1019034, MRP-209	See previous page
B-DM-07 - Chloride Transient Effects on Low Alloy Steel Crack Growth Rates **Issue:** There is a need to better characterize the effect of chloride on low alloy steel crack growth rates. New data suggests that increased crack growth occurs at chloride concentrations below the EPRI BWR Water Chemistry Guideline action level 1 value of 5 ppb. **Description:** Recent testing by the GE Global Research Center indicates the potential for increased crack growth rates at chloride concentrations at least as low as 3.5 ppb (lower values were not tested). Previously, chloride concentrations below 5 ppb were not thought to be sufficient to significantly affect crack growth rates. The EPRI BWR Water Chemistry Guidelines Action Level 1 for chlorides is 5 ppb. Additional research is needed to fully assess the effect of low chloride concentrations on crack growth. Resolution of this gap should include sufficient study of low chloride conditions < 5 ppb to determine if a change to the BWR Water Chemistry Guideline is warranted. **References:** 2010 MDM (Note b1-1a)	**Priority:** R2(2010): Medium R1.1(2009): N/A R1(2008): N/A **Status:** New **Responsibility:** BWRVIP: Assessment **Affected by LTO?** No

Table 3-2 Degradation Mechanism Understanding Gaps (Continued)

R&D Gap Description	Results Data
B-DM-08 - Long Term Neutron Fluence Effect on Low Alloy Steel Cracking Susceptibility **Issue:** There is a need to assess the potential for increased crack susceptibility of irradiated low alloy steel reactor pressure vessel materials associated with an 80 year service life. **Description:** There is concern that increased growth rates may occur as the yield strength of the pressure vessel increases with fluence. This is a more complex and expensive experimental activity, but requires some attention because it is known that SCC susceptibility increases with yield strength and that the yield strength of low alloy steel increases with fluence. Also, since this SCC potential derives from a somewhat different mechanism than that for stainless steel, the threshold fluence for an effect may be significantly different. Although there is little, if any, unclad LAS in the BWR beltline region, concern remains from cracks initiated in cladding propagating into the LAS. As a result, irradiation assisted SCC may be plausible for long term operation of irradiated vessel steels. Resolution of this gap would require sufficient irradiated materials testing to characterize the susceptibility of alloy steels to cracking after irradiation equivalent to an 80 year service life. **References:** 2010 MDM (Note b1-2a)	**Priority:** R2(2010): Low R1.1(2009): N/A R1(2008): N/A **Status:** New **Responsibility:** BWRVIP: Assessment **Affected by LTO?** Yes

Table 3-2 Degradation Mechanism Understanding Gaps (Continued)

R&D Gap Description	Results Data
B-DM-09 - Long Term SCC Susceptibility (Late Life SCC Initiation) **Issue:** Longer term exposure of materials to environments conducive to SCC may lead to additional incidents of initiation or initiation in materials or components where it has not previously been observed. **Description:** For stainless steels, there are concerns regarding long term behavior of cold worked surface layers. Cracking in unsensitized low carbon material has been attributed to accelerated oxidation of the cold worked surface layer and oxide penetrations into the surface layer. Longer times for oxide formation could lead to an increased potential for cracking, or cracking of less severely cold worked layers. Even for surfaces that are not cold worked, or that have had the cold worked layer removed, it is currently unknown if long term exposure to the environment can lead to crack initiation in the strained regions of the weld heat affected zones. While surface cold work has not specifically been seen to promote SCC initiation in nickel alloys to date, it could become a factor at long exposure times. Additionally, there is concern that long term deterioration of the surface condition could lead to crack initiation at progressively lower levels of stress intensity. This could lead to cracking in locations or components not previously experiencing SCC. While no cracking of Alloy 82 has been observed in operating BWRs to date, there is some concern that with additional exposure time some cracking could occur, at least in selected heats of weld deposit. Long term SCC initiation concerns are highest for components not protected by HWC. **References:** 2010 MDM (Note b1-1c)	**Priority:** R2(2010): Low R1.1(2009): N/A R1(2008): N/A **Status:** New **Responsibility:** BWRVIP: Assessment **Affected by LTO?** Yes

Table 3-2 Degradation Mechanism Understanding Gaps (Continued)

R&D Gap Description	Results Data
B-DM-10 - Long Term Stress Stability **Issue:** There is a need to better characterize the long term effectiveness of surface stress improvement techniques. **Description:** Stress improvement methods have been applied to a number of reactor components as an SCC mitigation technique. These include surface techniques such as water and laser peening, and bulk techniques such as MSIP or IHSI. In all cases, the objective is to suppress SCC initiation by putting the surface exposed to the environment in compression. While effective, there is some concern for the long term stability of these compressive stress states. In particular, there is concern that techniques that rely on a thin layer of surface stress improvement may not survive (remain in compressive stress state) the many thermal and stress cycles associated with long term operation. Some shakedown of secondary stresses is known to occur. However, it is presently unclear if such shakedown could substantially affect the stress improvement benefit and leave the treated component susceptible to SCC. **References:** 2010 MDM (Notes b1-1c, b2-1f)	**Priority:** R2(2010): Low R1.1(2009): N/A R1(2008): N/A **Status:** New **Responsibility:** BWRVIP: Assessment **Affected by LTO?** Yes

Table 3-3 Assessment Gaps

R&D Gap Description	Results Data
B-AS-01 - RAMA Code Validation **Gap closed** in Revision 1 (2008) – See EPRI BWRVIP-167NP, Revision 1 (EPRI 1018111) for Gap Description and Closure Basis.	**Status:** Closed
B-AS-02 - NMCA Plant Corrosion Products **Gap closed** – See Table B-2 for Gap Description and Closure Basis.	**Status:** Closed
B-AS-03 - Alternate ASME Section XI Appendix G Methodology **Gap closed** – See Table B-2 for Gap Description and Closure Basis.	**Status:** Closed
B-AS-04 - Thermal Embrittlement of C&LAS **Gap closed** in Revision 1 (2008) – See EPRI BWRVIP-167NP, Revision 1 (EPRI 1018111) for Gap Description and Closure Basis.	**Status:** Closed

Table 3-3 Assessment Gaps (Continued)

R&D Gap Description	Results Data
B-AS-05 - Assess Neutron Dose Rate Effects on Embrittlement of C&LAS **Issue:** Additional evaluation is needed to assess the relative significance of neutron dose rate on low alloy steel RPV material embrittlement rates. **Description:** BWR neutron dose rates are believed to enhance the embrittlement of low alloy steel reactor vessel materials. Depending on the magnitude of this effect, some additional embrittlement of BWR reactor vessels could be predicted over present embrittlement correlations. Much of the current database for higher neutron fluence values comes from PWRs. Life extension to 80 years aggravates the concern because the higher fluence levels are beyond the current BWR database which increases the uncertainty to accurately predict the embrittlement. For very high fluence levels (e.g. 80 year life), new concerns may emerge such as the formation of Ni, Mn, and Si clusters in very low copper materials which (in some materials) have shown to increase the hardening and thus, reduce the fracture toughness. Additionally, this gap has an important regulatory aspect. The NRC is planning to issue a revision to Reg. Guide 1.99, Revision 2. The new embrittlement trend curves are expected to be more conservative for BWRs due to the inclusion of factors to account for flux effect, which would increase the calculated RTNDT for BWRs. The flux effect is expected to be greater for BWRs than for PWR vessels. **References:** 2010 MDM (Note b1-12a) NRC R.G. 1.99 Rev. 2	**Priority:** R2(2010): Medium R1.1(2009): Medium R1(2008): Medium **Status:** Open **Responsibility:** BWRVIP: Assessment **Affected by LTO?** Yes
B-AS-06 - Neutron Embrittlement of Nozzle Forgings **Gap closed** in Revision 1 (2008) – See EPRI BWRVIP-167NP, Revision 1 (EPRI 1018111) for Gap Description and Closure Basis.	**Status:** Closed

Table 3-3 Assessment Gaps (Continued)

R&D Gap Description	Results Data
B-AS-07 - Environmental Effects on Fatigue Life: Pressure Boundary Components **Issue:** There is a need to address implementation issues associated with environmental fatigue. This issue is exacerbated by consideration of 80 year operations since the number of fatigue cycles continues to accumulate through an additional 20 years of operation. **Description:** An improved understanding of the relationship between laboratory environmental testing and actual operating conditions is needed. Environmental effects testing in the laboratory has demonstrated that the phenomena are real and that fatigue resistance in a water environment is lower than testing conducted in air. However, there is an apparent discrepancy between the fatigue correlations and field experience, since the environmental component of fatigue has not yet been identified in the field. It is possible that the current, relatively simplified methods for application of environmental effects are inadequate to address the complex, three dimensional loading configurations that occur in actual plant components and the non-linear, time-dependent stress transients. Current license renewal guidance provided by the NRC staff in NUREG-1801 requires assessment of environmental fatigue effects for a relatively small set of locations within the primary pressure boundary. Most plants can address environmental fatigue issues through stress-based monitoring and cycle counting. As such, any issues related to initial license renewals are considered to be generally resolved. When considering 80 year operation, the impact of environmental fatigue effects becomes more significant. In many cases, multiple component locations will exceed a calculated CUF of 1.0. As a result, there is a need for the industry to develop an improved understanding of environmental fatigue effects, especially with regards to modeling real plant strain rate and chemistry effects. Additional testing and development of advanced calculation methodologies are needed to address this issue so that the true impact of 80 year fatigue usage on actual plant components can be better understood. An additional concern is the potential for increased fatigue crack growth rates as a result of environmental effects. Ultimately, resolution of this gap involves management of the issue through incorporation of updated fatigue curves into the ASME B&PVC. **References:** 2010 MDM (Note b1-9a), ASME B&PVC NUREG-1801, NUREG-6260, NUREG/CR-6909, Reg. Guide 1.207	**Priority:** R2(2010): High R1.1(2009): Medium R1(2008): Medium **Status:** Open **Responsibility:** BWRVIP: Assessment **Affected by LTO?** Yes

Table 3-3 Assessment Gaps (Continued)

R&D Gap Description	Results Data
B-AS-08 - High Cycle Fatigue: RPV Locations **Gap closed** in Revision 1 (2008) – See EPRI BWRVIP-167NP, Revision 1 (EPRI 1018111) for Gap Description and Closure Basis.	**Status:** Closed
B-AS-09 - Assess the Impact of High Fluence on Fracture Toughness [*NOTE: This gap has been re-defined to address only fracture toughness data. All crack growth rate issues are addressed in B-AS-10.*] **Issue:** There is a need for additional data to fully characterize the effect of high neutron fluence on the fracture toughness properties of austenitic stainless steel weld and HAZ materials. **Description:** The austenitic stainless steel alloys in BWR core structures experience significant fracture toughness reductions at elevated fluence levels. While the data sets for austenitic stainless steel base metal is considered to be sufficient, the data sets for fracture toughness of highly irradiated stainless steel weld and HAZ materials are more limited for typical BWR 60-year and 80-year end of life fluences. As a result, there is incentive to fill this gap with supplemental data. The serviceability of BWR core structures and components is verified periodically through a prescribed program of inspection and evaluation. Evaluations of current serviceability and projections of future serviceability rely on accurate fracture toughness data. Results of these evaluations support run/repair decisions. Resolution of this gap includes development of comprehensive guidance for evaluating fracture toughness through development of sufficient irradiated materials data to address the fluence ranges of interest. Current work plans include an international IASCC project to extract material from the reactor pressure vessel of Zorita, a decommissioned plant located in Spain. The extraction is currently planned for 2011, with work planned to begin in 2012. Stainless steel weld and HAZ materials irradiated to 5-10 dpa are targeted for additional fracture toughness testing. Because lower bound saturation fracture toughness values for weld and HAZ materials cannot be characterized with existing data for either 60 or 80-year operations, this gap is considered an LTO issue. (continued on next page)	**Priority:** R2(2010): High R1.1(2009): High R1(2008): High **Status:** Open **Responsibility:** BWRVIP: Assessment Other: PSCR Program **Affected by LTO?** Yes

Table 3-3 Assessment Gaps (Continued)

R&D Gap Description	Results Data
B-AS-09 (continued) **Note regarding 300 Series Stainless Steel Base Metal:** *Previously, this gap included a need to obtain additional irradiated 300 series base metal fracture toughness data. Lacking some as yet unknown embrittlement phenomenon, reductions in material toughness will saturate at some predictable level and are not considered to be an LTO issue for 300 series stainless steel base metals. The results of recent BWRVIP fracture toughness testing of irradiated base metal materials are consistent with previous data and are bounded by the BWRVIP-100-A lower bound fracture toughness curves. Therefore, no additional 300 series stainless steel base metal fracture toughness data is considered to be presently needed.* **References:** 2010 MDM (Note b2-12a) BWRVIP-100-A, BWRVIP-140, BWRVIP-154R2	See previous page

Table 3-3 Assessment Gaps (Continued)

R&D Gap Description	Results Data
B-AS-10 - Assess the Impact of High Fluence and HWC Mitigation Technologies on SCC Crack Growth Rates **Issue:** Additional data is needed to characterize the effect of high fluence and HWC mitigation technologies (i.e. HWC-M, NMCA, and OLNC) on SCC and IASCC crack growth rates. Sufficient crack growth rate data is not available to address expected end of life neutron fluences. Additionally, there are concerns about the effectiveness of HWC mitigation technologies at higher fluence. **Description:** Recently completed research includes testing of highly irradiated control rod blade handles ($3x10^{21}$ n/cm^2, E > 1.0 MeV) and of materials removed from a retired BWR. Additionally, there remains a substantial amount of research in progress to investigate irradiation effects for stainless steels. Broad base research programs are focused on improving the understanding of the role of neutron fluence in initiating SCC in stainless steel reactor internals and on development of additional crack growth rate data. In addition, the BWRVIP is conducting additional crack growth rate testing on materials removed from a retired Swedish reactor. Currently planned testing conducted by the CIR Program, the DOE Halden Test Reactor Program and the BWRVIP is presently judged to be sufficient to address near term data needs. The effects of HWC and NMCA on crack growth continue to be examined using inspection data from the core shroud. Analysis of crack length and depth data continues to be performed on a periodic basis. BWRVIP-174, Rev. 1 presents updated data associated with SCC of BWR core shrouds under NWC, HWC-M, and NMCA. These results validate previously established crack growth rate curves. The results of this study validate current bounding crack growth rates for NWC and highlight the potential for some continued crack lengthening even when HWC and NMCA mitigation is applied. This initial data will be supplemented as new inspection data become available. In particular, the effect of HWC mitigation technologies on crack growth rates at high fluences (> 3 x 10^{21} n/cm^2) are not well understood because of limited data. This gap remains open based on the following near term needs: 1. Completion of ongoing irradiated materials programs and evaluation of the resulting data. 2. Additional collection and evaluation of inspection information for shroud SCC. Inspection data sets need to be expanded and there needs to be an assessment of OLNC mitigation technology on crack growth rates. 3. Development of an improved understanding of the effect of material variability on IASCC. (continued on next page)	**Priority:** R2(2010): High R1.1(2009): High R1(2008): High **Status:** Open **Responsibility:** BWRVIP: Assessment Other: PSCR Program **Affected by LTO?** Yes

Table 3-3 Assessment Gaps (Continued)

R&D Gap Description	Results Data
B-AS-10 (continued) 4. Revision of BWRVIP-80-A to account for irradiation effects on SCC crack growth in shroud vertical seam welds. Application of BWRVIP-80-A without consideration of irradiation induced weld stress relaxation can result in overly conservative CGR estimates. Consideration of 80 year service lives introduces the need to assess the need for additional data to address neutron fluences exceeding $1x10^{22}$ n/cm^2 (E > 1.0 MeV) for some BWR components. As dose increases, there are concerns that IASCC may occur at lower stress levels, thereby initiating cracks in locations previously not considered vulnerable. **References:** BWRVIP-14-A, BWRVIP-80-A, BWRVIP-99-A, BWRVIP-160, BWRVIP-174R1, BWRVIP-221, BWRVIP-232 EPRI 1016548, 1019028, 1019029 NUREG/CR-6965, "IASCC of Austenitic SS and Alloy 690 from Halden Phase II Irradiations," Sept 2008. 2010 MDM (Note b2-2a)	See previous page

Table 3-3 Assessment Gaps (Continued)

R&D Gap Description	Results Data
B-AS-11 - Assess Non BWR Reactor Irradiated Materials Data Applicability to the BWR Environment **Issue:** The usefulness of irradiated materials data obtained from accelerated tests in fast neutron reactors is limited in that direct applicability of the data to BWR conditions has not been definitively established. Concerns are presently focused on the high end of life neutron fluence associated with 80 year operations. **Description:** A large body of radiation damage data exists from the fast and test reactor irradiation programs worldwide. However, there are concerns about the applicability of the data because, in part, fast reactor operating temperatures are generally higher than light water reactors, particularly BWRs. Likewise, the neutron fluence experienced by fast reactor internals is much higher than light water reactors. Additionally, a substantial amount of the existing high fluence data have been obtained from spent control rod blades. Control blade handles experience substantially higher neutron dose rates within the core than long-lived reactor internals components located outside the core. There is a need to determine if the effects observed at high neutron dose rates can be accurately applied to components experiencing lower neutron dose rates (e.g. shrouds and top guides). **Recent Work:** Recent Cooperative IASCC Research (CIR) Program test results indicate that irradiation in either a fast reactor or a BWR resulted in similar crack growth rate response. However, a possible exception was noted for the effect of corrosion potential where HWC reduced the CGR in the specimen irradiated in a fast reactor, but not in the specimen irradiated in a BWR. The difference may relate to K validity effects, but this effect should be confirmed before this gap can be closed. **References:** EPRI 1016548, 1019028, BWRVIP-232 2010 MDM (Note b2-2a)	**Priority:** R2(2010): Low R1.1(2009): Low R1(2008): Low **Status:** Open **Responsibility:** BWRVIP: Assessment Other: PSCR Program **Affected by LTO?** Yes

Table 3-3 Assessment Gaps (Continued)

R&D Gap Description	Results Data
B-AS-12 - Thermal & Irradiation Embrittlement: Synergistic Effects (on CASS BWR Reactor Internals) **Issue:** The NRC has raised a potential concern related to thermal aging of CASS reactor vessel internals with focus on the potential synergistic effects of thermal aging and irradiation embrittlement. Thermal aging concerns are limited to castings meeting specific screening criteria in NUREG-1801 for casting method, molybdenum content, and ferrite content (as calculated by Hull's equivalent factor method specified in NUREG/CR-4513 Revision 1). Currently, this is primarily an issue for license renewal. Augmented inspection requirements, such as EVT-1, may be recommended for castings exceeding the NRC specified fluence threshold or meeting thermal embrittlement screening criteria contained in a May 19, 2000 letter from NRC to NEI. **Description:** The fluence threshold set by NUREG-1801 Section XI.M13 is $1x10^{17}$ n/cm^2 (E > 1.0 MeV). This threshold is much lower than fluence thresholds for onset of irradiation effects that have been identified in laboratory studies, which are on the order of $1x10^{20}$ n/cm^2 (E > 1.0 MeV). The thermal embrittlement screening criteria is based on casting method (centrifugal vs. static), Molybdenum content, and Ferrite number. Concerns for BWR reactor internals are mitigated by relatively low operating temperatures and limited use of high molybdenum castings (CF8M). BWRVIP-234 documents the results of a comprehensive assessment to address embrittlement concerns for 60 year operation using the criteria contained in NUREG-1801. Based on this study, the end-of-life fluence levels for the orificed fuel support, the jet pump assembly castings and the LPCI couplings (BWR/6) exceed the assumed fluence threshold, but the toughness data for irradiated austenitic stainless steel show that that these components will have sufficient fracture toughness at the end of license renewal period. Potential reductions in toughness (due to higher fluence) will be somewhat greater for 80 year operating lives. However, since thermal aging is a diffusion dependent process, further reductions in fracture toughness between 60 and 80 years are not very significant relative to earlier operating periods. Additional thermal aging beyond 60 years is not considered to be a generic long term operations issue. Regardless, this gap is being held open to highlight the need to revisit the BWRVIP-234 study with 80 year service life criteria. **References:** 2010 MDM (Notes b2-10c), <u>BWRVIP-234</u>, ASME Section XI Duane Arnold Energy Center License Renewal Application NUREG-1801 (Section XI.M13), May 19, 2000 NRC Letter to NEI	**Priority:** R2(2010): Low R1.1(2009): Low R1(2008): Low **Status:** Open **Responsibility:** BWRVIP: Assessment **Affected by LTO?** Yes

Table 3-3 Assessment Gaps (Continued)

R&D Gap Description	Results Data
B-AS-13 - Assess the Impact of High Fluence on Nickel-Base Alloys **Gap closed** – See Table B-2 for Gap Description and Closure Basis.	**Status:** Closed
B-AS-14 - Environmental Effects on the Fatigue Life of Reactor Internals **Issue:** There is a need to assess reactor vessel internals fatigue with consideration of environmental effects on fatigue life. **Description:** When environmental fatigue factors are considered, fatigue usage for selected reactor internals components could become a concern for some internals components. For high fluence reactor internals, there are limited data related to the effects of neutron fluence on fatigue life. It is presently not clear if there is any effect of neutron irradiation with respect to environmental fatigue effects (except that irradiation increases the yield strength and reduces the endurance limit). While there are gaps in the available data regarding the impact of neutron fluence on fatigue life, a mitigating factor is that fatigue usage values for near core reactor internals experiencing high neutron fluence are quite low, generally below 0.1. For higher strength alloys currently in use in BWRs (i.e. X-750 and XM-19), there are few fatigue life data addressing environmental effects and neutron fluence. Available data are all associated with low alloy steel, 300-series austenitic stainless steels, and ordinary austenitic nickel alloys (Alloys 600, 82, and 182). Resolution of this gap may include assessment of the design criteria applied to the reactor internals, with consideration of appropriate reactor environmental factors and neutron fluence effects. **References:** 2010 MDM (Note b2-9a) NUREG-6260, NUREG-6909, NRC R.G 1.207	**Priority:** R2(2010): Low R1.1(2009): Low R1(2008): Low **Status:** Open **Responsibility:** BWRVIP: Assessment **Affected by LTO?** Yes

Table 3-3 Assessment Gaps (Continued)

R&D Gap Description	Results Data
B-AS-15 - FIV and High Cycle Fatigue Assessment: Reactor Internals **Issue:** High-cycle fatigue, FIV, and associated wear has been an operational concern for a number of reactor internals locations. This gap addresses the need to comprehensively assess the reactor internals for potential high-cycle fatigue, FIV, and associated wear concerns. **Description:** Major high-cycle fatigue issues occurring in BWR reactor internals to date include jet pump and steam dryer. Jet pumps can experience flow induced vibration (FIV) and wear while steam dryers can experience acoustic loads emanating in the steam lines. These major issues are now addressed from separate gaps. Jet pump concerns are addressed in a comprehensive jet pump management gap, B-AS-17. Steam dryer concerns are addressed in gap B-AS-29. FIV and associated wear is also believed to be occurring on the feedwater sparger end pins. Some shroud head bolts have experienced wear that are potentially associated with high-cycle vibration. There may be additional locations where FIV and wear eventually occur due to power uprates and additional service time. A full review of the internals for potential vibration related issues is potentially needed to resolve flow induced high cycle fatigue concerns. **References:** BWRVIP-198	**Priority:** R2(2010): Medium R1.1(2009): Medium R1(2008): Medium **Status:** Open **Responsibility:** BWRVIP: Assessment **Affected by LTO?** No
B-AS-16 - Loose Parts Assessment **Gap closed** – See Table B-2 for Gap Description and Closure Basis.	**Status:** Closed

Table 3-3 Assessment Gaps (Continued)

R&D Gap Description	Results Data
B-AS-17 - Evaluate Hidden Weld Locations **Issue:** BWRVIP I&E guidelines recommend inspection of hidden welds when the technology becomes available. The cost to develop the technology could be high, even when excluding the actual cost of the inspections. Further, recent EPRI NDE Center efforts have not yielded promising results. In view of these obstacles, a re-evaluation of the assumptions and analyses which resulted in the present inspection requirements is a reasonable course of action. **Description:** Hidden welds in BWR reactor internals include: • Jet Pump Thermal Sleeves TS-1,-2,-3,-4 and Diffuser Welds DF-3, AD-1,-2 for Lasalle and Fermi 2. • Core Spray Thermal Sleeves and piping welds P1 and P9. • LPCI Thermal Sleeve 45-12 and Elbow to Thermal Sleeve 6-1a. Closure of this gap depends on BWRVIP development of an approach that is subsequently approved by NRC. Recently, BWRVIP completed a revision to BWRVIP-18 which includes a method for addressing hidden weld locations. This approach bases inspection of remaining hidden welds on the performance of similar accessible welds in the core spray system. BWRVIP-18, Rev. 1 has been submitted to the NRC for review and approval. If BWRVIP-18. Rev. 1 is approved by the NRC, then similar revisions of BWRVIP-41 and BWRVIP-42 will be submitted to the NRC for approval. **References:** BWRVIP-18R1, BWRVIP-41R2, BWRVIP-42-A, BWRVIP-152, BWRVIP-168	**Priority:** R2(2010): High R1.1(2009): High R1(2008): High **Status:** Open **Responsibility:** BWRVIP: Assessment **Affected by LTO?** No

Table 3-3 Assessment Gaps (Continued)

R&D Gap Description	Results Data
B-AS-18 - Jet Pump Degradation Management **Issue:** Most BWRs are experiencing various problems with jet pump performance and reliability. In a few instances, degradation of certain components has been significant. This ongoing experience with jet pump failure and / or degradation results in a need to evaluate jet pump flow conditions and develop an improved understanding of the parameters driving jet pump flow instabilities. **Description:** Jet pump wedge wear has been attributed to flow induced vibration (FIV) pressure loads produced by high velocity flow in the inlet-mixer, increased slip joint leakage flow, and cross flow between jet pumps. In addition, loads from recirculation vane passing frequency may also contribute to jet pump wear. Recently, a substantial crack was identified at an international plant in a jet pump riser extending 240 degrees around the circumference. Slip joint leakage flow instability is the probable cause of this cracking. This degradation, if not controlled, could cause cracking in locations such as the riser brace attachment to the RPV. Presently, a number of units have implemented various jet pump assembly repairs including labyrinth seals and auxiliary restraints (e.g., auxiliary wedges, slip joint clamps) in an effort to mitigate jet pump vibration issues. There is growing evidence that these auxiliary restraints are not fully mitigating wedge and rod wear. The trend of degradation at the restrainer bracket location continues. Work completed by the BWRVIP through 2009 includes sub-scale phenomenological testing, jet pump computational fluid dynamics (CFD) analysis, slip joint flow modeling and full scale low flow testing to understand the factors that affect slip joint instability. There are still open issues with respect to the mechanisms which are causing the degradation. Additional testing is planned to better characterize the mechanisms. Test results will also be used to evaluate and improve existing restrainer designs and to investigate new restrainer design concepts, with the end goal of eliminating and / or minimizing wedge wear and to establish plant operating parameters to avoid FIV. Resolution of this gap requires an improved understanding of the factors that most affect susceptibility to FIV damage and development of proven tools to prevent future FIV and subsequent component damage. **References:** BWRVIP-41R2, BWRVIP-165	**Priority:** R2(2010): High R1.1(2009): High R1(2008): High **Status:** Open **Responsibility:** BWRVIP: Assessment **Affected by LTO?** No

Table 3-3 Assessment Gaps (Continued)

R&D Gap Description	Results Data
B-AS-19 - Assess In-Vessel Fastener Loosening **Description:** Bolted connections occur in a number of in-vessel components. Examples include jet pump adjusting screws, LPCI coupling clamps, feedwater brackets, shroud repairs, and core plate bolts. The common method of securing these joints is by tack welding. However, this may not always be the optimum method. Tack welded jet pump adjusting screws, for instance, have a history of cracking and failure. In addition, underwater tack welding during a repair is sometimes difficult due to the material composition of the fasteners or, in some cases, due to the high irradiation level of the component. Alternatives to tack welding would be desirable in some cases. In addition, the potential exists for irradiation enhanced stress relaxation of some fastener joints. This concern is aggravated by 80 year service lives since the amount of relaxation occurring will certainly increase with irradiation and the number of components affected will potentially increase. There is a need to assess locations that may be prone to loss of pre-load. Where preload is critical to joint function or generation of loose parts is of substantial concern, additional assessment may be needed to address relaxation concerns or to identify and evaluate alternatives to tack welding and to develop recommendations for when these methods should be considered. Issues such as the security of each method, ease of installation and removal, the potential for material degradation (e.g., susceptibility to cracking) and tooling design concepts should be addressed. [*NOTE: Assessment of core plate rim hold down bolts are evaluated separately in B-AS-32.*] **References:** BWRVIP-06R1-A	**Priority:** R2(2010): Low R1.1(2009): Low R1(2008): Low **Status:** Open **Responsibility:** BWRVIP: Assessment Other: NDE Center **Affected by LTO?** No

Table 3-3 Assessment Gaps (Continued)

R&D Gap Description	Results Data
B-AS-20 - Assess Non-Safety Locations **Issue:** A qualitative evaluation is needed to assess the potential consequences of non-safety component failures. **Description:** BWRVIP-06-A was initially developed to determine the short-term and long-term actions appropriate to assure continuing safe operation of the RPV. The evaluation focused primarily on systems critical to safety. In recent years, there has been an increased frequency of cracking and in some instances gross failures of non-safety related RPV Internal components, e.g., steam dryer assemblies. Failure of non-safety RPV internal components can result in forced outages and significant loss of production. Results from an assessment would include recommendations for managing degradation of non-safety related components. Guidance may include monitoring, augmented inspections, analyses, etc. Future tasks, such as development of component-specific I&E Guidelines, could be defined pending results of this work. **References:** BWRVIP-06R1-A	**Priority:** R2(2010): Low R1.1(2009): Medium R1(2008): Low **Status:** Open **Responsibility:** BWRVIP: Assessment **Affected by LTO?** No
B-AS-21 - Assess Adequacy of FAC Modeling for RPV Drain Line & Bottom Head Nozzle **Gap closed** in Revision 1 (2008) – See EPRI BWRVIP-167NP, Revision 1 (EPRI 1018111) for Gap Description and Closure Basis.	**Status:** Closed

Table 3-3 Assessment Gaps (Continued)

R&D Gap Description	Results Data
B-AS-22 - High Cycle Thermal Fatigue: Piping Locations **Description:** The PWR piping system has been found to be susceptible to high cycle fatigue, depending on piping geometry and operating conditions. The two high cycle fatigue types identified within MRP-146 are: • Interaction of swirl flow with cold water in-leakage past normally closed valves in normally stagnant lines. This high cycle fatigue process has resulted in the fatigue cracking of PWR Residual Heat Removal branch connections. • Cyclic penetration and retreat of swirl flow in the branch line, combined with heat transfer to the environment. No valve in-leakage is required. This high cycle fatigue process has resulted in fatigue cracking of PWR reactor coolant loop drain lines. For the BWR design, recent studies have shown that while in-leakage events are not plausible, cyclic penetration and retreat of swirl flow in branch lines could potentially impact BWR branch lines. For BWRs, the primary location of concern would be stagnant down-horizontal (DH) oriented drain lines. The results of investigation into this issue are documented in BWRVIP-155. This report provides guidance for evaluation of stagnant DH oriented lines. BWRVIP-155 is adapted for BWRs from PWR guidance provided in MRP-146 and MRP-170. Recent updates to the model equations contained in these MRP reports introduced a swirl factor. Efforts were limited to assessment of swirl factor for branch to main pipe diameter ratios < 0.35. This is adequate for PWR applications, but BWRs have branch to main pipe diameter ratios up to 0.80. Consequently. there is a need to address swirl factors exceeding 0.35 for BWRs. There are ongoing efforts to investigate options for resolution, including linear extrapolation of the existing model results or modeling of high branch to main pipe diameters using computational fluid dynamics. Closure of this gap should include resolution of the outstanding modeling issues and development of a comprehensive tool for use by BWR utilities to assess thermal fatigue vulnerabilities. *[NOTE: A separate issue is the potential for fatigue at mixing tee locations. BWRVIP-196 documents an assessment of mixing tee thermal fatigue concerns based on French PWR events. BWRVIP-196 identified that mixing of reactor water cleanup return flow with feedwater flow during BWR heat-up is identified as a potential thermal fatigue concern, and recommends a one-time inspection using inspection methods appropriate for detecting thermal fatigue cracking. This issue is considered to be resolved.]* **References:** BWRVIP-155, BWRVIP-196, MRP-146, MRP-146S, MRP-170 2010 MDM (Note b1-8a)	**Priority:** R2(2010): Low R1.1(2009): Low R1(2008): Low **Status:** Open **Responsibility:** BWRVIP: Assessment **Affected by LTO?** No

Table 3-3 Assessment Gaps (Continued)

R&D Gap Description	Results Data
B-AS-23 - Mechanical (Vibratory) Fatigue: Small Bore Piping **Gap closed** in Revision 1 (2008) – See EPRI BWRVIP-167NP, Revision 1 (EPRI 1018111) for Gap Description and Closure Basis.	**Status:** Closed
B-AS-24 - Corrosion of C&LAS Piping Locations **Gap closed** in Revision 1 (2008) – See EPRI BWRVIP-167NP, Revision 1 (EPRI 1018111) for Gap Description and Closure Basis.	**Status:** Closed
B-AS-25 - TGSCC of Cladding via Hydrogen Embrittlement Mechanism **Gap closed** in Revision 1 (2008) – See EPRI BWRVIP-167NP, Revision 1 (EPRI 1018111) for Gap Description and Closure Basis.	**Status:** Closed

Table 3-3 Assessment Gaps (Continued)

R&D Gap Description	Results Data
B-AS-26 - High Strength Alloys **Issue:** There are material performance data gaps for high strength materials being used in BWR reactor internals and reactor internals hardware. Data is needed to fully characterize SCC susceptibility and neutron effects for these materials. **Description:** X-750 and XM-19 are both high strength alloys. They can exhibit highly variable microstructure, the effects of which are not understood. Stress Corrosion Cracking (SCC) resistance of these alloys is not well characterized, especially in a hydrogen water chemistry (HWC) environment. Hydrogen has been found to promote embrittlement in nickel-base alloys, leading to decreases in ductility (see gaps B-DM-03 and B-DM-06 for additional discussion regarding hydrogen issues). Field experience includes cracking of jet pump beams and a core shroud tie rod repair component. While jet pump beam cracking is limited to older design beams, the tie rod repair cracking occurred in a component which is believed to satisfy current heat treatment recommendations, but was later determined by GEH to exceed the peak stress recommended for X-750 contained in BWRVIP-84. Additionally, the degradation in material properties due to neutron fluence has not been quantified. X-750 and XM-19 materials are located in the annulus between the core shroud and reactor vessel and will experience moderate to high levels of fluence especially if the materials remain in the reactor through 60 years of operation and beyond. Generation of mechanical property data, SCC growth rates and stresses required to initiate cracks in these alloys is necessary to determine the long term viability of currently installed materials. Such information can also be extremely valuable to hardware designers to reduce the potential for inservice failures. Improvements in fabrication specifications to improve SCC resistance can also be identified and implemented for future hardware. Issues needing to be resolved for gap closure include characterization of SCC and irradiated materials properties, resolution of material microstructure variability concerns, and development of a strategy for cost-effective management of high strength alloys through end of life. Consideration of 80-year service lives increases the need for irradiated materials data. Another long term operational concern is late life SCC initiation. **References:** 2010 MDM (Notes b2-1f, b2-1g) <u>BWRVIP-218</u>	**Priority:** R2(2010): High R1.1(2009): High R1(2008): High **Status:** Open **Responsibility:** BWRVIP: Assessment **Affected by LTO?** Yes

Table 3-3 Assessment Gaps (Continued)

R&D Gap Description	Results Data
B-AS-27 - Alloy 182 / Creviced Alloy 600 SCC Susceptibility & Irradiation Effects **Issue:** Although SCC of Alloy 600, 82, and 182 in BWR environments has been studied extensively, there are remaining areas needing further attention, including crack growth rate characterization and the effects of neutron fluence. **Description:** *[NOTE: This gap has been substantially modified to incorporate irradiation concerns previously addressed in B-AS-13 and to better reflect current issue status.]* Service experience has shown that SCC of Alloy 182 and creviced Alloy 600 can occur, particularly in NWC conditions and in the above core regions where HWC and NMCA are not effective. An associated high priority concern shared by MDM panel members and utility personnel alike is the possibility of crack extension into the low alloy steel RPV material after initiation of a stress corrosion crack, particularly for the jet pump riser brace attachment welds which are exposed to significant neutron fluence. Open issues related to crack growth assessment remain. For some welds, K value predictions exceed the K values addressed by the BWRVIP-59-A CGR correlations. The effect of neutron fluence is a separate concern that has not been well characterized. In particular, jet pump riser brace welds will be subject to substantial neutron fluence. Neutron fluence effects are aggravated by 80 year service life considerations. Presently, there is little data available to characterize the effects of neutron fluence on nickel alloy weld material performance, particularly for A182 weld metal. There is a need to assess 80-year fluence values and determine what data, if any, is needed to fully resolve this concern. Neutron fluence also introduces weldability concerns. See gap B-RR-02. **References:** 2010 MDM (Note b1-1f) BWRVIP-59-A, BWRVIP-222	**Priority:** R2(2010): Medium R1.1(2009): Medium R1(2008): High **Status:** Open **Responsibility:** BWRVIP: Assessment **Affected by LTO?** Yes

Table 3-3 Assessment Gaps (Continued)

R&D Gap Description	Results Data
B-AS-28 - Impact of BWR Nozzle Penetrations on Pressure-Temperature Limit Curves **Issue:** The methodology for addressing stress concentrations occurring at sharp corner instrument nozzles is not well defined. Methodologies have been approved for individual plants, but an industry-wide solution or revision of ASME B&PVC to address the issue does not exist. **Description:** In most BWR designs, there are 2 instrument nozzles located approximately 6 inches above the top of active fuel. Heretofore, the stress concentration effect occurring at these penetrations have not been specifically included in the determination of pressure-temperature curves required by 10CFR50 Appendix G using the methodology in ASME Section XI Appendix G because the predicted 40-year design life accumulated fluence at the instrument penetration was below the $1x10^{17}$ n/cm^2 (E > 1.0 MeV) fluence threshold specified in 10CFR50 Appendix H (above which materials must be evaluated for the effects of radiation damage). As plants continue to age and accumulate more fluence, and as methods have improved for calculating fluence, these penetrations are now predicted to exceed the $1x10^{17}$ n/cm^2 (E > 1.0 MeV) fluence threshold. Furthermore, there are no explicit rules in the ASME Code for evaluating this geometry. A stress concentration occurs at these locations which could become limiting as compared to the peak fluence location. *[NOTE: The BWROG has been working to address this issue and the NRC has approved a generic Pressure-Temperature Limits Report, developed by General Electric-Hitachi (GEH), which includes a methodology for addressing the instrument nozzles. The methodology, or a similar methodology, still needs to be incorporated into the ASME Code.]* **References:** BWRVIP-49-A ASME Section XI, Appendix G 10CFR50, Appendix G and H	**Priority:** R2(2010): Medium R1.1(2009): Medium R1(2008): High **Status:** Open **Responsibility:** BWRVIP: Assessment **Affected by LTO?** Yes

Table 3-3 Assessment Gaps (Continued)

R&D Gap Description	Results Data
B-AS-29 - Steam Dryer Evaluation Methodology **Issue:** Industry operating experience has shown that high frequency acoustic pressure oscillations in the main steam header can cause increased loading on not only the steam dryer, but also on the entire steam path. **Description:** The BWRVIP has published various documents addressing steam dryer inspection & evaluation (BWRVIP-139-A) and integrity assessment to address power uprate (BWRVIP-182, and BWRVIP-194). Although there has been substantial progress in modeling the flow conditions, acoustic loadings, and resultant steam dryer assembly loadings causing the degradation, there are still some remaining items needing resolution. In particular, there are ongoing efforts to address NRC RAIs on BWRVIP-194. Open NRC questions include minimum stress margin, FEA sub-modeling approach, and overall benchmarking of the acoustic circuit model. Additionally, there remains a need to review the power uprate integrity assessment data to determine if this information may be useful in evaluating FIV concerns in non-uprated units. **References:** BWRVIP-139-A, BWRVIP-182, BWRVIP-194, BWRVIP-230	**Priority:** R2(2010): High R1.1(2009): High R1(2008): N/A **Status:** Open **Responsibility:** BWRVIP: Assessment **Affected by LTO?** No

Table 3-3 Assessment Gaps (Continued)

R&D Gap Description	Results Data
B-AS-30 - Material Surveillance Program Implementation for 80-Year Service Lives **Issue:** Maintenance of the ISP is necessary to optimize testing requirements and prevent unnecessary capsule tests. This program adequately addresses operation through 60 years of operation. There is a need to assess the program to address 80 year operating lifetimes. **Description:** Program requirement B-RQ-02 addresses ongoing maintenance of the ISP. The ISP combines surveillance materials from across the BWR fleet, including the BWROG supplemental surveillance program (SSP), to provide a better representation of the limiting beltline materials for each plant, while simultaneously reducing the total number of capsules to be tested by the BWR fleet. The program was developed to address BWR fleet operation through 40-year operations and was approved by NRC in 2002. As soon as the NRC approved the BWRVIP ISP for the original BWR operating license period, the BWRVIP began development of a plan to extend the ISP into the license renewal period. The updated ISP to address 60-year operations was approved by NRC in 2006. Specific assessment of the material surveillance data needed to meet BWR fleet needs for 80-year operations has not yet been performed. It may be that additional specimen materials based on capsule reconstitution and capsule re-insertion may be necessary. In contrast with some other long term operations gaps, this issue needs attention relatively soon. Because BWRs lack substantial lead factors (in some cases having lag factors), if surveillance capsule reconstitution and re-insertion is needed, then near term action is likely needed to ensure relevant end of life data. *[Note: Regulatory issues associated with 80-year RPV surveillance programs is addressed by gap B-RG-08.]* **References:** BWRVIP-86R1, BWRVIP-135R2	**Priority:** R2(2010): Medium R1.1(2009): N/A R1(2008): N/A **Status:** New **Responsibility:** BWRVIP: Assessment **Affected by LTO?** Yes

Table 3-3 Assessment Gaps (Continued)

R&D Gap Description	Results Data
B-AS-31 - BWRVIP-47-A (CRGT) Re-Inspection Requirements **Issue:** There is a need to develop appropriate re-inspection criteria for CRGTs. Only a baseline inspection program is addressed by BWRVIP-47-A. Description: Currently, most units have completed baseline exams of CRGT components as specified in BWRVIP-47-A and remaining units will complete their baseline exams in the near future. There are currently no re-inspection requirements. However, BWRVIP-47-A states: *"Baseline inspection results will be reviewed by the BWRVIP and, if deemed necessary, reinspection recommendations will be developed at a later date and provided to the NRC."* As a result, there is an NRC commitment to revisit the guideline and develop either re-inspection criteria or criteria for a second "re-baseline" inspection to be initiated at some future date. **References:** BWRVIP-47-A	**Priority:** R2(2010): Medium R1.1(2009): N/A R1(2008): N/A **Status:** New **Responsibility:** BWRVIP: Assessment **Affected by LTO?** No

Table 3-3 Assessment Gaps (Continued)

R&D Gap Description	Results Data
B-AS-32 - Assessment of Core Plate Rim Hold Down Bolts **Issue:** BWRVIP-25 requires inspection of core plate bolts when lateral support wedges are not installed. Efforts to develop effective NDE have not been successful to date (see gap B-I&E-01). **Description:** Although development of advanced NDE techniques may eventually make some meaningful inspection of core plate bolts possible, current BWRVIP efforts are focused on assessment to support elimination or relaxation of core plate bolt inspection requirements. In the past, the BWRVIP has undertaken generic analyses in an attempt to justify that no inspections are required. These analyses did not provide satisfactory results for several of the affected plants. This new BWRVIP study is taking a different approach by focusing on determining the minimum number of core plate bolts (with no preload assumed) in combination with the core plate aligner pins that are necessary to prevent unacceptable lateral displacement of the core plate and fuel assemblies. If the minimum number of core plate bolts is sufficiently low, this result can justify relaxation or deletion of the core plate bolt inspection requirement in BWRVIP-25. **References:** BWRVIP-25, BWRVIP-168, BWRVIP-170	**Priority:** R2(2010): High R1.1(2009): N/A R1(2008): N/A **Status:** New **Responsibility:** BWRVIP: Assessment **Affected by LTO?** No

Table 3-4 Mitigation Gaps

R&D Gap Description	Results Data
B-MT-01 - Alternative Mitigation Technologies **Description:** Mitigation technology is needed to extend IGSCC protection to internal components above the core, which cannot be protected using NMCA or moderate HWC because H_2 is stripped into the boiling phase. Unprotected components include the top guide; core spray nozzle, piping and sparger; and steam dryer support ring and hold down brackets. Other component locations that could potentially benefit from development of alternative mitigation technologies include the creviced region of thermal sleeves. Development of alternative technologies may also reduce the costs associated with main steam line radiation field issues and hydrogen addition. Resolution of this gap would include demonstration of the alternative technology (effectiveness, durability, cost) for specific locations, along with practical implementation guidance. Review for potentially adverse effects should also be included. While there may be economic benefits for locations protected by NMCA / HWC, this gap is currently applied only to reactor pressure vessel and reactor internals locations not mitigated by NMCA / HWC. **References:** BWRVIP-62, BWRVIP-109, BWRVIP-163, BWRVIP-190	**Priority:** R2(2010): Medium R1.1(2009): Medium R1(2008): Medium **Status:** Open **Responsibility:** BWRVIP: Mitigation **Affected by LTO?** No

Table 3-4 Mitigation Gaps (Continued)

R&D Gap Description	Results Data
B-MT-02 - Demonstrate Improved ECP Model **Issue:** It is highly desirable to develop a validated model to verify protection under moderate HWC or NMCA in regions that are not directly monitored by ECP probes because it is not feasible to monitor ECP at various locations in the vessel. Also, ECP probes in the LPRM dry tubes are expensive to install and have a limited life. **Description:** The BWRVIA code is currently used to monitor protection in the vessel for Hydrogen Water Chemistry (HWC) and NMCA/OLNC plants and supports utilities in the optimization of hydrogen addition to assure protection of vessel internals without the need to directly measure electrochemical corrosion potential (ECP) in the vessel which is difficult, or in some areas, impossible to perform due to reactor internals configurations. Currently, plants on moderate HWC, which have no ECP probes, use a validated Radiolysis/ECP model as the primary parameter in BWRVIP-62 to demonstrate adequate mitigation. For NMCA plants, the model predicts local hydrogen to oxygen molar ratio, which is used as a secondary parameter in BWRVIP-62 to verify protection in NMCA plants. In summary, an accurate and validated model is necessary provide a sound technical basis for mitigation and to justify inspection relief of vessel internals. The BWRVIA model currently used to assess mitigation protection in the vessel for HWC and NMCA plants has areas in need of improvement. ECP predictions, particularly for the bottom lower plenum, remain less than satisfactory. Resolution of this gap includes testing and qualification of the latest BWRVIA model and resolution of remaining modeling uncertainties. **References:** EPRI 1015470, BWRVIP-62	**Priority:** 2R2(2010): High R1.1(2009): High R1(2008): High **Status:** Open **Responsibility:** BWRVIP: Mitigation **Affected by LTO?** No
B-MT-03 - High Fluence Effect on HWC & NMCA **Gap closed** in Revision 1 (2008) – See EPRI BWRVIP-167NP, Revision 1 (EPRI 1018111) for Gap Description and Closure Basis.	**Status:** Closed

Table 3-4 Mitigation Gaps (Continued)

R&D Gap Description	Results Data
B-MT-04 - Noble Metal Catalyst-Based Mitigation Technology Improvement There is a need to improve noble metal technologies to maximize component protection available from the technology. There is also a need to fully characterize the mitigating benefits and limitations of noble metal catalyst-based mitigation technologies. **Description:** There is a need to improve the IGSCC protection of reactor internals components during periods when hydrogen injection becomes unavailable. This need arises from data suggesting that cracking can occur during extended off-hydrogen periods. During these periods, development of crack surfaces which are not protected by NMCA can occur, resulting in significant crack growth until protected conditions are reestablished. To solve this problem, GEH has developed online noble metal application (OLNC) that mitigates crack growth caused by lack of noble metal on new crack surfaces during off-hydrogen periods. This process also eliminates the need for two or more days of critical path time required by the conventional NMCA process. At this time, efforts are focused on characterization of the OLNC process. Initial demonstrations have been successful and the process has been implemented at several BWRs worldwide. However, there are several issues that still remain to be addressed, including OLNC deposition, crack flanking technical bases, and revision of BWRVIP-62 to address OLNC. <u>OLNC Deposition:</u> If noble metals applied via the OLNC process preferentially deposit on sensors vs. reactor internals, there is the potential to overestimate catalyst loading and to lose mitigation for some components. <u>Crack Flanking:</u> The effectiveness of electro-catalysis in mitigating SCC can be lost if critical regions of the crack become non-catalytic. Extended hydrogen injection outages can accelerate crack growth, which produces new crack regions or "flanks" having no catalyst on the surface. This crack flanking phenomenon has been characterized and the outstanding need is for development of a technical basis document supporting the 3 mm criterion and reapplication periodicity recommended by GEH. <u>BWRVIP-62 Revision:</u> It is desirable to use research data as a technical basis for inspection relief for BWR internal components for plants that are using OLNC to mitigate cracking. BWRVIP-219 contains a technical basis for OLNC mitigation and criteria for inspection relief. There is a need to update BWRVIP-62 to include the OLNC results contained in BWRVIP-219 and to get it approved by the NRC. (continued on next page)	**Priority:** R2(2010): High R1.1(2009): Medium R1(2008): Medium **Status:** Open **Responsibility:** BWRVIP: Mitigation **Affected by LTO?** No

Table 3-4 Mitigation Gaps (Continued)

R&D Gap Description	Results Data
B-MT-04 (continued) Closure of this gap requires demonstration of application processes and quantification of the conditions required to assure protection of specific component locations and incorporation of OLNC as an accepted mitigation method having a technical basis for inspection relief. **References:** BWRVIP-143, BWRVIP-159, BWRVIP-171, BWRVIP-175R1, BWRVIP-204, BWRVIP-219	See previous page

Table 3-4 Mitigation Gaps (Continued)

R&D Gap Description	Results Data
B-MT-05 - Startup & Shutdown Chemistry **Issue:** Plants may experience a significant portion of their fuel cycle crack growth rate during startup and early power ascension, when dissolved oxygen and hydrogen peroxide concentrations in the reactor coolant are high. During startup periods following refueling outages, reactor coolant chemistry transients may occur due to system flow changes and residual chemical impurities from outage-related work activities. **Description:** IGSCC mitigation is vital for the BWR fleet for long term operation. The injection of hydrogen and the application of noble metal addition technologies are beneficial as applied. However, hydrogen injection cannot typically be initiated until significant power levels are achieved, and the ECP reduction caused by noble metals is not effective without hydrogen injection. Additionally, the oxidant concentration of reactor water is high following an outage. One approach for resolution is through operational methodologies to attain ECP reductions earlier in the start-up phase, while simultaneously minimizing dose rates. HWC availability goals are recommended in the BWR Water Chemistry Guidelines for moderate HWC (>95%) and NMCA (>98%) plants. In many cases, the majority of hydrogen unavailability time occurs during start-ups. A second method is through the application of alternate reducing agents. BWRVIP-226 documents an evaluation of the feasibility of early hydrogen injection to mitigate IGSCC during startups at BWRs. The favorable results obtained support proceeding with a demonstration of EHWC (early hydrogen water chemistry) at a U.S. BWR. This work is currently ongoing. Resolution of this gap includes development of chemistry control guidance to support BWR start-ups and shutdowns such that the detrimental impact on plant components is minimized or eliminated. Guidance may include recommendations for extending hydrogen injection regimes or the application of alternate reducing agents. This gap is indirectly related to the mechanistic understanding of low temperature crack propagation (LTCP), since hydrogen injections at low temperatures (< 150 °C) could conceivably increase the potential for LTCP. See gap B-DM-03. **References:** <u>BWRVIP-225</u>, <u>BWRVIP-226</u>	**Priority:** R2(2010): High R1.1(2009): High R1(2008): High **Status:** Open **Responsibility:** BWRVIP: Mitigation Other: Water Chemistry **Affected by LTO?** No

Table 3-4 Mitigation Gaps (Continued)

R&D Gap Description	Results Data
B-MT-06 - NMCA Durability & Long Term Effectiveness **Gap closed** – See Table B-2 for Gap Description and Closure Basis.	**Status:** Closed

Table 3-5 Inspection & Evaluation Gaps

R&D Gap Description	Results Data
B-I&E-01 - Inspection of Core Plate Rim Hold Down Bolts Inspection of Core Plate Bolts, currently required by BWRVIP-25 cannot be effectively performed using currently available technologies. EVT-1 does not have access to the threaded areas where cracking is most likely to occur. UT could be performed from either the top or bottom end of the bolt. At the top of the bolt, the only location where sound can be introduced is at the center of the top face. However, most of the top of the bolt is covered by an anti-rotation keeper. **Description:** The core plate assembly provides lateral support for the fuel bundles, control rod guide tubes, and in-core instrumentation during seismic events, as well as vertical support for the peripheral fuel assemblies. The typical core plate assembly consists of a perforated stainless steel plate reinforced by stiffener beams and supported on the perimeter by a circular rim. The core plate rim is bolted to a ledge on the core shroud by stainless steel studs that prevent vertical movement. Recommended inspection locations, methods, and frequency are published in BWR Core Plate Inspection and Flaw Evaluation Guidelines (BWRVIP-25). Only the core plate bolts are identified as an inspection location. BWRVIP-25 identifies both EVT-1 and UT as being appropriate for inspecting the bolts. Originally, resolution of this gap was targeted at development of a complete NDE system capable of detecting relevant flaws in core plate bolts. However, development of a reliable UT technique was determined to not be possible and considering the access limitations, meaningful EVT-1 exams are not practical either. As such, alternative visual examinations, and/or an assessment that would support relaxation of the inspection requirements, need to be developed. Gap B-AS-32 addresses this issue from an assessment perspective. **References:** <u>BWRVIP-25</u>, <u>BWRVIP-94R1</u>, <u>BWRVIP-152</u>, <u>BWRVIP-170</u>	**Priority:** R2(2010): Medium R1.1(2009): Medium R1(2008): Medium **Status:** Open **Responsibility:** BWRVIP: Assessment BWRVIP: Inspection Other: NDE Ctr. **Affected by LTO?** No

Table 3-5 Inspection & Evaluation Gaps (Continued)

R&D Gap Description	Results Data
B-I&E-02 - Inspection of Hidden Weld Locations (Thermal Sleeves & Piping) BWRVIP I&E guidelines recommend inspection of hidden welds when the technology becomes available. To date, efforts to develop effective NDE solutions have not been successful. **Description:** BWRVIP I&E guidelines require inspection of several hidden welds. Hidden welds include: • Jet Pump Thermal Sleeves TS-1,-2,-3,-4 and Diffuser Welds DF-3, AD-1,-2 for Lasalle and Fermi 2. • Core Spray Thermal Sleeves, and piping welds P1 and P9. • LPCI Thermal Sleeve 45-12 and Elbow to Thermal Sleeve 6-1a. Investigations into alternatives for ultrasonic examination of weld P9 by the EPRI NDE Center suggest that no ultrasonic solution will be feasible. Future efforts will likely be focused on other NDE techniques. Another resolution approach is re-assessment of the inspection requirements. In view of the difficulties associated with development of an effective NDE solution, this is the current focus of BWRVIP efforts. Gap B-AS-17 addresses management of hidden welds from an assessment perspective. Resolution of this gap includes development of an NDE system capable of detecting relevant flaws in hidden welds. **References:** BWRVIP-18R1, BWRVIP-41R2, BWRVIP-42-A, BWRVIP-152	**Priority:** R2(2010): Medium R1.1(2009): Medium R1(2008): Medium **Status:** Open **Responsibility:** BWRVIP: Assessment BWRVIP: Inspection Other: NDE Center **Affected by LTO?** No

Table 3-5 Inspection & Evaluation Gaps (Continued)

R&D Gap Description	Results Data
B-I&E-03 - Inspection of Shroud & Shroud Support Weld Locations **Description:** UT techniques are not capable of demonstrating all expected cracking orientations and locations for Welds H3, H7, H8, and H9. Two-sided visual examination is not feasible for H8 and H9 since access below the shroud support plate is not available. Weld H3: The H3 weld of a BWR/6 core shroud has a unique configuration. The weld is a double-V geometry which attaches the upper ring to the plate shell course. The height of the ring is approximately 7.25 inches. The lower portion of the ring has a machined chamfer transitioning to the weld. The upper ring contains threaded bolt holes around the circumference. The top guide is bolted to this upper ring. The height of the ring and proximity of the bolt holes inhibits the ability to scan the ring side of the weld using conventional or phased array UT technology. Thus, detection of cracks on the ring side is a challenge. A section of the upper shroud assembly from River Bend's cancelled unit is being obtained by the NDEC so that mock ups and UT techniques for this specific configuration can be developed. Weld H7: Due to limited access conditions and/or shroud configurations (e.g., scalloped shrouds), the dissimilar metal H7 weld can only be ultrasonically examined from one direction at some plants. This access constraint and the coarse grain structures of the welds negatively impact the effectiveness of ultrasonic techniques. Improved UT techniques are needed. Weld H8: From a structural perspective, updated BWRVIP analyses indicate that a single-sided exam of H8 is sufficient as there would have to be significant through-wall cracking in the weld to challenge integrity of the component. If cracking is observed in the annulus-side exam of H8, scope expansion is required by BWRVIP-38. Such scope expansion may include, in some cases, an examination of the core-side of H8. If cracking is detected on the annulus-side of H8, evaluations are required to determine the extent of scope expansion in accordance with the guidance provided in BWRVIP-38. This scope expansion may include supplemental examinations from the top and bottom if and where access is available. Therefore, identification of NDE techniques capable of detecting and sizing indications regardless of location or orientation remains a gap. (Continued on next page.)	**Priority:** R2(2010): High R1.1(2009): High R1(2008): High **Status:** Open **Responsibility:** BWRVIP: Inspection Other: NDE Center **Affected by LTO?** No

Table 3-5 Inspection & Evaluation Gaps (Continued)

R&D Gap Description	Results Data
B-I&E-03 (Continued) Weld H9: Several BWR units do not have access to the outside surface of the RPV at the elevation of weld H9. Vendors have demonstrated capabilities for detecting and sizing circumferential cracking by scanning on the horizontal surface of the shroud support plate, however, attempts to detect and characterize transverse cracking of weld H9 have not been successful. Closure of this gap involves development of effective NDE techniques for detection of relevant flaws in shroud support welds which are not currently detectable. As a result of this issue, BWRVIP has updated the analytical evaluation of cracking in H9 originally presented in BWRVIP-104. The results of the updated analysis show that transverse and circumferential cracking in H9 will not reach a critical size in the RPV shell for a period of 60 years. The updated analysis and the BWRVIP-38 report confirms large flaw tolerance both from the viewpoint of shroud support load carrying capability and structural integrity of the vessel even considering crack growth into the vessel wall. However, due to the potential for scope expansion should cracking in Weld H9 be detected, continued investigation into effective NDE techniques is warranted. **References:** BWRVIP-03R12, BWRVIP-38, BWRVIP-231, BWRVIP Correspondence 2006-334.	See previous page
I&E-04 - I&E Guidance: AHCs **Gap closed** in Revision 1 (2008) – See EPRI BWRVIP-167NP, Revision 1 (EPRI 1018111) for Gap Description and Closure Basis.	**Status:** Closed

Table 3-5 Inspection & Evaluation Gaps (Continued)

R&D Gap Description	Results Data
B-I&E-05 - Appendix VIII Compliance **Issue:** This gap tracks remaining open issues and NDE technology development needs associated with ASME Section XI, Appendix VIII compliance for BWR applications. **Description:** Remaining Appendix VIII issues include: Availability of Plant-Specific Applications of Qualified Nozzle Inner Radius and Nozzle-to-Shell Weld UT Procedures Using EPRI Computer Models Resolution of remaining issues associated with examination of dissimilar metal welds. In particular, development of guidance for evaluation of embedded (i.e., fabrication) flaws, both inside and outside of the ASME XI Code required examination volume, is needed. Note that Appendix VIII Supplement 10 procedures require examination of the full volume, but the Code required volume is only the lower 1/3T. Two-sided inspection of welds associated with CASS valve bodies. **References:** ASME Section XI Appendix VIII, 1020593 (PDI Revision 4)	**Priority:** R2(2010): Low R1.1(2009): Low R1(2008): Medium **Status:** Open **Responsibility:** NDE Center **Affected by LTO?** No

Table 3-5 Inspection & Evaluation Gaps (Continued)

R&D Gap Description	Results Data
B-I&E-06 - NDE Capability: CASS Components **Issue:** Detection of flaws within cast austenitic stainless steel components continues to represent a significant challenge for the industry. **Description:** Field examination of CASS materials using ultrasonic examination techniques are characterized by high attenuation and scattering of the acoustic energy due to coarse grain structure, and variety of grain structures. As a result, inservice inspection techniques currently available for examination of CASS piping are not effective at identifying and sizing indications. Currently, a long term NDE Center project is planned to develop and implement a PDI program for CASS materials through development of qualification samples, evaluation of examination techniques, and qualification standards for examination equipment and personnel. Other planned work includes assessment of casting microstructure using ultrasonic investigation to assess which castings have microstructures susceptible to more rapid crack growth. The importance of this gap is reduced (as compared with the need in PWR designs) by a number of factors. The use of CASS is more limited in BWR designs than in PWR designs and does not include any pressure boundary piping and fittings. Due to lower operating temperatures and lower neutron dose, the expected thermal and irradiation embrittlement is substantially lower than for PWRs. Finally, recent study of BWR CASS reactor internals thermal and irradiation embrittlement susceptibility (BWRVIP-234) indicates that there are no concerns for 60-year operations. However, Gap B-AS-12 also addresses the need to evaluate CASS components for 80-year service lives. *[NOTE: The ability to successfully inspect weldments associated with cast components represents an ASME Section XI Appendix VIII compliance issue. See gap B-I&E-05.]* **References:** BWRVIP-234 2010 MDM (note b1-10e)	**Priority:** R2(2010): Low R1.1(2009): Low R1(2008): Low **Status:** Open **Responsibility:** EPRI NDE Ctr. **Affected by LTO?** No

Table 3-5 Inspection & Evaluation Gaps (Continued)

R&D Gap Description	Results Data
B-I&E-07 - NDE Capability: RPV Bottom Head Drain Line **Issue:** The BWR reactor vessel bottom drain line has been identified as FAC susceptible because of its material and flow conditions. Although no damage has been identified, condition assessment is warranted on the grounds that a break or leak of the drain line cannot be isolated. Further, failure of this line would be a high consequence event since the drain line is un-isolable from the RPV. While CHECKWORKS modeling and initial inspections do not indicate any emergent concerns regarding FAC of these locations, the possibility of significant wall thinning due to FAC cannot be ruled out and development of inspection methods is an NRC commitment. **Description:** Factors complicating development of NDE tooling include geometric issues (including the presence of socket welded fittings), interferences, and high area dose rates. Since 2007/2008, there has been substantial progress toward resolution of these obstacles. NDE tooling to examine drain line first elbows has been developed and deployed at a select number of plants. Success has been achieved for some applications, particularly those conducive to application of UT systems. Additional testing is needed to improve deployment of RT systems, which potentially will be able to examine locations where geometric and access issues prevent use of UT. However, additional work is needed to meet the objective of a field ready, fleet-wide solution. Resolution of this gap involves development of tooling which can accurately ascertain the extent of FAC occurring in the bottom head line for all critical locations and for various piping configurations. Resolution of this gap is an NRC commitment. **References:** EPRI 1013013, 1013469, 1017446	**Priority:** R2(2010): High R1.1(2009): High R1(2008): High **Status:** Open **Responsibility:** BWRVIP: Inspection Other: NDE Center **Affected by LTO?** No

Table 3-5 Inspection & Evaluation Gaps (Continued)

R&D Gap Description	Results Data
B-I&E-08 - Inspection and Evaluation Guidance for Repairs **Issue:** Current BWRVIP guidance regarding inspection of repair hardware is provided only for the core shroud tie rods (BWRVIP-76). For other repair hardware, the I&E guidelines state that the inspection criteria should be obtained from the hardware vendor. Generic criteria to guide the utilities in developing an appropriate inspection program for repaired components do not currently exist. **Description:** Some repairs use threaded connections that present unique challenges for inspection and overall material condition assessment. Other repairs are pre-loaded and verification of pre-load following some years of service might be required. Resolution of this gap includes development of generic aging management and inspection guidance for repairs to ensure inspectability of repair hardware and consistent specification of inspection requirements. Resulting technical data should include the following areas: 1. Summary of repairs installed 2. Review of inspections performed to date 3. Materials degradation assessment 4. General inspection guidance following installation of a repair 5. Recommended revisions to BWRVIP-84 The importance of guidance to address long term management of repair hardware is increased by consideration of 80-year service lives. Extended service lives for repair hardware increase the likelihood of some degradation mechanisms. SCC may be a concern for long term service of X-750 and XM-19 (also see gap B-AS-26). Irradiation enhanced stress relaxation is an increased concern for shroud tie rod repairs (also see gap B-AS-19). **References:** BWRVIP-76-A, BWRVIP-84	**Priority:** R2(2010): Low R1.1(2009): Low R1(2008): Low **Status:** Open **Responsibility:** BWRVIP: Assessment **Affected by LTO?** No

Table 3-5 Inspection & Evaluation Gaps (Continued)

R&D Gap Description	Results Data
B-I&E-09 - Examination Techniques for Detection of Loss of Preload in Reactor Internals Components **Issue:** Currently, field ready technologies are not available to accurately assess the remaining joint pre-stress in BWR reactor internals bolted connections. **Description:** Maintenance of adequate preload can be an important parameter for some internals locations. Shroud repair hardware is a primary example of an installation associated with preload requirements for certain designs. Additionally, assessment of bolt preload can be used as a parameter indicative of bolt condition (i.e., to ensure bolt integrity is maintained). The importance of ensuring adequate pre-load is maintained is increased by consideration of 80-year operations due to increased irradiation enhanced stress relaxation. Gap B-AS-19 address management of loss of preload from an assessment perspective. EPRI 1019122 documents that detection of loss of bolted connection preload is possible. These tests, performed on Seabrook spare vessel internals, indicated that the vibration-acoustic response of the bolts that are free from creep damage or cracks is similar throughout the vessel, independent of the bolt position and that the vibration-acoustic technique was found to effectively characterize the no-load condition of the bolt when compared to bolts in the loaded stress state. In addition, engineering design of a submersible system for deployment during reactor in-service examinations was completed. However, this technology would need to be adapted to BWR applications. **References:** EPRI 1019122	**Priority:** R2(2010): Low R1.1(2009): Low R1(2008): Low **Status:** Open **Responsibility:** BWRVIP: Inspection Other: NDE Center **Affected by LTO?** No

Table 3-6 Repair / Replacement Gaps

R&D Gap Description	Results Data
B-RR-01 - Roll / Expansion Repair Technique Approval **Gap closed** in Revision 1 (2008) – See EPRI BWRVIP-167NP, Revision 1 (EPRI 1018111) for Gap Description and Closure Basis.	**Status:** Closed
B-RR-02 - *Welding Processes for Repair of Irradiated Material* **Issue:** While welding is often a preferred method for repairing degraded reactor internal components, welding on irradiated materials is problematic due to helium that develops within the steel as fluence accumulates. If the material to be welded is highly irradiated, welding can result in cracking due to the generation and coalescence of helium bubbles at the grain boundaries in the material. **Description:** Development of qualified and approved low heat input weld processes such as laser welding allow for application of welding as a repair technique in cases where welding was previously not an option. In some cases, welding represents a cost effective alternative to mechanical repair in terms of time saved during repair design and implementation. In other cases, it represents the only viable option for repair. Previously completed work has resulted in development of a modeling approach to determine acceptable welding parameters, predict thermal and stress profiles in a material, and estimate the growth of bubbles from the entrapped helium. Development and qualification of specific parameters for welding of highly irradiated material is needed to perform welding on irradiated reactor internal components. While the current model can be used to determine the propensity of welds to crack, additional work is needed to reduce the level of conservatism and extend the model to other welding techniques. Development of specific laser welding processes for application to irradiated materials is addressed in a separate gap, B-RR-08. Closure of this gap includes development of approved welding processes for highly irradiated materials. The qualification effort should be completed before the technology is needed so that when a weld repair to an irradiated component is needed, weld repairs can be performed without significantly extending an outage or impacting plant operation. **References:** BWRVIP-97-A, BWRVIP-98, BWRVIP-151, BWRVIP-228	**Priority:** R2(2010): High R1.1(2009): High R1(2008): Medium **Status:** Open **Responsibility:** BWRVIP: Repair **Affected by LTO?** Yes

Table 3-6 Repair / Replacement Gaps (Continued)

R&D Gap Description	Results Data
B-RR-03 - Access Hole Cover (AHC) Repair Design Criteria (RDC) **Gap closed** – See Table B-2 for Gap Description and Closure Basis.	**Status:** Closed
B-RR-04 - Steam Dryer Repair Design Criteria **Gap closed** in Revision 1 (2008) – See EPRI BWRVIP-167NP, Revision 1 (EPRI 1018111) for Gap Description and Closure Basis.	**Status:** Closed

Table 3-6 Repair / Replacement Gaps (Continued)

R&D Gap Description	Results Data
B-RR-05 - Alternate High-Strength Materials **Issue:** Due to SCC concerns associated with X-750, it is desirable to identify suitable alternatives to Alloy X-750. **Description:** Alloy X-750 is a nickel base alloy used for BWR internal components where high strength, corrosion resistance, and in some cases, thermal expansion coefficient are considerations. The application of the high strength alloys is most often found in the design of repair hardware, but also exists in un-repaired components (e.g., jet pump beams). In these applications, the common 300-series stainless steels typically utilized for the majority of reactor internals are not capable of meeting the minimum strength requirements. Unfortunately, Alloy X-750 has been found to be susceptible to stress corrosion cracking at sustained stress levels less than the yield strength of the material. This has led to several field failures in components fabricated from this material. While the heat treatment for Alloy X-750 has been improved to optimize the SCC resistance, concerns regarding SCC susceptibility remain. At present, although a number of other high strength alloys exists, none have been qualified for BWR service. BWRVIP-229 documents initial work funded by EPRI into investigation of alternate alloys. This study recommended that X-725 should be investigated for future use. It notes, however, that other alloys, such as X-718, could be considered. Additional testing is required to fully qualify the material. BWRVIP-229 includes a discussion of necessary additional work, which includes development of an improved manufacturing specification, as well as additional corrosion testing. Resolution of this gap involves qualification of alternative materials as acceptable for use in BWR environments and to inclusion of these alloys in updates to BWRVIP-84 (Material Guidelines for Repairs). **References:** BWRVIP-84, BWRVIP-229, 1016550	**Priority:** R2(2010): Medium R1.1(2009): Medium R1(2008): Medium **Status:** Open **Responsibility:** BWRVIP: Repair **Affected by LTO?** No

Table 3-6 Repair / Replacement Gaps (Continued)

R&D Gap Description	Results Data
B-RR-06 - Repair Solutions for Bottom Head Drain Line Locations **Issue:** Based on FAC concerns associated with bottom head drain lines, repair solutions are needed in advance. If unacceptable degradation is detected in a bottom head drain line, a repair would need to be implemented in a reasonable time period. **Description:** The BWR RPV bottom head drain line location is un-isolable from the reactor vessel and as such represents a high consequence failure location. While initial inspections do not indicate any emergent concerns regarding FAC of these locations, the possibility of significant wall thinning due to FAC cannot be ruled out. The economic impact of detection of bottom head drain line damage without the availability of pre-developed repair or plugging solutions could be significant in terms of forced outage time and dose. There has been recent progress toward development of improved repair solutions for the bottom head drain line. However, there are no proven solutions. Plugging needs previously addressed by this gap are considered to be resolved. BWRVIP-213 concludes that the important functions of the drain line can be maintained by alternative means if the line is plugged. The most significant challenge is devising an alternate way to measure lower plenum temperature. Several feasible options are presented. BWRVIP-213 also includes a design specification for hardware that would be used to plug the drain line. Finally, two different plugs that comply with the specification were designed and are described in the report. Since 2007, the relative importance of this gap is somewhat reduced since significant FAC has not been identified in initial plant inspections and most units are moving to catalyst based HWC, which substantially reduces bulk hydrogen concentrations and lessens FAC concerns. **References:** EPRI 1013013, 1013469, BWRVIP-213	**Priority:** R2(2010): High R1.1(2009): High R1(2008): High **Status:** Open **Responsibility:** BWRVIP: Repair **Affected by LTO?** No
B-RR-07 - ICMH Roll / Expansion Repair Technique Approval **Gap closed** – See Table B-2 for Gap Description and Closure Basis.	**Status:** Closed

Table 3-6 Repair / Replacement Gaps (Continued)

R&D Gap Description	Results Data
B-RR-08 - Availability of Laser Welding for Repairs to Highly Irradiated Components **Description:** In order to perform successful weld repairs on highly irradiated reactor internal components, it is necessary to utilize low-heat-input welding techniques. In some cases, the only currently feasible method for obtaining sufficiently low heat input is to employ laser welding. Laser welding provides the ultra-low heat input levels required to repair highly irradiated reactor internals. Available data indicates that laser welding is likely to be successful for some applications. However, underwater laser welding processes have not been developed for typical repair configurations and have not been qualified for use in repairing BWR reactor internals. Development of qualified and approved low heat input weld processes such as laser welding allow for application of welding as a repair technique in cases where welding was previously not an option. In some cases, welding represents a cost effective alternative to mechanical repair in terms of time saved during repair design and implementation. In other cases, it represents the only viable option for repair. BWRVIP plans to perform work in 2010 and 2011 to develop underwater laser welding capability applicable to BWR repair scenarios. Work is also ongoing under the management of EPRI Welding & Repair Technology Center to evaluate seal-welding capabilities on dissimilar material welds, partial-penetration welds, and fillet weld repair applications. This gap is related to repair gap B-RR-02 associated with development of welding processes for highly irradiated materials. **References:** BWRVIP-151, 1019167	**Priority:** R2(2010): Medium R1.1(2009): Medium R1(2008): Low **Status:** Open **Responsibility:** BWRVIP: Repair **Affected by LTO?** Yes
B-RR-09 - Improved Jet Pump Restrainer Bracket Design **Gap closed** – See Table B-2 for Gap Description and Closure Basis.	**Status:** Closed

Table 3-7 Regulatory Issue Gaps

R&D Gap Description	Results Data
B-RG-01 – IGSCC & High-Cycle Thermal Fatigue of Small Bore Piping (SBP) **Gap closed** – See Table B-2 for Gap Description and Closure Basis.	**Status:** Closed
B-RG-02 - Thermal Embrittlement of CASS Piping **Gap closed** in Revision 1 (2008) – See EPRI BWRVIP-167NP, Revision 1 (EPRI 1018111) for Gap Description and Closure Basis.	**Status:** Closed
B-RG-03 - Top Guide License Renewal Assessment **Gap closed** in Revision 1 (2008) – See EPRI BWRVIP-167NP, Revision 1 (EPRI 1018111) for Gap Description and Closure Basis.	**Status:** Closed
B-RG-04 - Integrated Surveillance Program (ISP) Maintenance **Gap closed** in Revision 1 (2008) – See EPRI BWRVIP-167NP, Revision 1 (EPRI 1018111) for Gap Description and Closure Basis.	**Status:** Closed

Table 3-7 Regulatory Issue Gaps (Continued)

R&D Gap Description	Results Data
B-RG-05 - Evaluation of EVT-1 **Issue:** There are NRC concerns that EVT-1 as currently implemented by the BWRVIP may not reliably detect tight IGSCC cracking. The BWRVIP maintains that these visual inspections are capable of reliably detecting cracks of significance to reactor operations. **Description:** EVT-1 makes use of high-resolution camera systems to routinely examine nuclear plant components, including core shrouds and other pressure vessel internals. Techniques and methods for performing EVT-1 examinations were developed in the field during core shroud examinations that were performed in the 1993-1995 time frame. As a result, EVT-1 did not have a formal laboratory-derived technical basis. The methods and techniques evolved as lessons were learned about the necessary camera distance, lighting, and surface-condition requirements. Increased attention on EVT-1 has resulted from recent questions and assessments concerning its effectiveness. The Research division of USNRC has recently been evaluating the suitability of remote visual methods, specifically EVT-1, for detection of tight cracking in nuclear safety-related components. NUREG-6860, prepared by Pacific Northwest National Laboratory, expresses serious reservations about the reliability of EVT-1 for detection of tight cracking, and makes recommendations for modifications to the technique and for further study. This study additionally concludes that the inspection reliability of the various VT systems, calibration standards, and procedures is not well characterized and that a performance demonstration initiative is needed. The NUREG cites VT experiments performed by PNNL; Swedish studies of VT reliability and qualification; various references regarding general aspects of measuring and specifying visual systems' performance; and various studies that have measured the opening dimensions of IGSCC and other types of cracking. In response, EPRI NDE Center member utilities initiated a multi-year effort in 2005 to evaluate EVT-1 and investigate the findings presented in NUREG/CR-6860. EPRI reports 1011625, 1013537, and 1019144 document the results of the studies performed to date. The earlier studies resulted in some tightening of the EVT-1 resolution, angle, and scan speed requirements in Revision 10 of BWRVIP-03. The more recent study found that care should be taken when selecting the equipment used for data acquisition and review. The entire system should be viewed as a whole, and every step in the process should be evaluated. Inferior components were found to effectively degrade the performance of the entire system. (Continued on next page.)	**Priority:** R2(2010): High R1.1(2009): Medium R1(2008): High **Status:** Open **Responsibility:** BWRVIP: Integration Inspection Other: EPRI NDE Ctr. **Affected by LTO?** No

Table 3-7 Regulatory Issue Gaps (Continued)

R&D Gap Description	Results Data
B-RG-05 (continued) Although progress has been made toward resolution of this issue, future NRC actions remain uncertain. Resolution of this issue with the NRC staff remains an open regulatory gap requiring development of appropriate technical justifications and plans for laboratory experiments to address NRC concerns related to BWRVIP visual examination implementation. The impact of not proactively resolving this issue could be an NRC mandate for a NDE qualification program similar to PDI, resulting in significant, ongoing cost. **References:** BWRVIP-03R12, BWRVIP-231, EPRI 1011625, EPRI 1013537, EPRI 1019144 BWRVIP Correspondence 2006-322, 2007-144, 2008-186 NUREG/CR-6860	See previous page
B-RG-06 – Reactor Internals NDE Qualification **Gap closed** – See Table B-2 for Gap Description and Closure Basis.	**Status:** Closed
B-RG-07 - Flaw Sizing Criteria **Gap closed** – See Table B-2 for Gap Description and Closure Basis.	**Status:** Closed

Table 3-7 Regulatory Issue Gaps (Continued)

R&D Gap Description	Results Data
B-RG-08 - Reactor Pressure Vessel Material Surveillance Program Implementation for 80-Year Service Lives **Issue:** Plant RPV material surveillance program regulations and embrittlement correlations were not designed with the potential for 80 year service lives. In effect, interim guidance was provided by the NRC within NUREG-1801, which describes the NRC position for material surveillance programs through 60 years of operation. However, regulatory guidance for 80 year operations is currently not well defined and there is a need to proactively work with the NRC to develop appropriate guidance for 80-year service lives. **Description:** Guidance for material surveillance programs are established by 10 CFR 50 Appendix H. ASTM E185-82, which is incorporated by reference into 10 CFR 50 Appendix H, provides specific guidance on testing of surveillance specimens, the minimum number of capsules needed for a surveillance program, and on capsule withdrawal schedules. ASTM E185-82 does not specifically consider service beyond 40 years (32 EFPY). With initial license renewals, the NRC adopted a standard position regarding maintenance of surveillance programs for 60-year operations in NUREG-1801. Presently, there is no guidance regarding what will be required for approval of a 2nd license renewal term. A second area of uncertainty is the ongoing NRC efforts to revise the embrittlement correlations contained in Regulatory Guide 1.99 to fit current data and adequately predict all anticipated embrittlement processes. *[NOTE: 80-year implementation issues associated with the BWRVIP Integrated Surveillance Program (ISP) are addressed in a separate assessment gap, B-AS-30.]* **References:** NUREG-1801, R.G. 1.99R2 10 CFR Part 50, Appendix H, *Reactor Vessel Material Surveillance Program Requirements*, Office of the Federal Register, National Archives and Records Administration, 2005. ASTM E185-82, *Standard Practice for Conducting Surveillance Tests for Light-Water Cooled Nuclear Power Reactor Vessels*. ASTM International, West Conshohocken, PA.	**Priority:** R2(2010): Medium R1.1(2009): N/A R1(2008): N/A **Status:** New **Responsibility:** BWRVIP: Assessment **Affected by LTO?** Yes

Table 3-7 Regulatory Issue Gaps (Continued)

R&D Gap Description	Results Data
B-RG-09 - Management of License Renewal Issues **Issue:** There are issues where NRC license renewal guidance contained in NUREG-1801R1 is inconsistent with BWRVIP guidance. In some cases, this results in the unnecessary expenditure of resources on low value inspections. **Description:** NUREG-1801 Volume 2, Revision 1 (the GALL Report) outlines NRC guidance for a number of aging management programs, including BWR Stress Corrosion Cracking, BWR Reactor Vessel Internals, and ASME Class 1 small bore piping. NRC staff are presently working on a revision to the GALL report. There is a need to work with the NRC to affect revision of this report so that the BWRVIP program is addressed in a way that prevents additional burden on license renewal applicants where NRC expectations based on guidance contained in GALL do not align with BWRVIP guidance. Examples include: <u>Management of ASME Class 1 small bore piping (< NPS 4) to address SCC and high-cycle thermal fatigue:</u> There are technical bases for management of SCC and high-cycle thermal fatigue of small bore piping without implementation of volumetric examinations. Visual (VT-2) examinations combined with management of high-cycle fatigue concerns consistent with BWRVIP-155 and BWRVIP-196 represent a technically sound approach. The GALL Report (in section XI.M35) recommends volumetric examination. While volumetric examination of some small bore piping segments could result from implementation of risk-informed ISI programs, generic implementation of volumetric inspections is not warranted. At present, practical volumetric examination technologies for socket welded fittings that accurately detect relevant flaws without false positives are not available. Resolution may be accomplished through either development of accurate NDE solutions or through interaction with NRC to achieve relaxation of the current position in the GALL Report. <u>Management of CASS Reactor Internals</u>: The GALL report recommends augmented inspection for CASS components exceeding $1x10^{17}$ n/cm^2 (E > 1.0 MeV). This position conflicts with existing BWRVIP (and MRP) guidance for CASS and recent BWRVIP studies addressing CASS vulnerability to thermal and irradiation embrittlement (BWRVIP-234). (continued on next page)	**Priority:** R2(2010): High R1.1(2009): N/A R1(2008): N/A **Status:** New **Responsibility:** BWRVIP: Integration **Affected by LTO?** No

Table 3-7 Regulatory Issue Gaps (Continued)

R&D Gap Description	Results Data
B-RG-09 (continued) Reference Updates: The BWRVIP is an active management program with periodic updates to important management guidance such as inspection & evaluation guidelines and water chemistry guidelines. GALL references to BWRVIP reports quickly become out of date once GALL is published. As a result, there is a need to work with the NRC to improve the manner in which BWRVIP references are cited in GALL so that applicants need not justify differences in revision level from those specified in the GALL report. **References:** NUREG-1801R1, BWRVIP-155, BWRVIP-196, BWRVIP-234 NRC Safety Evaluation Related to the Fourth 10-Year Interval Inservice Inspection Program, Surry Power Station, Unit 2 - Virginia Electric and Power Company - Docket No. 50-281, U.S. Nuclear Regulatory Commission: August 2005. Hope Creek Generating Station License Renewal Application Duane Arnold Energy Center License Renewal Application "Safety Evaluation Report Related to the License Renewal of the Susquehanna Steam Electric Station, Units 1 and 2." Vogtle Electric Generating Plant License Renewal Application	See previous page

Table 3-8 Program Requirements

Program Requirement Description
B-RQ-01 - Regulatory Interface The Integration Committee serves as the focal point for regulatory issues and NRC communications and is responsible for ensuring that regulatory commitments are understood and met. New reports are published and transmitted to NRC each year for review and approval. The BWRVIP submits, on average, 5-8 reports each year to NRC. Responses to NRC requests for additional information and revision of submitted reports are coordinated by the BWRVIP. **Responsible Program:** BWRVIP Integration **References:** None

Table 3-8 Program Requirements (Continued)

Program Requirement Description
B-RQ-02 - Integrated Surveillance Program (ISP) Maintenance 10CFR50, Appendix H requires that each BWR have a vessel materials surveillance program. The purpose of the surveillance program is to monitor the changes in vessel material properties resulting from neutron irradiation damage. Appendix H specifies the design requirements of the surveillance program and for the withdrawal schedule for each capsule. The data from the surveillance program is used to establish pressure-temperature limits for heatup and cooldown, as well as to determine hydrotest temperatures. The purpose of the BWR ISP is to implement a BWR fleet-wide integrated surveillance capsule testing program that utilizes individual plant programs and the Supplemental Surveillance Program (SSP) previously initiated by the BWR Owners' Group (BWROG). The objective of the ISP is to proactively address vessel surveillance requirements on a fleet-wide basis and to eliminate testing of some capsules of lower value that would not be possible on an individual plant basis. The NRC issued a Safety Evaluation in February 2002 that approved the ISP. Although not a safety concern, NRC has indicated that some BWRs (about 11) are not in full compliance with 10CFR50 App. H. The costs for affected utilities to address the NRC concerns could be significant if NRC imposes more conservative estimates of embrittlement thereby affecting heatup, cooldown, and hydrotest limits. Consideration of 80 year operation results in new challenges for the ISP. Issues associated with changes to the ISP to address 80 year operations are addressed in a new IMT gap (B-AS-30). **Responsible Program:** BWRVIP Assessment **References:** BWRVIP-86R1, BWRVIP-102, BWRVIP-135R2 10CFR50 Appendix H, NUREG-1801R1 (Section XI.M31)

Table 3-8 Program Requirements (Continued)

Program Requirement Description
B-RQ-03 - BWR Fluence Modeling (RAMA Code)
Accurate neutron fluence determinations are needed to 1) determine neutron fluence in the RPV shells and welds and at surveillance capsule locations and 2) determine fracture toughness and crack growth rates for flaw evaluations, structural assessments, and for evaluating repair technologies. The RAMA Fluence Methodology provides BWRVIP members with state-of-the-art software that can be used to determine the fluence of the BWR internals, reactor pressure vessels, and surveillance capsules.
Regulatory Guide 1.190 defines acceptable methods and criteria for conducting fluence calculations. All new fluence calculations must comply with this regulatory guidance. Uncertainties associated with the RAMA Fluence Methodology have been shown to be well within the uncertainty guidelines provided in Regulatory Guide 1.190.
The nature of maintenance and improvement of the RAMA codes is most accurately described as a program requirement. Maintenance of the code is necessary to support maintenance of the ISP (B-RQ-02) and conformance with NRC R.G. 1.190.
Responsible Program:
BWRVIP Assessment
References:
BWRVIP-114-A, BWRVIP-115-A, BWRVIP-157, BWRVIP-189, BWRVIP-209
NRC R.G 1.190

Table 3-8 Program Requirements (Continued)

Program Requirement Description
B-RQ-04 - Maintain Inspection Trends Database
BWRVIP has committed to NRC to track and evaluate results of component inspections to determine whether the existing guidelines are adequate to monitor SCC.
For the BWRVIP membership, the purpose of this activity is to continue to assemble re-inspection data on core internals and to use this information to justify a relaxation in re-inspection requirements. Inspection scope and frequencies in existing guidelines are believed to be very conservative. The most effective means of demonstrating this is to obtain actual field data from successive inspections to show that crack growth is slower than current predictions. The disadvantage of not doing this work is that current prediction methods for crack growth remain unchanged or are negatively impacted, resulting in more frequent inspections and higher costs to utilities.
In addition to the availability of many new inspection data, there have been a number of significant technology advances in recent years that should be periodically assessed for some component locations. For example, hydrogen water chemistry (HWC) technologies provide demonstrated IGSCC protection for many component locations. In other situations, accurate volumetric NDE techniques are now available and provide a better understanding of weld condition than visual NDE techniques. Trending of inspection data allows the BWRVIP to appropriately assess the impacts of these technologies on inspection trends.
This issue program requirement is expected to continue indefinitely, i.e., for the life of the U. S. BWR fleet.
Responsible Program:
BWRVIP Assessment
References:
BWRVIP-94 Revision 1, BWRVIP-133, BWRVIP-160, BWRVIP-198

Table 3-8 Program Requirements (Continued)

Program Requirement Description
B-RQ-05 - BWR Water Chemistry Control Guideline Maintenance The EPRI BWR Water Chemistry Guidelines are reviewed biennially, with fully revised guidelines being issued every four years. Water chemistry experience in BWRs continues to be collected and analyzed. Trends, plant-specific impacts and the development of short and long term plant operating strategies are key to the successful operation of plants over long service lives. Impacts to fuel also need to be understood and managed. Reapplications of NMCA and the advent of on-line noble metal chemical application play a key role in plant operation and increase the need for a better understanding of chemistry's impact on IGSCC, plant operation, fuel performance and dose control. Feedwater iron control and depleted zinc addition are also key parameters in understanding BWR chemistry behavior. BWRVIP-62 provides technical bases for inspection relief for BWR internal components with hydrogen injection. Maintenance of BWRVIP-62-A to address new mitigation technologies (e.g. OLNC), represents a significant value to the BWRVIP membership in terms of reduced inspection costs for locations protected by hydrogen water chemistry technologies. As a result, continued maintenance of the BWR water chemistry guidelines and technical bases for inspection relief for components mitigated by HWC technologies represents an issue program requirement. **Responsible Program:** EPRI Water Chemistry Program, BWRVIP Mitigation **References:** BWRVIP-62, BWRVIP-94 Revision 1, BWRVIP-190 NEI 03-08 Rev. 2

Table 3-8 Program Requirements (Continued)

Program Requirement Description
B-RQ-06 - Inspection & Evaluation Guideline Maintenance BWRVIP Inspection and Evaluation Guidelines are an essential part of the BWRVIP program. These documents provide the structure for development of inspection programs for BWR reactor internals (including inspection locations, inspection techniques, sample sets, scope expansion, and re-inspection intervals). These documents additionally provide guidance for evaluation of inspection results and disposition of relevant indications. Maintenance of these documents is necessary to ensure that the guideline requirements remain adequate to address the applicable degradation mechanisms and reflect information gained through new operating experience and research results. As inspections are implemented and new experience is gained, revisions to these documents are likely to be needed to address emergent degradation concerns or to update inspection requirements based on the collection of inspection results data. In addition to I&E Guidelines, BWRVIP maintains a number of documents that are used to evaluate crack growth rates or estimate the impact of neutron fluence on material properties and performance. These basis documents are an essential part of the BWRVIP program. Member utilities are committed to implement BWRVIP Inspection and Evaluation guidelines as a means of managing degradation of reactor internals. Additionally, the process of document maintenance includes responding to NRC RAIs, and preparation of NRC-approved versions of the guidelines. **Responsible Program:** BWRVIP Assessment **References:** I&E Guideline Documents: BWRVIP-18R1, BWRVIP-25, BWRVIP-26-A, BWRVIP-27-A, BWRVIP-38, BWRVIP-41R2, BWRVIP-42-A, BWRVIP-47-A, BWRVIP-48-A, BWRVIP-74-A, BWRVIP-75-A, BWRVIP-76-A, BWRVIP-139-A, BWRVIP-180, BWRVIP-183, BWRVIP-222 Technical Basis Documents: BWRVIP-14-A, BWRVIP-59-A, BWRVIP-60-A, BWRVIP-80-A, BWRVIP-94R1, BWRVIP-99-A, BWRVIP-100-A

Table 3-8 Program Requirements (Continued)

Program Requirement Description
B-RQ-07 - NDE Program Maintenance Maintenance of the BWRVIP NDE program as implemented by BWRVIP-03 represents one of the central functions of the Inspection Focus Group. This involves, in part, the continuous activity of supporting demonstrations of new NDE techniques before they are applied in plants. When applying new techniques in the field, usually UT, the technique must be demonstrated on realistic mockups and documented prior to implementation. A key part of this process is BWRVIP maintenance of an evolving set of NDE mockups to support these demonstrations. These are (almost always) non-Code inspections for which BWRVIP is the only avenue for qualification. Included in this issue program requirement are the tasks of design and fabrication of any new mock-ups necessary to support field configurations not addressed by the existing mockups, and support for implementation of NDE techniques for which the existing mockups are not applicable. The task also includes administering, monitoring and documenting the new demonstrations for inclusion into revisions to "Reactor Pressure Vessel and Internals Examination Guidelines (BWRVIP-03)." Finally, resources are needed to support NRC inquiries. Funding of this work is necessary to ensure that member utilities have access to qualified NDE techniques for use in implementing BWRVIP inspection and evaluation guideline requirements. **Responsible Program:** BWRVIP Inspection **References:** BWRVIP-03R12, BWRVIP-94R1

Table 3-8 Program Requirements (Continued)

Program Requirement Description
B-RQ-08 - BWRVIP Repair and Replacement Design Criteria Maintenance The BWRVIP has developed Repair and Replacement Design Criteria and other reports that provide guidance on the repair and replacement of BWR internal components. In order to maintain the applicability and effectiveness of these documents, maintenance activities must be performed. In addition, BWRVIP-84 provides guidance on procurement, design, welding requirements, and fabrication limitations for BWR reactor internals repair hardware. As utilities and vendors gain experience using these documents, it is likely that modifications and improvements to the guidance will be appropriate. In some cases, these documents apply to repairs that have yet to be performed. As a result, modifications will also likely be required based on feedback from field experience. Additionally, the process of document maintenance includes responding to NRC RAIs, and preparation of NRC-approved versions of the guidelines. **Responsible Program:** BWRVIP Repair **References:** Repair Design Criteria: BWRVIP-02-A, BWRVIP-16-A, BWRVIP-19-A, BWRVIP-50-A, BWRVIP-51-A, BWRVIP-52-A, BWRVIP-53-A, BWRVIP-55-A, BWRVIP-56-A, BWRVIP-57-A, BWRVIP-181. Supporting Documents: BWRVIP-44-A, BWRVIP-84, BWRVIP-94R1, BWRVIP-97-A.

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A

BWR ISSUE MANAGEMENT TABLES

The issue management tables (IMTs) address components, materials of construction, degradation mechanisms, consequences of failure, management guidance (mitigation, repair / replacement, and I&E guidance), and applicable R&D gaps. Chapter 2, Methodology discusses the approaches used in populating the IMTs.

Appendix A contains the following IMTs:

The IMTs use abbreviations for applicable degradation mechanisms. The following degradation mode and associated degradation sub-mode abbreviations are used in the IMTs:

- **Stress Corrosion Cracking (SCC):**
  - Intergranular & Transgranular SCC (IG / TG)
  - Irradiation-Assisted SCC (IASCC)
- **Corrosion & Wear (C&W):**
  - Wastage (Wstg.)
  - Pitting
  - Wear
  - Flow-Accelerated Corrosion (FAC)
  - Fouling
- **Fatigue (Fat):**
  - High-Cycle Fatigue (HC)
  - Low-Cycle and Environmental Fatigue (LC-Env.)
- **Reduction in Fracture Properties (RiFP):**
  - Thermal Aging (Th.)
  - Reduction in Fracture Properties due to Environmental Effects (Env.)[1]
- **Irradiation Effects (Irr.):**
  - Irradiation Embrittlement (Emb.)
  - Stress Relaxation (SR) - includes irradiation creep
- **External Effects (Ext.)**

1. This degradation sub-mode is broadly defined to include several related phenomena including both high temperature and low temperature observations and both K_{IC} (fracture toughness) and J-R tearing (fracture resistance) conditions. LTCP is also included in this category.

The IMTs use a key for consequences of failure. The following consequences of failure key is used throughout the IMTs:

A - Loss of reactor coolant pressure boundary integrity

B - Loss of component support

C - Loss of component constraint
(This consequence includes the potential for crack extension into the RPV alloy steel base material.)

D - Loss of Integrity
(This consequence is applied to the steam dryers where recent operating experience with loose part generation indicates that maintaining the integrity of steam dryer components is important to safety due to the potential for generation of loose parts and the impact of these loose parts on safety-related components.)

E - Loss of core flow distribution
(This consequence is specifically related to flow distribution within the reactor vessel to ensure adequate cooling of fuel assemblies.)

F - Loss of core support and / or orientation
(This consequence is related to support and / or orientation of the reactor core, internals components, or control rod assemblies, or incore instrumentation.)

G - Loss of two-thirds core height coverage

H - Loss of Flow restriction capability

None - There are no safety-related consequences of failure
(This function indicates that there is no safety consequence directly associated with failure of the component location. Economic or non-safety related operational consequences may exist for these component locations.)

Gap ID numbers listed in the far right-hand column of the IMTs are hyper linked to results presented in Section 3. Alternatively, users may refer to Table 3-1: R&D Gap Priority Results, for a master listing of currently open gaps.

Table A-1 Reactor Pressure Vessel

Components & ID No.	Material	Degradation Mechanisms	Conseq. of Failure	Mitigation	Repair / Replace	I & E Guidance	Gaps
1.1 Shells and Heads							
1.1-1 Top Head and Flange	C&LAS *(SA-533, Gr B, Cl 1; SA-508 Cl 2)*	SCC: IG/TG Fat: LC-Env RiFP: Env Ext: Pitting	A, B	**Water Chemistry** BWRVIP-190 BWRVIP-225	**ASME Sect. XI** IWA-4000	**ASME Sect. XI** IWB-2500-1 *(BWRVIP-74-A)*	B-DM-06 B-DM-07 B-AS-07
1.1-2 Vessel Flange	C&LAS *(SA-336 or SA-508, Cl 2)*	SCC: IG/TG Fat: LC-Env RiFP: Env Ext: Pitting	A, B	**Water Chemistry** BWRVIP-190 BWRVIP-225	**ASME Sect. XI** IWA-4000	**ASME Sect. XI** IWB-2500-1 *(BWRVIP-74-A)*	B-DM-06 B-DM-07 B-AS-07
1.1-3 Upper Intermediate (Nozzle), Beltline, and Lower Shells	C&LAS *(A-302, Gr B or SA-533, Gr B, Cl 1)* SS Clad[1]	SCC: IG/TG Fat: LC-Env RiFP: Th (clad) Env IE: Emb Ext: Pitting	A, B, G	**Water Chemistry** BWRVIP-190 BWRVIP-225 **HWC Technology** BWRVIP-62 BWRVIP-156 BWRVIP-159 BWRVIP-219	**ASME Sect. XI** IWA-4000	**ASME Sect. XI** IWB-2500-1 *(BWRVIP-74-A & BWRVIP-203)* **EPRI BWRVIP Integrated Surveillance Program** BWRVIP-86R1 BWRVIP-102 BWRVIP-135R2 **LC-Env Fatigue** NUREG-1801-X.M1 NUREG-6260 NUREG-6909	B-DM-06 B-DM-07 B-DM-08 B-AS-05 B-AS-07 B-AS-11 B-AS-30 B-RG-08

Table A-1 Reactor Pressure Vessel (Continued)

Components & ID No.	Material	Degradation Mechanisms	Conseq. of Failure	Mitigation	Repair / Replace	I & E Guidance	Gaps
1.1-4 Bottom Head	C&LAS *(A-302, Gr B or SA-533, Gr B, Cl 1)* SS Clad[1]	SCC: IG/TG Fat: LC-Env RiFP: Th (clad) Env Ext: Pitting	A, B, G	**Water Chemistry** BWRVIP-190 BWRVIP-225 **HWC Technology** BWRVIP-62 BWRVIP-156 BWRVIP-159 BWRVIP-219	**ASME Sect. XI** IWA-4000	**ASME Sect. XI** IWB-2500-1 *(BWRVIP-74-A)* **LC-Env Fatigue** NUREG-1801-X.M1 NUREG-6260 NUREG-6909	B-DM-06 B-DM-07 B-AS-07

Table A-1 Reactor Pressure Vessel (Continued)

Components & ID No.	Material	Degradation Mechanisms	Conseq. of Failure	Mitigation	Repair / Replace	I & E Guidance	Gaps
1.2 Head Closure Studs and Nuts, Top of Head Flange Bolts							
1.2-1 Closure Head Studs, Washers, Nuts	C&LAS *(SA-193, Gr B16, or SA-540, Gr B23 or B24)*	SCC: IG/TG C&W: Pitting Fat: LC-Env	A	**Bolting Integrity** EPRI 1018959 EPRI NP-5769 NUREG-1339 NUREG-1801 Reg. Guide 1.65	**ASME Sect. XI** IWA-4000	**ASME Sect. XI** IWB-2500-1 *(BWRVIP-74-A)*	B-DM-06
1.2-2 Top of Head Flange Bolts	C&LAS *(SA-193)*	SCC: IG/TG C&W: Pitting Fat: LC-Env	A	**Bolting Integrity** EPRI 1018959 EPRI NP-5769 NUREG-1339 NUREG-1801	**ASME Sect. XI** IWA-4000	**ASME Sect. XI** IWB-2500-1 *(BWRVIP-74-A)*	B-DM-06

Table A-1 Reactor Pressure Vessel (Continued)

Components & ID No.	Material	Degradation Mechanisms	Conseq. of Failure	Mitigation	Repair / Replace	I & E Guidance	Gaps
1.3 Nozzles and Safe Ends (Thermal Sleeves Included in Reactor Vessel Internals IMT, Table A-2)							
1.3-1 Top Head Nozzle *(Head Spray and Vent)*	C&LAS *(SA-508, Cl 2)*	SCC: IG/TG Fat: LC-Env RiFP: Env Ext: Pitting	A	**Water Chemistry** BWRVIP-190 BWRVIP-225	**ASME Sect. XI** IWA-4000	**ASME Sect. XI** IWB-2500-1 *(BWRVIP-74-A)*	B-DM-06 B-DM-07 B-AS-07
1.3-2 Main Steam Nozzles and Safe Ends	C&LAS *(SA-508, Cl 2)*	SCC: IG/TG RiFP: Env Ext: Pitting	A	**Water Chemistry** BWRVIP-190 BWRVIP-225	**ASME Sect. XI** IWA-4000	**ASME Sect. XI** IWB-2500-1 *(BWRVIP-74-A)*	B-DM-06 B-DM-07 B-AS-07
1.3-3 Feedwater Nozzles	C&LAS *(SA-508, Cl 2)*	SCC: IG/TG Fat: LC-Env RiFP: Env Ext: Pitting	A	**Water Chemistry** BWRVIP-190 BWRVIP-225 **Oper. Changes** GE-NE-523-A71-0594 *(Low Flow Controller Oper.)*	**ASME Sect. XI** IWA-4000	**ASME Sect. XI** IWB-2500-1 *(BWRVIP-74-A)* **LC-Env Fatigue** NUREG-1801-X.M1 NUREG-6260 NUREG-6909 **HC Thermal Fatigue** NUREG-0619 GE-NE-523-A71-0594	B-DM-06 B-DM-07 B-AS-07

Table A-1 Reactor Pressure Vessel (Continued)

Components & ID No.	Material	Degradation Mechanisms	Conseq. of Failure	Mitigation	Repair / Replace	I & E Guidance	Gaps
1.3-4 Feedwater Nozzle Safe Ends	C&LAS *(SA-508, Cl 1, CS)*	SCC: IG/TG Fat: LC-Env RiFP: Env Ext: Pitting	A	**Water Chemistry** BWRVIP-190 BWRVIP-225 **Oper. Changes** GE-NE-523-A71-0594 *(Low Flow Controller Oper.)*	**ASME Sect. XI** IWA-4000	**ASME Sect. XI** IWB-2500-1 *(BWRVIP-74-A)* **LC-Env Fatigue** NUREG-1801-X.M1 NUREG-6260 NUREG-6909 **HC Thermal Fatigue** NUREG-0619 GE-NE-523-A71-0594	B-DM-06 B-AS-07
1.3-5 Feedwater Nozzle Safe Ends	Ni-Alloy *(Some safe ends - A600 with A82/ A182 welds)*	SCC: IG/TG Fat: LC-Env RiFP: Env Ext: Pitting	A	**Water Chemistry** BWRVIP-190 BWRVIP-225 **HWC Technology** BWRVIP-62 BWRVIP-156 BWRVIP-159 BWRVIP-219 **Oper. Changes** GE-NE-523-A71-0594 *(Low Flow Controller Oper.)* **Stress Improvement** BWRVIP-61 *(Weld Overlay, IHSI, MSIP)*	**ASME Sect. XI** IWA-4000 **Weld Overlay** CC-N-504-2 *(Vendor Controlled)*	**ASME Sect. XI** IWB-2500-1 *(BWRVIP-74-A)* **IGSCC** Generic Letter 88-01 BWRVIP-75-A BWRVIP-222 **LC-Env Fatigue** NUREG-1801-X.M1 NUREG-6260 NUREG-6909 **HC Thermal Fatigue** NUREG-0619 GE-NE-523-A71-0594	B-DM-03 B-DM-06 B-DM-09 B-DM-10 B-AS-07 B-AS-27

Table A-1 Reactor Pressure Vessel (Continued)

Components & ID No.	Material	Degradation Mechanisms	Conseq. of Failure	Mitigation	Repair / Replace	I & E Guidance	Gaps
1.3-6 Core Spray Nozzles	C&LAS *(SA-508, Cl 2)*	SCC: IG/TG Fat: LC-Env RiFP: Env Ext: Pitting	A	**Water Chemistry** BWRVIP-190 BWRVIP-225	**ASME Sect. XI** IWA-4000	**ASME Sect. XI** IWB-2500-1 *(BWRVIP-74-A)* **LC-Env Fatigue** NUREG-1801-X.M1 NUREG-6260 NUREG-6909	B-DM-06 B-DM-07 B-AS-07
1.3-7 Core Spray Nozzle Safe Ends	C&LAS *(Carbon Steel)*	SCC: IG/TG Fat: LC-Env RiFP: Env Ext: Pitting	A	**Water Chemistry** BWRVIP-190 BWRVIP-225	**ASME Sect. XI** IWA-4000	**ASME Sect. XI** IWB-2500-1 *(BWRVIP-74-A)* **LC-Env Fatigue** NUREG-1801-X.M1 NUREG-6260 NUREG-6909	B-DM-06 B-DM-07 B-AS-07
1.3-8 Core Spray Nozzle Safe Ends	SS *(incl. SS welds)*	SCC: IG/TG Fat: LC-Env RiFP: Env Ext: IG/TG Pitting	A	**Water Chemistry** BWRVIP-190 BWRVIP-225 *(Not mitigated by HWC / NMCA / OLNC)* **Stress Improvement** BWRVIP-61 *(Weld Overlay, IHSI, MSIP)*	**ASME Sect. XI** IWA-4000 **Weld Overlay** CC-N-504-2 *(Vendor Controlled)*	**ASME Sect. XI** IWB-2500-1 *(BWRVIP-74-A)* **IGSCC** Generic Letter 88-01 BWRVIP-75-A BWRVIP-222 **LC-Env Fatigue** NUREG-1801-X.M1 NUREG-6260 NUREG-6909	B-DM-03 B-DM-06 B-DM-09 B-DM-10 B-AS-07 B-AS-27 B-MT-01 B-MT-02

Table A-1 Reactor Pressure Vessel (Continued)

Components & ID No.	Material	Degradation Mechanisms	Conseq. of Failure	Mitigation	Repair / Replace	I & E Guidance	Gaps
1.3-9 Core Spray Nozzle Safe Ends	Ni-Alloy *(A600 with A82/ A182 welds)*	SCC: IG/TG Fat: LC-Env RiFP: Env Ext: Pitting	A	**Water Chemistry** BWRVIP-190 BWRVIP-225 *(Not mitigated by HWC / NMCA / OLNC)* **Stress Improvement** BWRVIP-61 *(Weld Overlay, IHSI, MSIP)*	**ASME Sect. XI** IWA-4000 **Weld Overlay** CC-N-504-2 *(Vendor Controlled)*	**ASME Sect. XI** IWB-2500-1 *(BWRVIP-74-A)* **IGSCC** Generic Letter 88-01 BWRVIP-75-A BWRVIP-222 **LC-Env Fatigue** NUREG-1801-X.M1 NUREG-6260 NUREG-6909	B-DM-03 B-DM-06 B-DM-09 B-DM-10 B-AS-07 B-AS-27 B-MT-01
1.3-10 LPCI Nozzles	C&LAS *(SA-508, Cl 2)*	SCC: IG/TG Fat: LC-Env RiFP: Env IE: Emb Ext: Pitting	A	**Water Chemistry** BWRVIP-190 BWRVIP-225	**ASME Sect. XI** IWA-4000	**ASME Sect. XI** IWB-2500-1 *(BWRVIP-74-A)*	B-DM-06 B-DM-07 B-AS-05 B-AS-07
1.3-11 LPCI Nozzle Safe Ends *(BWR/5)*	C&LAS *(Carbon Steel)*	Fat: LC-Env RiFP: Env Ext: Pitting	A	**Water Chemistry** BWRVIP-190 BWRVIP-225	**ASME Sect. XI** IWA-4000	**ASME Sect. XI** IWB-2500-1 *(BWRVIP-74-A)*	B-DM-06 B-DM-07 B-AS-07

Table A-1 Reactor Pressure Vessel (Continued)

Components & ID No.	Material	Degradation Mechanisms	Conseq. of Failure	Mitigation	Repair / Replace	I & E Guidance	Gaps
1.3-12 LPCI Nozzle Safe Ends *(BWR/5)*	Ni-Alloy *(A600 with A82/ A182 welds)*	SCC: IG/TG Fat: LC-Env RiFP: Env Ext: Pitting	A	**Water Chemistry** BWRVIP-190 BWRVIP-225 *(Not mitigated by HWC / NMCA / OLNC)* **Stress Improvement** BWRVIP-61 *(Weld Overlay, IHSI, MSIP)*	**ASME Sect. XI** IWA-4000 **Weld Overlay** CC-N-504-2 *(Vendor Controlled)*	**ASME Sect. XI** IWB-2500-1 *(BWRVIP-74-A)* **IGSCC** Generic Letter 88-01 BWRVIP-75-A BWRVIP-222	B-DM-03 B-DM-06 B-DM-09 B-DM-10 B-AS-07 B-AS-27 B-MT-01
1.3-13 CRD Return Line Nozzle *(Only BWR/2 not capped or flanged)*	C&LAS *(SA-508, Cl 2)*	SCC: IG/TG Fat: LC-Env RiFP: Th (clad) Env IE: Emb Ext: Pitting	A	**Water Chemistry** BWRVIP-190 BWRVIP-225	**ASME Sect. XI** IWA-4000	**ASME Sect. XI** IWB-2500-1 *(BWRVIP-74-A)* **HC Thermal Fatigue** NUREG-0619 GE-NE-523-A71-0594	B-DM-06 B-DM-07 B-AS-05 B-AS-07
1.3-14 CRD Return Line Nozzle Cap *(BWR/3-6)*	Ni-Alloy *(A600 with A82/ A182 welds)*	SCC: IG/TG Fat: LC-Env RiFP: Env Ext: Pitting	A	**Water Chemistry** BWRVIP-190 BWRVIP-225 *(Not mitigated by HWC / NMCA / OLNC)*	**ASME Sect. XI** IWA-4000	**ASME Sect. XI** IWB-2500-1 *(BWRVIP-74-A)* **IGSCC** BWRVIP-75-A BWRVIP-222	B-DM-03 B-DM-06 B-DM-09 B-AS-07 B-AS-27 B-MT-01
1.3-15 Recirculation Inlet and Outlet Nozzles	C&LAS *(SA-508, Cl 2)*	SCC: IG/TG Fat: LC-Env RiFP: Th (clad) Env IE: Emb Ext: Pitting	A, G	**Water Chemistry** BWRVIP-190 BWRVIP-225	**ASME Sect. XI** IWA-4000	**ASME Sect. XI** IWB-2500-1 *(BWRVIP-74-A)*	B-DM-06 B-DM-07 B-AS-05 B-AS-07

Table A-1 Reactor Pressure Vessel (Continued)

Components & ID No.	Material	Degradation Mechanisms	Conseq. of Failure	Mitigation	Repair / Replace	I & E Guidance	Gaps
1.3-16 Recirculation Inlet and Outlet Nozzle Safe Ends	SS *(304, 316, 316L, 316NG & incl. SS welds)* Ni-Alloy *(A82/A182 welds)*	SCC: IG/TG Fat: LC-Env RiFP: Env Ext: IG/TG Pitting	A, G	**Water Chemistry** BWRVIP-190 BWRVIP-225 **HWC Technology** BWRVIP-62 BWRVIP-156 BWRVIP-159 BWRVIP-219 **Stress Improvement** BWRVIP-61 *(Weld Overlay, IHSI, MSIP)*	**ASME Sect. XI** IWA-4000 **Weld Overlay** CC-N-504-2 *(Vendor Controlled)*	**ASME Sect. XI** IWB-2500-1 *(BWRVIP-74-A)* **IGSCC** Generic Letter 88-01 BWRVIP-75-A BWRVIP-222 **LC-Env Fatigue** NUREG-1801-X.M1 NUREG-6260 NUREG-6909	B-DM-03 B-DM-06 B-DM-09 B-DM-10 B-AS-07 B-AS-27 B-MT-02
1.3-17 Bottom Drain Nozzles	C&LAS *(Carbon Steel)*	C&W: FAC RiFP: Env Ext: Pitting	A, G	**Water Chemistry** BWRVIP-190 BWRVIP-225	**ASME Sect. XI** IWA-4000 **EPRI BWRVIP** BWRVIP-208	**ASME Sect. XI** IWB-2500-1 *(BWRVIP-74-A)*	B-DM-06 B-DM-07 B-I&E-07 B-RR-06

Table A-1 Reactor Pressure Vessel (Continued)

Components & ID No.	Material	Degradation Mechanisms	Conseq. of Failure	Mitigation	Repair / Replace	I & E Guidance	Gaps
1.4 CRD Housing and Stub Tube							
1.4-1 CRD Stub Tube	Ni-Alloy *(A600 with A82/ A182 welds)*	SCC: IG/TG Fat: LC-Env RiFP: Env Ext: Pitting	A, G	**Water Chemistry** BWRVIP-190 BWRVIP-225 **HWC Technology** BWRVIP-62 BWRVIP-156 BWRVIP-159 BWRVIP-219	**ASME Sect. XI** IWA-4000 CC-N-730 **EPRI BWRVIP** BWRVIP-55-A BWRVIP-58-A BWRVIP-146NP(R1)	**ASME Sect. XI** IWB-2500-1 *(BWRVIP-74-A & BWRVIP-47-A)* **LC-Env Fatigue** NUREG-1801-X.M1 NUREG-6260 NUREG-6909	B-DM-03 B-DM-06 B-DM-09 B-AS-07 B-AS-27 B-MT-04 B-MT-05
1.4-2 CRD Stub Tube	SS *(304 typ., furnace sensitized)*	SCC: IG/TG Fat: LC-Env RiFP: Env Ext: IG/TG Pitting	A, G	**Water Chemistry** BWRVIP-190 BWRVIP-225 **HWC Technology** BWRVIP-62 BWRVIP-156 BWRVIP-159 BWRVIP-219	**ASME Sect. XI** IWA-4000 CC-N-730 **EPRI BWRVIP** BWRVIP-55-A BWRVIP-58-A BWRVIP-146NP(R1)	**ASME Sect. XI** IWB-2500-1 *(BWRVIP-74-A & BWRVIP-47-A)* **LC-Env Fatigue** NUREG-1801-X.M1 NUREG-6260 NUREG-6909	B-DM-03 B-DM-06 B-DM-09 B-AS-07 B-AS-27 B-MT-02 B-MT-04 B-MT-05
1.4-3 CRD Housing Tube, Flange & Cap	SS *(304 typ., 304L, 316L)*	SCC: IG/TG RiFP: Env Ext: IG/TG Pitting	A, G	**Water Chemistry** BWRVIP-190 BWRVIP-225 **HWC Technology** BWRVIP-62 BWRVIP-156 BWRVIP-159 BWRVIP-219	**ASME Sect. XI** IWA-4000 CC-N-730 **EPRI BWRVIP** BWRVIP-55-A BWRVIP-58-A BWRVIP-146NP(R1)	**ASME Sect. XI** IWB-2500-1 *(BWRVIP-74-A & BWRVIP-47-A)*	B-DM-06 B-DM-09 B-MT-02 B-MT-04 B-MT-05

Table A-1 Reactor Pressure Vessel (Continued)

Components & ID No.	Material	Degradation Mechanisms	Conseq. of Failure	Mitigation	Repair / Replace	I & E Guidance	Gaps
1.4-4 CRD Housing Tube *(Straight-thru design-middle tube)*	Ni-Alloy *(A600 with A82/ A182 welds)*	SCC: IG/TG RiFP: Env Ext: Pitting	A, G	**Water Chemistry** BWRVIP-190 BWRVIP-225 **HWC Technology** BWRVIP-62 BWRVIP-156 BWRVIP-159 BWRVIP-219	**ASME Sect. XI** IWA-4000 CC-N-730 **EPRI BWRVIP** BWRVIP-55-A BWRVIP-58-A BWRVIP-146NP(R1)	**ASME Sect. XI** IWB-2500-1 *(BWRVIP-74-A & BWRVIP-47-A)* **LC-Env Fatigue** NUREG-1801-X.M1 NUREG-6260 NUREG-6909	B-DM-03 B-DM-06 B-DM-09 B-AS-27 B-MT-04 B-MT-05
1.4-5 CRD Housing Cap Screws and Nuts	C&LAS	SCC: IG/TG C&W: Pitting Fat: LC-Env	A, G	**Bolting Integrity** EPRI 1018959 EPRI NP-5769 NUREG-1339 NUREG-1801	**ASME Sect. XI** IWA-4000 **Vendor** GE SIL 483R2	**ASME Sect. XI** IWB-2500-1	None

Table A-1 Reactor Pressure Vessel (Continued)

Components & ID No.	Material	Degradation Mechanisms	Conseq. of Failure	Mitigation	Repair / Replace	I & E Guidance	Gaps
1.5 Core Plate ΔP/Standby Liquid Control (SLC) Penetration and Stub Tube							
1.5-1 SLC Housing	Ni-Alloy *(A600 with A82/ A182 welds)*	SCC: IG/TG RiFP: Env Ext: Pitting	A	**Water Chemistry** BWRVIP-190 BWRVIP-225 **HWC Technology** BWRVIP-62 BWRVIP-156 BWRVIP-159 BWRVIP-219	**ASME Sect. XI** IWA-4000 **EPRI BWRVIP** BWRVIP-53-A	**ASME Sect. XI** IWB-2500-1 *(BWRVIP-74-A & BWRVIP-27-A)*	B-DM-03 B-DM-06 B-DM-09 B-AS-27 B-MT-04 B-MT-05
1.5-2 SLC Housing	SS *(304)*	SCC: IG/TG RiFP: Env Ext: IG/TG Pitting	A	**Water Chemistry** BWRVIP-190 BWRVIP-225 **HWC Technology** BWRVIP-62 BWRVIP-156 BWRVIP-159 BWRVIP-219	**ASME Sect. XI** IWA-4000 **EPRI BWRVIP** BWRVIP-53-A	**ASME Sect. XI** IWB-2500-1 *(BWRVIP-74-A & BWRVIP-27-A)*	B-DM-03 B-DM-06 B-DM-09 B-AS-27 B-MT-02 B-MT-04 B-MT-05
1.5-3 SLC Nozzle *(Full Penetration Weld)* *(BWR/3-4 B&W, CB&I designs)*	C&LAS *(SA-508, Cl 2)*	SCC: IG/TG RiFP: Env Ext: Pitting	A	**Water Chemistry** BWRVIP-190 BWRVIP-225	**ASME Sect. XI** IWA-4000 **EPRI BWRVIP** BWRVIP-53-A	**ASME Sect. XI** IWB-2500-1 *(BWRVIP-74-A & BWRVIP-27-A)*	B-DM-06 B-DM-07

Table A-1 Reactor Pressure Vessel (Continued)

Components & ID No.	Material	Degradation Mechanisms	Conseq. of Failure	Mitigation	Repair / Replace	I & E Guidance	Gaps
1.5-4 SLC Housing / Nozzle Safe End	SS *(304)* Ni-Alloy (A82/A182 welds)	SCC: IG/TG RiFP: Env Ext: IG/TG Pitting	A	**Water Chemistry** BWRVIP-190 BWRVIP-225 **HWC Technology** BWRVIP-62 BWRVIP-156 BWRVIP-159 BWRVIP-219	**ASME Sect. XI** IWA-4000 **EPRI BWRVIP** BWRVIP-53-A	**ASME Sect. XI** IWB-2500-1 *(BWRVIP-74-A & BWRVIP-27-A)*	B-DM-03 B-DM-06 B-DM-09 B-AS-27 B-MT-02 B-MT-04 B-MT-05
1.5-5 SLC Stub Tube *(BWR/6 RDM Vessel Design Only)*	Ni-Alloy Weld *(A600 with A82/ A182 welds)*	SCC: IG/TG RiFP: Env Ext: Pitting	A	**Water Chemistry** BWRVIP-190 BWRVIP-225 **HWC Technology** BWRVIP-62 BWRVIP-156 BWRVIP-159 BWRVIP-219	**ASME Sect. XI** IWA-4000 **EPRI BWRVIP** BWRVIP-53-A	**ASME Sect. XI** IWB-2500-1 *(BWRVIP-74-A & BWRVIP-27-A)*	B-DM-03 B-DM-06 B-DM-09 B-AS-27 B-MT-04 B-MT-05

Table A-1 Reactor Pressure Vessel (Continued)

Components & ID No.	Material	Degradation Mechanisms	Conseq. of Failure	Mitigation	Repair / Replace	I & E Guidance	Gaps
1.6 In-Core Monitor Housing							
1.6-1 In-Core Housing & Flange	SS *(304 typ.)*	SCC: IG/TG RiFP: Env Ext: IG/TG Pitting	A	**Water Chemistry** BWRVIP-190 BWRVIP-225 **HWC Technology** BWRVIP-62 BWRVIP-156 BWRVIP-159 BWRVIP-219	**ASME Sect. XI** IWA-4000 CC-N-769 **EPRI BWRVIP** BWRVIP-17 BWRVIP-55-A BWRVIP-214NP	**ASME Sect. XI** IWB-2500-1 *(BWRVIP-74-A & BWRVIP-47-A)*	B-DM-06 B-DM-09
1.6-2 In-Core Housing & Flange	Ni-Alloy Weld *(A600 with A82/ A182 welds)*	SCC: IG/TG RiFP: Env Ext: Pitting	A	**Water Chemistry** BWRVIP-190 BWRVIP-225 **HWC Technology** BWRVIP-62 BWRVIP-156 BWRVIP-159 BWRVIP-219	**ASME Sect. XI** IWA-4000 CC-N-769 **EPRI BWRVIP** BWRVIP-17 BWRVIP-55-A BWRVIP-214NP	**ASME Sect. XI** IWB-2500-1 *(BWRVIP-74-A & BWRVIP-47-A)*	B-DM-03 B-DM-06 B-DM-09 B-AS-27 B-MT-04 B-MT-05

Table A-1 Reactor Pressure Vessel (Continued)

Components & ID No.	Material	Degradation Mechanisms	Conseq. of Failure	Mitigation	Repair / Replace	I & E Guidance	Gaps
1.7 Instrumentation Penetrations and Nozzles							
1.7-1 Instrument Penetrations *(Water Level and Jet Pump Sensing Lines)* *(Partial Penetration Welds)*	Ni-Alloy Weld *(A600 with A82/ A182 welds)*	SCC: IG/TG RiFP: Env Ext: Pitting	A	**Water Chemistry** BWRVIP-190 BWRVIP-225 **HWC Technology** BWRVIP-62 BWRVIP-156 BWRVIP-159 BWRVIP-219	**ASME Sect. XI** IWA-4000 **EPRI BWRVIP** BWRVIP-57-A	**ASME Sect. XI** IWB-2500-1 *(BWRVIP-74-A & BWRVIP-49-A)*	B-DM-03 B-DM-06 B-DM-09 B-AS-27 B-MT-01 B-MT-02 B-MT-04 B-MT-05
1.7-2 Instrument Penetrations *(Water Level and Jet Pump Sensing Lines)* *(Partial Penetration Welds)*	SS *(304, 308 / 309 welds)*	SCC: IG/TG RiFP: Env Ext: IG/TG Pitting	A	**Water Chemistry** BWRVIP-190 BWRVIP-225 **HWC Technology** BWRVIP-62 BWRVIP-156 BWRVIP-159 BWRVIP-219	**ASME Sect. XI** IWA-4000 **EPRI BWRVIP** BWRVIP-57-A	**ASME Sect. XI** IWB-2500-1 *(BWRVIP-74-A & BWRVIP-49-A)*	B-DM-06 B-DM-09 B-MT-01 B-MT-02
1.7-3 Instrument Penetrations *(Water Level and Jet Pump Sensing Lines)* *(Partial Penetration Welds)*	C&LAS *(SA-508, Cl 1, SA-541 Cl 1 Mod)*	SCC: IG/TG RiFP: Env IE: Emb Ext: Pitting	A	**Water Chemistry** BWRVIP-190 BWRVIP-225	**ASME Sect. XI** IWA-4000 **EPRI BWRVIP** BWRVIP-57-A	**ASME Sect. XI** IWB-2500-1 *(BWRVIP-74-A & BWRVIP-49-A)*	B-DM-06 B-DM-07 B-AS-05 B-AS-28

Table A-1 Reactor Pressure Vessel (Continued)

Components & ID No.	Material	Degradation Mechanisms	Conseq. of Failure	Mitigation	Repair / Replace	I & E Guidance	Gaps
1.8 Internal Attachments							
1.8-1 Jet Pump Riser Brace Pad Attachment *(BWR/3-6)*	SS *(300 Series)* Ni-Alloy *(A600 with A82/ A182 welds)*	SCC: IG/TG Fat: HC RiFP: Env	B, C	**Water Chemistry** BWRVIP-190 BWRVIP-225 **HWC Technology** BWRVIP-62 BWRVIP-156 BWRVIP-159 BWRVIP-219	**ASME Sect. XI** IWA-4000 **EPRI BWRVIP** BWRVIP-52-A	**ASME Sect. XI** IWB-2500-1 *(BWRVIP-74-A)* **EPRI BWRVIP** BWRVIP-48-A	B-DM-03 B-DM-06 B-DM-09 B-AS-27 B-MT-02
1.8-2 Core Spray Pipe Bracket Attachment *(BWR/3-6)*	SS *(300 Series)* Ni-Alloy *(A182 welds)*	SCC: IG/TG RiFP: Env	B, C	**Water Chemistry** BWRVIP-190 BWRVIP-225 *(Not mitigated by HWC / NMCA / OLNC)*	**ASME Sect. XI** IWA-4000 **EPRI BWRVIP** BWRVIP-52-A	**ASME Sect. XI** IWB-2500-1 *(BWRVIP-74-A)* **EPRI BWRVIP** BWRVIP-48-A	B-DM-03 B-DM-06 B-DM-09 B-AS-27 B-MT-01 B-MT-02
1.8-3 Shroud Support Pad	Ni-Alloy *(A82/A182 welds)*	SCC: IG/TG RiFP: Env	B, C, E	**Water Chemistry** BWRVIP-190 BWRVIP-225 **HWC Technology** BWRVIP-62 BWRVIP-156 BWRVIP-159 BWRVIP-219	**ASME Sect. XI** IWA-4000 **EPRI BWRVIP** BWRVIP-52-A	**ASME Sect. XI** IWB-2500-1 **EPRI BWRVIP** BWRVIP-38	B-DM-03 B-DM-06 B-DM-09 B-AS-27 B-MT-01 B-MT-02

Table A-1 Reactor Pressure Vessel (Continued)

Components & ID No.	Material	Degradation Mechanisms	Conseq. of Failure	Mitigation	Repair / Replace	I & E Guidance	Gaps
1.8-4 Steam Dryer Support Bracket	SS *(300 Series)* Ni-Alloy *(A182 welds)*	SCC: IG/TG C&W: Wear Fat: HC RiFP: Env	B, C	**Water Chemistry** BWRVIP-190 BWRVIP-225 *(Not mitigated by HWC / NMCA / OLNC)*	**ASME Sect. XI** IWA-4000 **EPRI BWRVIP** BWRVIP-52-A	**ASME Sect. XI** IWB-2500-1 *(BWRVIP-74-A)* **EPRI BWRVIP** BWRVIP-48-A	B-DM-03 B-DM-06 B-DM-09 B-AS-27 B-MT-02
1.8-5 Steam Dryer Hold-down Bracket	C&LAS *(LAS)*	SCC: IG/TG C&W: Wear Fat: HC RiFP: Env	B, C	**Water Chemistry** BWRVIP-190 BWRVIP-225	**ASME Sect. XI** IWA-4000 **EPRI BWRVIP** BWRVIP-52-A	**ASME Sect. XI** IWB-2500-1 *(BWRVIP-74-A & BWRVIP-48-A)*	B-DM-06 B-DM-07
1.8-6 Feedwater Sparger Support Bracket	SS *(300 Series)* Ni-Alloy *(A182 welds)*	SCC: IG/TG C&W: Wear Fat: HC RiFP: Env	B, C	**Water Chemistry** BWRVIP-190 BWRVIP-225 *(Not mitigated by HWC / NMCA / OLNC)*	**ASME Sect. XI** IWA-4000 **EPRI BWRVIP** BWRVIP-52-A	**ASME Sect. XI** IWB-2500-1 *(BWRVIP-74-A)* **EPRI BWRVIP** BWRVIP-48-A	B-DM-03 B-DM-06 B-DM-09 B-AS-27 B-MT-01 B-MT-02
1.8-7 Surveillance Capsule Holder Bracket	SS *(300 Series)* Ni-Alloy *(A182 welds)*	SCC: IG/TG RiFP: Env	B, C	**Water Chemistry** BWRVIP-190 BWRVIP-225 **HWC Technology** BWRVIP-62 BWRVIP-156 BWRVIP-159 BWRVIP-219	**ASME Sect. XI** IWA-4000 **EPRI BWRVIP** BWRVIP-52-A	**ASME Sect. XI** IWB-2500-1 *(BWRVIP-74-A & BWRVIP-48-A)*	B-DM-03 B-DM-06 B-DM-09 B-AS-27 B-MT-02

Table A-1 Reactor Pressure Vessel (Continued)

Components & ID No.	Material	Degradation Mechanisms	Conseq. of Failure	Mitigation	Repair / Replace	I & E Guidance	Gaps
1.8-8 Guide Rod Bracket	SS *(300 Series)* Ni-Alloy *(A182 welds)*	SCC: IG/TG RiFP: Env	B, C	**Water Chemistry** BWRVIP-190 BWRVIP-225 *(Not mitigated by HWC / NMCA / OLNC)*	**ASME Sect. XI** IWA-4000 **EPRI BWRVIP** BWRVIP-52-A	**ASME Sect. XI** IWB-2500-1 *(BWRVIP-74-A & BWRVIP-48-A)*	B-DM-03 B-DM-06 B-DM-09 B-AS-27 B-MT-01 B-MT-02

Table A-1 Reactor Pressure Vessel (Continued)

Components & ID No.	Material	Degradation Mechanisms	Conseq. of Failure	Mitigation	Repair / Replace	I & E Guidance	Gaps
1.9 Vessel Support Skirt Assembly							
1.9-1 Support Skirt *(Skirt Forging, Cylinder, Flange)*	C&LAS *(A-302, Gr B or SA-533, Gr B, Cl 1)*	Ext: Pitting	B	**None**	**ASME Sect. XI** IWA-4000	**ASME Sect. XI** IWB-2500-1	None

Table A-1 Reactor Pressure Vessel (Continued)

Components & ID No.	Material	Degradation Mechanisms	Conseq. of Failure	Mitigation	Repair / Replace	I & E Guidance	Gaps
1.10 RPV External Attachments							
1.10-1 Stabilizer Bracket	C&LAS	Ext: Pitting	B	**None**	**ASME Sect. XI** IWA-4000	**ASME Sect. XI** IWB-2500-1	None
1.10-2 Top Head Lifting Lugs	C&LAS	Ext: Pitting	B	**None**	**ASME Sect. XI** IWA-4000	**ASME Sect. XI** IWB-2500-1	None
1.10-3 Insulation Brackets	C&LAS	Ext: Pitting	None	N/A	**ASME Sect. XI** IWA-4000	**ASME Sect. XI** IWB-2500-1	B-AS-20 B-MT-05

1.[Degradation of cladding is only significant as related to potential crack propagation into the LAS base metal. Clad degradation may be possibly influenced by neutron effects.]

Table A-2 Reactor Vessel Internals

Components & ID No.	Material	Degradation Mechanisms	Conseq. of Failure	Mitigation	Repair / Replace	I & E Guidance	Gaps
2.1 Control Rod Guide Tube Assembly							
2.1-1 Control Rod Guide Tube Assembly *(Sleeve, Base, Alignment Lugs)*	SS *(304, 316L)*	SCC: IG/TG RiFP: Env	B, F	**Water Chemistry** BWRVIP-190 BWRVIP-225 **HWC Technology** BWRVIP-62 BWRVIP-156 BWRVIP-159 BWRVIP-219	**EPRI BWRVIP** BWRVIP-55-A BWRVIP-84	**EPRI BWRVIP** BWRVIP-47-A	B-DM-06 B-DM-09 B-AS-31 B-MT-02 B-MT-04 B-RG-05
2.1-2 Control Rod Guide Tube Assembly *(Cast Body)*	CASS *(CF3 / CF8)*	SCC: IG/TG RiFP: Env IE: Emb	B, F	**None**	**EPRI BWRVIP** BWRVIP-55-A BWRVIP-84	**EPRI BWRVIP** BWRVIP-47-A No Inspection Required	B-DM-06 B-DM-09 B-AS-31 B-MT-05
2.1-3 Guide Tube & Fuel Support Alignment Pin	SS *(304 typ.)*	SCC: IG/TG RiFP: Env	B, F	**Water Chemistry** BWRVIP-190 BWRVIP-225 **HWC Technology** BWRVIP-62 BWRVIP-156 BWRVIP-159 BWRVIP-219	**EPRI BWRVIP** BWRVIP-55-A BWRVIP-84	**EPRI BWRVIP** BWRVIP-47-A	B-DM-06 B-DM-09 B-AS-31 B-MT-02 B-MT-04

Table A-2 Reactor Vessel Internals (Continued)

Components & ID No.	Material	Degradation Mechanisms	Conseq. of Failure	Mitigation	Repair / Replace	I & E Guidance	Gaps
2.2 SLC / Core Plate ΔP Piping Assembly							
2.2-1 SLC / Core Plate ΔP Piping, Fittings, Tee, Support Brackets inside Vessel	SS *(304 typ.)*	SCC: IG/TG Fat: LC-Env RiFP: Env	None	**Water Chemistry** BWRVIP-190 BWRVIP-225 **HWC Technology** BWRVIP-62 BWRVIP-156 BWRVIP-159 BWRVIP-219	**EPRI BWRVIP** BWRVIP-53-A BWRVIP-84	**EPRI BWRVIP** BWRVIP-27-A No Inspection Required	B-AS-20

Table A-2 Reactor Vessel Internals (Continued)

Components & ID No.	Material	Degradation Mechanisms	Conseq. of Failure	Mitigation	Repair / Replace	I & E Guidance	Gaps
2.3 Core Plate							
2.3-1 Core Plate Welded Assy *(Plate, Rim, Stiffener Beams, Stabilizer Beams, Aligner Pins, Peripheral Fuel Support)*	SS *(304, 304L)*	SCC: IG/TG, IA Fat: LC-Env RiFP: Env IE: Emb	None	**Water Chemistry** BWRVIP-190 BWRVIP-225 **HWC Technology** BWRVIP-62 BWRVIP-156 BWRVIP-159 BWRVIP-219	**EPRI BWRVIP** BWRVIP-55-A BWRVIP-84	**EPRI BWRVIP** BWRVIP-25 No Inspection Required	B-AS-20
2.3-2 Rim Hold-Down Bolts	SS *(304)*	SCC: IG/TG, IA Fat: LC-Env RiFP: Env IE: Emb, SR	F	**Water Chemistry** BWRVIP-190 BWRVIP-225 **HWC Technology** BWRVIP-62 BWRVIP-156 BWRVIP-159 BWRVIP-219	**EPRI BWRVIP** BWRVIP-55-A BWRVIP-84	**EPRI BWRVIP** BWRVIP-25 *(No Inspection Required for Plants with Seismic Wedges)*	B-DM-06 B-DM-09 B-AS-11 B-AS-14 B-AS-15 B-AS-32 B-MT-02 B-MT-05 B-I&E-01 B-I&E-09 B-RG-05

Table A-2 Reactor Vessel Internals (Continued)

Components & ID No.	Material	Degradation Mechanisms	Conseq. of Failure	Mitigation	Repair / Replace	I & E Guidance	Gaps
2.3-3 Rim Hold-Down Bolts	SS *(XM-19)*	SCC: IG/TG, IA Fat: LC-Env RiFP: Env IE: Emb, SR	F	**Water Chemistry** BWRVIP-190 BWRVIP-225 **HWC Technology** BWRVIP-62 BWRVIP-156 BWRVIP-159 BWRVIP-219	**EPRI BWRVIP** BWRVIP-55-A BWRVIP-84	**EPRI BWRVIP** BWRVIP-25 *(No Inspection Required for Plants with Seismic Wedges)*	B-DM-06 B-DM-09 B-AS-11 B-AS-14 B-AS-15 B-AS-19 B-AS-26 B-I&E-01 B-I&E-09 B-RG-05
2.3-4 Core Plate Wedge Retainers	SS	SCC: IG/TG RiFP: Env IE: Emb	F	**Water Chemistry** BWRVIP-190 BWRVIP-225 **HWC Technology** BWRVIP-62 BWRVIP-156 BWRVIP-159 BWRVIP-219	**EPRI BWRVIP** BWRVIP-55-A BWRVIP-84	**EPRI BWRVIP** BWRVIP-25 No Inspection Required	B-DM-06 B-DM-09 B-AS-11 B-AS-27 B-MT-02 B-MT-05
2.3-5 Core Plate Wedge Retainers *(Replacement Design)*	Ni-Alloy *(X-750)*	SCC: IG/TG, IA RiFP: Env IE: Emb	F	**Water Chemistry** BWRVIP-190 BWRVIP-225 **HWC Technology** BWRVIP-62 BWRVIP-156 BWRVIP-159 BWRVIP-219	**EPRI BWRVIP** BWRVIP-55-A BWRVIP-84	**EPRI BWRVIP** BWRVIP-25 No Inspection Required	B-DM-03 B-DM-06 B-DM-09 B-AS-11 B-AS-26 B-RR-05

Table A-2 Reactor Vessel Internals (Continued)

Components & ID No.	Material	Degradation Mechanisms	Conseq. of Failure	Mitigation	Repair / Replace	I & E Guidance	Gaps
2.3-6 Core Plate Plugs	SS	SCC: IG/TG, IA RiFP: Env IE: Emb	None	**Water Chemistry** BWRVIP-190 BWRVIP-225 **HWC Technology** BWRVIP-62 BWRVIP-156 BWRVIP-159 BWRVIP-219	**EPRI BWRVIP** Letter 99-056 *(Re-evaluate Plug Life)* Replace	**EPRI BWRVIP** BWRVIP-25 No Inspection Required	B-AS-20

Table A-2 Reactor Vessel Internals (Continued)

Components & ID No.	Material	Degradation Mechanisms	Conseq. of Failure	Mitigation	Repair / Replace	I & E Guidance	Gaps
2.4 Core Spray Assembly							
2.4-1 Nozzle Thermal Sleeve	SS *(304, 304L, 316L)*	SCC: IG/TG Fat: LC-Env RiFP: Env	E	**Water Chemistry** BWRVIP-190 BWRVIP-225 *(Not mitigated by HWC / NMCA / OLNC)*	**EPRI BWRVIP** BWRVIP-16-A BWRVIP-19-A BWRVIP-84	**EPRI BWRVIP** BWRVIP-18R1	B-DM-03 B-DM-06 B-DM-09 B-AS-10 B-AS-14 B-AS-17 B-AS-27 B-MT-01 B-MT-02 B-I&E-02
2.4-2 Nozzle Thermal Sleeve	Ni-Alloy *(A600 with A82/ A182 welds)*	SCC: IG/TG Fat: LC-Env RiFP: Env	E	**Water Chemistry** BWRVIP-190 BWRVIP-225 *(Not mitigated by HWC / NMCA / OLNC)*	**EPRI BWRVIP** BWRVIP-16-A BWRVIP-19-A BWRVIP-84	**EPRI BWRVIP** BWRVIP-18R1	B-DM-03 B-DM-06 B-DM-09 B-AS-14 B-AS-17 B-AS-27 B-MT-01 B-MT-02 B-I&E-02

Table A-2 Reactor Vessel Internals (Continued)

Components & ID No.	Material	Degradation Mechanisms	Conseq. of Failure	Mitigation	Repair / Replace	I & E Guidance	Gaps
2.4-3 Piping Assembly *(Junction Boxes, Piping, Elbows, Sleeves, Couplings, Tee Boxes, Flanges, Fasteners)*	SS *(304, 304L, 316L)*	SCC: IG/TG RiFP: Env IE: SR	E	**Water Chemistry** BWRVIP-190 BWRVIP-225 *(Not mitigated by HWC / NMCA / OLNC)*	**EPRI BWRVIP** BWRVIP-16-A BWRVIP-19-A BWRVIP-34-A BWRVIP-84	**EPRI BWRVIP** BWRVIP-18R1	B-DM-06 B-DM-09 B-AS-10 B-AS-17 B-AS-19 B-MT-01 B-MT-02 B-I&E-02 B-I&E-09 B-RG-05
2.4-4 Sparger Assembly *(Piping, Fittings, Drains)*	SS *(304, 304L, 316L)*	SCC: IG/TG RiFP: Env	E	**Water Chemistry** BWRVIP-190 BWRVIP-225 *(Not mitigated by HWC / NMCA / OLNC)*	**EPRI BWRVIP** BWRVIP-16-A BWRVIP-19-A BWRVIP-34-A BWRVIP-84	**EPRI BWRVIP** BWRVIP-18R1	B-DM-06 B-DM-09 B-AS-10 B-MT-01 B-MT-02 B-RG-05

Table A-2 Reactor Vessel Internals (Continued)

Components & ID No.	Material	Degradation Mechanisms	Conseq. of Failure	Mitigation	Repair / Replace	I & E Guidance	Gaps
2.5 Jet Pump Assembly							
2.5-1 Riser Brace	SS *(304, 304L, 316L)*	SCC: IG/TG Fat: HC RiFP: Env	B	**Water Chemistry** BWRVIP-190 BWRVIP-225 **HWC Technology** BWRVIP-62 BWRVIP-156 BWRVIP-159 BWRVIP-219	**EPRI BWRVIP** BWRVIP-51-A BWRVIP-84	**EPRI BWRVIP** BWRVIP-41R2 *2009-202 - Interim Guidance*	B-DM-06 B-DM-09 B-AS-10 B-AS-15 B-AS-18 B-MT-01 B-MT-02 B-RG-05
2.5-2 Hold-down Beam	Ni-Alloy *(X-750)*	SCC: IG/TG, IA Fat: HC RiFP: Env IE: Emb	B, G	**Water Chemistry** BWRVIP-190 BWRVIP-225 **HWC Technology** BWRVIP-62 BWRVIP-156 BWRVIP-159 BWRVIP-219	**EPRI BWRVIP** BWRVIP-51-A BWRVIP-84 BWRVIP-207 BWRVIP-210	**EPRI BWRVIP** BWRVIP-41R2 BWRVIP-138R1	B-DM-03 B-DM-06 B-DM-09 B-AS-11 B-AS-15 B-AS-18 B-AS-26 B-AS-27 B-RR-05 B-RG-05
2.5-3 Hold-down Bolt Assembly *(Bolt, Keeper, Lock Plate, Saddle, Trunions, Screws)*	SS *(304, 316L)*	SCC: IG/TG Fat: HC, LC-Env RiFP: Env IE: SR	B, G	**Water Chemistry** BWRVIP-190 BWRVIP-225 **HWC Technology** BWRVIP-62 BWRVIP-156 BWRVIP-159 BWRVIP-219	**EPRI BWRVIP** BWRVIP-51-A BWRVIP-84 BWRVIP-207 BWRVIP-210	**EPRI BWRVIP** BWRVIP-41R2 No Inspection Required	B-DM-06 B-DM-09 B-AS-10 B-AS-15 B-AS-18 B-AS-19 B-MT-02 B-I&E-09

Table A-2 Reactor Vessel Internals (Continued)

Components & ID No.	Material	Degradation Mechanisms	Conseq. of Failure	Mitigation	Repair / Replace	I & E Guidance	Gaps
2.5-4 Nozzle Thermal Sleeve	SS *(304, 316L, 316NG)*	SCC: IG/TG Fat: HC, LC-Env RiFP: Env	E, G	**Water Chemistry** BWRVIP-190 BWRVIP-225 **HWC Technology** BWRVIP-62 BWRVIP-156 BWRVIP-159 BWRVIP-219	**EPRI BWRVIP** BWRVIP-51-A BWRVIP-84 BWRVIP-207 BWRVIP-210	**EPRI BWRVIP** BWRVIP-41R2	B-DM-03 B-DM-06 B-DM-09 B-AS-10 B-AS-14 B-AS-15 B-AS-17 B-AS-18 B-AS-27 B-MT-01 B-MT-02 B-I&E-02
2.5-5 Riser Assembly *(Elbow, Pipe, Sleeve)* *(Sleeve applies to BWR/3 and VY only)*	SS *(304, 316L)*	SCC: IG/TG Fat: HC RiFP: Env	E, G	**Water Chemistry** BWRVIP-190 BWRVIP-225 **HWC Technology** BWRVIP-62 BWRVIP-156 BWRVIP-159 BWRVIP-219	**EPRI BWRVIP** BWRVIP-51-A BWRVIP-84 BWRVIP-207 BWRVIP-210	**EPRI BWRVIP** BWRVIP-41R2	B-DM-06 B-DM-09 B-AS-10 B-AS-15 B-AS-18 B-MT-02 B-RG-05

Table A-2 Reactor Vessel Internals (Continued)

Components & ID No.	Material	Degradation Mechanisms	Conseq. of Failure	Mitigation	Repair / Replace	I & E Guidance	Gaps
2.5-6 Transition Piece & Inlet (Elbow and Nozzle), and Mixer (Throat)	SS *(304)*	SCC: IG/TG Fat: HC RiFP: Env	E, G	**Water Chemistry** BWRVIP-190 BWRVIP-225 **HWC Technology** BWRVIP-62 BWRVIP-156 BWRVIP-159 BWRVIP-219	**EPRI BWRVIP** BWRVIP-51-A BWRVIP-84 BWRVIP-207 BWRVIP-210	**EPRI BWRVIP** BWRVIP-41R2	B-DM-06 B-DM-09 B-AS-10 B-AS-15 B-AS-18 B-MT-02 B-RG-05
2.5-7 Transition Piece & Inlet (Elbow and Nozzle), and Mixer (Throat)	CASS *(CF8)*	SCC: IG/TG Fat: HC RiFP: Env	E, G	**Water Chemistry** BWRVIP-190 BWRVIP-225 **HWC Technology** BWRVIP-62 BWRVIP-156 BWRVIP-159 BWRVIP-219	**Not Required** *(CASS components not likely to fail)*	**EPRI BWRVIP** BWRVIP-41R2 No Inspection Required	B-DM-06 B-DM-09 B-AS-15 B-AS-18
2.5-8 Restrainer Bracket, Wedge Assembly, and Adjusting Screws	SS *(304)* *(Note: Stellite surfacing)*	SCC: IG/TG C&W: Wear Fat: HC RiFP: Env IE: SR	B	**Water Chemistry** BWRVIP-190 BWRVIP-225 **HWC Technology** BWRVIP-62 BWRVIP-156 BWRVIP-159 BWRVIP-219	**EPRI BWRVIP** BWRVIP-51-A BWRVIP-84 BWRVIP-207 BWRVIP-210	**EPRI BWRVIP** BWRVIP-41R2 *2009-202 - Interim Guidance*	B-DM-06 B-DM-09 B-AS-10 B-AS-15 B-AS-18 B-AS-19 B-MT-02 B-I&E-09

Table A-2 Reactor Vessel Internals (Continued)

Components & ID No.	Material	Degradation Mechanisms	Conseq. of Failure	Mitigation	Repair / Replace	I & E Guidance	Gaps
2.5-9 Restrainer Bracket *(BWR/4-6)*	CASS *(CF3)* *(Note: Stellite surfacing)*	SCC: IG/TG Fat: HC RiFP: Env	B	**Water Chemistry** BWRVIP-190 BWRVIP-225 **HWC Technology** BWRVIP-62 BWRVIP-156 BWRVIP-159 BWRVIP-219	**EPRI BWRVIP** BWRVIP-51-A BWRVIP-84 BWRVIP-207 BWRVIP-210	**EPRI BWRVIP** BWRVIP-41R2 No Inspection Required	B-DM-06 B-DM-09 B-AS-15 B-AS-18
2.5-10 Diffuser Collar	SS *(304)*	SCC: IG/TG Fat: HC RiFP: Env	E, G	**Water Chemistry** BWRVIP-190 BWRVIP-225 **HWC Technology** BWRVIP-62 BWRVIP-156 BWRVIP-159 BWRVIP-219	**EPRI BWRVIP** BWRVIP-51-A BWRVIP-84 BWRVIP-207 BWRVIP-210	**EPRI BWRVIP** BWRVIP-41R2	B-DM-09 B-AS-15 B-AS-18 B-MT-02
2.5-11 Diffuser Collar	CASS *(CF3)*	SCC: IG/TG Fat: HC RiFP: Env	E, G	**Water Chemistry** BWRVIP-190 BWRVIP-225 **HWC Technology** BWRVIP-62 BWRVIP-156 BWRVIP-159 BWRVIP-219	**EPRI BWRVIP** BWRVIP-51-A BWRVIP-84 BWRVIP-207 BWRVIP-210	**EPRI BWRVIP** BWRVIP-41R2 No Inspection Required	B-DM-06 B-DM-09 B-AS-15 B-AS-18

Table A-2 Reactor Vessel Internals (Continued)

Components & ID No.	Material	Degradation Mechanisms	Conseq. of Failure	Mitigation	Repair / Replace	I & E Guidance	Gaps
2.5-12 Diffuser Shell and Tailpipe	SS *(304, 304L)*	SCC: IG/TG Fat: HC RiFP: Env	E, G	**Water Chemistry** BWRVIP-190 BWRVIP-225 **HWC Technology** BWRVIP-62 BWRVIP-156 BWRVIP-159 BWRVIP-219	**EPRI BWRVIP** BWRVIP-51-A BWRVIP-84 BWRVIP-207 BWRVIP-210	**EPRI BWRVIP** BWRVIP-41R2	B-DM-06 B-DM-09 B-AS-10 B-AS-15 B-AS-17 B-AS-18 B-MT-02 B-I&E-02 B-RG-05
2.5-13 Diffuser Shell and Tailpipe *(BWR/6 only)*	CASS *(CF8)*	SCC: IG/TG Fat: HC RiFP: Env	E, G	**Water Chemistry** BWRVIP-190 BWRVIP-225 **HWC Technology** BWRVIP-62 BWRVIP-156 BWRVIP-159 BWRVIP-219	**EPRI BWRVIP** BWRVIP-51-A BWRVIP-84 BWRVIP-207 BWRVIP-210	**EPRI BWRVIP** BWRVIP-41R2 No Inspection Required	B-DM-06 B-DM-09 B-AS-15 B-AS-18
2.5-14 Lower Ring *(Alloy 600 Lower Ring applicable to LaSalle 2, NMP 2, WNP 2, and BWR/6s)*	Ni-Alloy *(A600)*	SCC: IG/TG Fat: HC RiFP: Env	E, G	**Water Chemistry** BWRVIP-190 BWRVIP-225 **HWC Technology** BWRVIP-62 BWRVIP-156 BWRVIP-159 BWRVIP-219	**EPRI BWRVIP** BWRVIP-51-A BWRVIP-84 BWRVIP-207 BWRVIP-210	**EPRI BWRVIP** BWRVIP-41R2	B-DM-03 B-DM-06 B-DM-09 B-AS-15 B-AS-18 B-AS-27 B-MT-02 B-RG-05

Table A-2 Reactor Vessel Internals (Continued)

Components & ID No.	Material	Degradation Mechanisms	Conseq. of Failure	Mitigation	Repair / Replace	I & E Guidance	Gaps
2.5-15 Adapter	SS *(300 Series)*	SCC: IG/TG Fat: HC RiFP: Env	B, E, G	**Water Chemistry** BWRVIP-190 BWRVIP-225 **HWC Technology** BWRVIP-62 BWRVIP-156 BWRVIP-159 BWRVIP-219	**EPRI BWRVIP** BWRVIP-51-A BWRVIP-84 BWRVIP-207 BWRVIP-210	**EPRI BWRVIP** BWRVIP-41R2	B-DM-03 B-DM-06 B-DM-09 B-AS-10 B-AS-15 B-AS-17 B-AS-18 B-AS-27 B-MT-02 B-I&E-02 B-RG-05
2.5-16 Adapter	Ni-Alloy *(A600)*	SCC: IG/TG Fat: HC RiFP: Th, Env	B, E, G	**Water Chemistry** BWRVIP-190 BWRVIP-225 **HWC Technology** BWRVIP-62 BWRVIP-156 BWRVIP-159 BWRVIP-219	**EPRI BWRVIP** BWRVIP-51-A BWRVIP-84 BWRVIP-207 BWRVIP-210	**EPRI BWRVIP** BWRVIP-41R2	B-DM-03 B-DM-06 B-DM-09 B-AS-15 B-AS-17 B-AS-18 B-AS-27 B-MT-02 B-I&E-02 B-RG-05

Table A-2 Reactor Vessel Internals (Continued)

Components & ID No.	Material	Degradation Mechanisms	Conseq. of Failure	Mitigation	Repair / Replace	I & E Guidance	Gaps
2.5-17 Jet Pump Sensing Lines *(Piping, Brackets, Couplings)*	SS *(304)*	SCC: IG/TG Fat: HC RiFP: Env	None	**Water Chemistry** BWRVIP-190 BWRVIP-225 **HWC Technology** BWRVIP-62 BWRVIP-156 BWRVIP-159 BWRVIP-219	**EPRI BWRVIP** BWRVIP-51-A BWRVIP-84 BWRVIP-207 BWRVIP-210	**EPRI BWRVIP** BWRVIP-41R2 No Inspection Required	B-AS-20

Table A-2 Reactor Vessel Internals (Continued)

Components & ID No.	Material	Degradation Mechanisms	Conseq. of Failure	Mitigation	Repair / Replace	I & E Guidance	Gaps
2.6 LPCI Coupling (BWR/4-6)							
2.6-1 Shroud Attachment Ring	SS *(304, 304L, 316L)* *(Note: Stellite surfacing)*	SCC: IG/TG, IA RiFP: Env IE: Emb	E	**Water Chemistry** BWRVIP-190 BWRVIP-225 *(Not mitigated by HWC / NMCA / OLNC)*	**EPRI BWRVIP** BWRVIP-56-A BWRVIP-84	**EPRI BWRVIP** BWRVIP-42-A	B-DM-06 B-DM-09 B-AS-09 B-AS-10 B-AS-11 B-MT-02 B-RG-05
2.6-2 Shroud Attachment Ring	CASS *(CF3)* *(Note: Stellite surfacing)*	SCC: IG/TG, IA RiFP: Env IE: Emb	E	None	**EPRI BWRVIP** BWRVIP-56-A BWRVIP-84	**EPRI BWRVIP** BWRVIP-42-A No Inspection Required	B-DM-06 B-DM-09 B-AS-11 B-AS-12
2.6-3 Thermal Shield Split Halves	SS *(304, 316L)*	SCC: IG/TG, IA Fat: LC-Env RiFP: Env IE: Emb	None	**Water Chemistry** BWRVIP-190 BWRVIP-225 *(Not mitigated by HWC / NMCA / OLNC)*	**EPRI BWRVIP** BWRVIP-56-A BWRVIP-84	**EPRI BWRVIP** BWRVIP-42-A No Inspection Required	B-AS-20

Table A-2 Reactor Vessel Internals (Continued)

Components & ID No.	Material	Degradation Mechanisms	Conseq. of Failure	Mitigation	Repair / Replace	I & E Guidance	Gaps
2.6-4 Shroud Strut and Elbow Support Pad *(BWR/6 only)*	SS *(304, 316L)*	SCC: IG/TG, IA RiFP: Env IE: Emb	B	**Water Chemistry** BWRVIP-190 BWRVIP-225 *(Not mitigated by HWC / NMCA / OLNC)*	**EPRI BWRVIP** BWRVIP-56-A BWRVIP-84	**EPRI BWRVIP** BWRVIP-42-A	B-DM-06 B-DM-09 B-AS-09 B-AS-10 B-AS-11 B-MT-01 B-MT-02 B-RR-02 B-RR-08 B-RG-05
2.6-5 Lifting Lugs	SS	SCC: IG/TG RiFP: Env	None	**Water Chemistry** BWRVIP-190 BWRVIP-225 *(Not mitigated by HWC / NMCA / OLNC)*	Not Required	**EPRI BWRVIP** BWRVIP-42-A No Inspection Required	B-AS-20
2.6-6 Clamp, Eye-Bolts, Nuts, and Pins *(BWR/4-5 only)*	SS *(304, 316L)*	SCC: IG/TG, IA Fat: LC-Env RiFP: Env IE: Emb, SR	B	**Water Chemistry** BWRVIP-190 BWRVIP-225 *(Not mitigated by HWC / NMCA / OLNC)*	**EPRI BWRVIP** BWRVIP-56-A BWRVIP-84	**EPRI BWRVIP** BWRVIP-42-A	B-DM-06 B-DM-09 B-AS-09 B-AS-10 B-AS-11 B-AS-19 B-MT-02 B-MT-05 B-I&E-09 B-RR-02 B-RR-08

Table A-2 Reactor Vessel Internals (Continued)

Components & ID No.	Material	Degradation Mechanisms	Conseq. of Failure	Mitigation	Repair / Replace	I & E Guidance	Gaps
2.6-7 Collars and Set Screws	CASS *(CF3, CF8)* *(Note: Stellite surfacing)*	SCC: IG/TG, IA RiFP: Env IE: Emb, SR	B	None	**EPRI BWRVIP** BWRVIP-56-A BWRVIP-84	**EPRI BWRVIP** BWRVIP-42-A No Inspection Required	B-DM-06 B-DM-09 B-AS-11 B-AS-12 B-AS-19 B-MT-05
2.6-8 Piston Ring Seal	Ni-Alloy *(X-750)* *(Note: Stellite surfacing)*	SCC: IG/TG, IA RiFP: Env IE: Emb	None	**Water Chemistry** BWRVIP-190 BWRVIP-225 *(Not mitigated by HWC / NMCA / OLNC)*	N/A	**EPRI BWRVIP** BWRVIP-42-A No Inspection Required	B-AS-20
2.6-9 Thermal Sleeve at RPV	SS *(304, 316L)*	SCC: IG/TG Fat: LC-Env RiFP: Env	E	**Water Chemistry** BWRVIP-190 BWRVIP-225 *(Not mitigated by HWC / NMCA / OLNC)*	**EPRI BWRVIP** BWRVIP-56-A BWRVIP-84	**EPRI BWRVIP** BWRVIP-42-A	B-DM-06 B-DM-09 B-AS-14 B-AS-17 B-MT-01 B-MT-02 B-I&E-02

Table A-2 Reactor Vessel Internals (Continued)

Components & ID No.	Material	Degradation Mechanisms	Conseq. of Failure	Mitigation	Repair / Replace	I & E Guidance	Gaps
2.6-10 Sleeve Flanges & Alignment Keys *(BWR/4-5)* Elbow Extensions *(BWR/6)*	SS *(304, 316L)* *(Note: Stellite surfacing)*	SCC: IG/TG, IA RiFP: Env IE: Emb	E	**Water Chemistry** BWRVIP-190 BWRVIP-225 *(Not mitigated by HWC / NMCA / OLNC)*	**EPRI BWRVIP** BWRVIP-56-A BWRVIP-84	**EPRI BWRVIP** BWRVIP-42-A	B-DM-06 B-DM-09 B-AS-09 B-AS-10 B-AS-11 B-AS-17 B-MT-01 B-MT-02 B-MT-05 B-RR-02 B-RR-08 B-RG-05
2.6-11 Sleeve Flanges & Alignment Keys *(BWR/4-5)* Elbow Extensions *(BWR/6)*	CASS *(CF3)* *(Note: Stellite surfacing)*	SCC: IG/TG, IA RiFP: Env IE: Emb	E	**Water Chemistry** BWRVIP-190 BWRVIP-225	**EPRI BWRVIP** BWRVIP-56-A BWRVIP-84	**EPRI BWRVIP** BWRVIP-42-A No Inspection Required	B-DM-06 B-DM-09 B-AS-11 B-AS-12 B-AS-17 B-MT-05
2.6-12 Sleeves *(BWR/4-5)* Coupling Sleeve *(BWR/6)*	CASS *(CF3, CF8)* *(Note: Stellite surfacing)*	SCC: IG/TG, IA RiFP: Env IE: Emb	E	**Water Chemistry** BWRVIP-190 BWRVIP-225	**EPRI BWRVIP** BWRVIP-56-A BWRVIP-84	**EPRI BWRVIP** BWRVIP-42-A No Inspection Required	B-DM-06 B-DM-09 B-AS-11 B-AS-12 B-MT-05

Table A-2 Reactor Vessel Internals (Continued)

Components & ID No.	Material	Degradation Mechanisms	Conseq. of Failure	Mitigation	Repair / Replace	I & E Guidance	Gaps
2.6-13 LPCI Baffle Assy *(BWR/4-5)* Flow Diverter *(BWR/6)*	SS *(304, 304L, XM-19)*	SCC: IG/TG, IA Fat: LC-Env RiFP: Env IE: Emb	None	**Water Chemistry** BWRVIP-190 BWRVIP-225 *(Not mitigated by HWC / NMCA / OLNC)*	**EPRI BWRVIP** BWRVIP-56-A BWRVIP-84	**EPRI BWRVIP** BWRVIP-42-A No Inspection Required	B-AS-20 B-AS-26 B-MT-05 B-RR-02 B-RR-08

Table A-2 Reactor Vessel Internals (Continued)

Components & ID No.	Material	Degradation Mechanisms	Conseq. of Failure	Mitigation	Repair / Replace	I & E Guidance	Gaps
2.7 Dry Tube & In-Core Support Hardware							
2.7-1 Dry Tubes	SS	SCC: IG/TG, IA Fat: HC RiFP: Env IE: Emb	None	**Water Chemistry** BWRVIP-190 BWRVIP-225 **HWC Technology** BWRVIP-62 BWRVIP-156 BWRVIP-159 BWRVIP-219	Replace	**EPRI BWRVIP** BWRVIP-47-A No Inspection Required	B-AS-20 B-MT-05
2.7-2 In-core Housing Support Hardware *(Tie Bars, Clamps, Bolts)*	SS *(304 typ.)*	SCC: IG/TG RiFP: Env	None	**Water Chemistry** BWRVIP-190 BWRVIP-225 **HWC Technology** BWRVIP-62 BWRVIP-156 BWRVIP-159 BWRVIP-219	**EPRI BWRVIP** BWRVIP-55-A BWRVIP-84	**EPRI BWRVIP** BWRVIP-47-A No Inspection Required	B-AS-20 B-MT-05
2.7-3 In-core Housing Support Hardware *(Tie Bars, Clamps, Bolts)*	Ni-Alloy *(A600)*	SCC: IG/TG RiFP: Env	None	**Water Chemistry** BWRVIP-190 BWRVIP-225 **HWC Technology** BWRVIP-62 BWRVIP-156 BWRVIP-159 BWRVIP-219	**EPRI BWRVIP** BWRVIP-55-A BWRVIP-84	**EPRI BWRVIP** BWRVIP-47-A No Inspection Required	B-AS-20

Table A-2 Reactor Vessel Internals (Continued)

Components & ID No.	Material	Degradation Mechanisms	Conseq. of Failure	Mitigation	Repair / Replace	I & E Guidance	Gaps
2.8 Orificed Fuel Support Assembly							
2.8-1 Fuel Support Casting	CASS *(CF3, CF8)*	SCC: IG/TG, IA RiFP: Env IE: Emb	F	**None**	**EPRI BWRVIP** BWRVIP-55-A BWRVIP-84	**EPRI BWRVIP** BWRVIP-47-A No Inspection Required	B-DM-06 B-DM-09 B-AS-11 B-AS-12 B-MT-05
2.8-2 Orifice Plate	SS *(304)*	SCC: IG/TG, IA RiFP: Env IE: Emb	None	**Water Chemistry** BWRVIP-190 BWRVIP-225 **HWC Technology** BWRVIP-62 BWRVIP-156 BWRVIP-159 BWRVIP-219	**EPRI BWRVIP** BWRVIP-55-A BWRVIP-84	**EPRI BWRVIP** BWRVIP-47-A No Inspection Required	B-AS-20

Table A-2 Reactor Vessel Internals (Continued)

Components & ID No.	Material	Degradation Mechanisms	Conseq. of Failure	Mitigation	Repair / Replace	I & E Guidance	Gaps
2.9 Shroud							
2.9-1 Shroud Cylinders *(Includes Welds H1-H7 and Shroud Vertical Welds)*	SS *(304, 304L)*	SCC: IG/TG, IA Fat: LC-Env RiFP: Env IE: Emb	B, E, F	**Water Chemistry** BWRVIP-190 BWRVIP-225 **HWC Technology** BWRVIP-62 BWRVIP-156 BWRVIP-159 BWRVIP-219 *(Some locations not mitigated by HWC / NMCA / OLNC)*	**EPRI BWRVIP** BWRVIP-02-A BWRVIP-84	**EPRI BWRVIP** BWRVIP-76-A BWRVIP-158 BWRVIP-200	B-DM-06 B-DM-09 B-AS-09 B-AS-10 B-AS-11 B-AS-14 B-MT-01 B-MT-02 B-MT-04 B-MT-05 B-I&E-03 B-RR-02 B-RR-08 B-RG-05

Table A-2 Reactor Vessel Internals (Continued)

Components & ID No.	Material	Degradation Mechanisms	Conseq. of Failure	Mitigation	Repair / Replace	I & E Guidance	Gaps
2.9-2 Shroud Rings	SS *(304, 304L)*	SCC: IG/TG, IA Fat: LC-Env RiFP: Env IE: Emb	B, E, F	**Water Chemistry** BWRVIP-190 BWRVIP-225 **HWC Technology** BWRVIP-62 BWRVIP-156 BWRVIP-159 BWRVIP-219 *(Some locations not mitigated by HWC / NMCA / OLNC)*	**EPRI BWRVIP** BWRVIP-02-A BWRVIP-84	**EPRI BWRVIP** BWRVIP-76-A BWRVIP-158	B-DM-06 B-DM-09 B-AS-09 B-AS-10 B-AS-11 B-AS-14 B-MT-01 B-MT-02 B-MT-04 B-MT-05 B-I&E-03 B-RR-02 B-RR-08 B-RG-05
2.9-3 Shroud Repair Assembly *(Hardware and Fasteners)*	SS *(316L)*	SCC: IG/TG, IA Fat: HC, LC-Env RiFP: Env IE: Emb, SR	B, F	**Water Chemistry** BWRVIP-190 BWRVIP-225 **HWC Technology** BWRVIP-62 BWRVIP-156 BWRVIP-159 BWRVIP-219	**EPRI BWRVIP** BWRVIP-02-A BWRVIP-84	**EPRI BWRVIP** BWRVIP-76-A BWRVIP-158	B-DM-06 B-DM-09 B-AS-09 B-AS-10 B-AS-11 B-AS-14 B-AS-15 B-AS-19 B-MT-01 B-MT-02 B-MT-04 B-MT-05 B-I&E-09

Table A-2 Reactor Vessel Internals (Continued)

Components & ID No.	Material	Degradation Mechanisms	Conseq. of Failure	Mitigation	Repair / Replace	I & E Guidance	Gaps
2.9-4 Shroud Repair Assembly *(Hardware and Fasteners)*	SS *(XM-19)*	SCC: IG/TG, IA Fat: HC, LC-Env RiFP: Env IE: Emb, SR	B, F	**Water Chemistry** BWRVIP-190 BWRVIP-225 **HWC Technology** BWRVIP-62 BWRVIP-156 BWRVIP-159 BWRVIP-219	**EPRI BWRVIP** BWRVIP-02-A BWRVIP-84	**EPRI BWRVIP** BWRVIP-76-A BWRVIP-158	B-DM-06 B-DM-09 B-AS-11 B-AS-14 B-AS-15 B-AS-19 B-AS-26 B-MT-05 B-I&E-09
2.9-5 Shroud Repair Assembly *(Hardware and Fasteners)*	Ni-Alloy *(X-750)*	SCC: IG/TG, IA Fat: HC, LC-Env RiFP: Env IE: Emb, SR	B, F	**Water Chemistry** BWRVIP-190 BWRVIP-225 **HWC Technology** BWRVIP-62 BWRVIP-156 BWRVIP-159 BWRVIP-219	**EPRI BWRVIP** BWRVIP-02-A BWRVIP-84	**EPRI BWRVIP** BWRVIP-76-A BWRVIP-158	B-DM-03 B-DM-06 B-DM-09 B-AS-11 B-AS-14 B-AS-15 B-AS-19 B-AS-26 B-AS-27 B-MT-01 B-MT-04 B-I&E-09 B-RR-05

Table A-2 Reactor Vessel Internals (Continued)

Components & ID No.	Material	Degradation Mechanisms	Conseq. of Failure	Mitigation	Repair / Replace	I & E Guidance	Gaps
2.10 Shroud Support Assembly - BWR/2 Skirt Type							
2.10-1 Support Ring	SS *(304)*	SCC: IG/TG Fat: LC-Env RiFP: Env	B, E, F	**Water Chemistry** BWRVIP-190 BWRVIP-225 **HWC Technology** BWRVIP-62 BWRVIP-156 BWRVIP-159 BWRVIP-219	**EPRI BWRVIP** BWRVIP-52-A BWRVIP-84	**EPRI BWRVIP** BWRVIP-38	B-DM-03 B-DM-06 B-DM-09 B-AS-10 B-AS-14 B-AS-27 B-MT-02 B-MT-04 B-MT-05 B-I&E-03 B-RG-05
2.10-2 Conical Support Plate	Ni-Alloy *(A600 with A82/ A182 welds)*	SCC: IG/TG Fat: Th, LC-Env RiFP: Env	B, E, F	**Water Chemistry** BWRVIP-190 BWRVIP-225 **HWC Technology** BWRVIP-62 BWRVIP-156 BWRVIP-159 BWRVIP-219	**EPRI BWRVIP** BWRVIP-52-A BWRVIP-84	**EPRI BWRVIP** BWRVIP-38	B-DM-03 B-DM-06 B-DM-09 B-AS-14 B-AS-27 B-MT-01 B-MT-02 B-MT-04

Table A-2 Reactor Vessel Internals (Continued)

Components & ID No.	Material	Degradation Mechanisms	Conseq. of Failure	Mitigation	Repair / Replace	I & E Guidance	Gaps
2.10-3 Lug / Clevis Pin Assembly *(Oyster Creek Only)*	SS	SCC: IG/TG RiFP: Env	None *(Assembly is redundant to H8 weld)*	**Water Chemistry** BWRVIP-190 BWRVIP-225 **HWC Technology** BWRVIP-62 BWRVIP-156 BWRVIP-159 BWRVIP-219	**EPRI BWRVIP** BWRVIP-52-A BWRVIP-84	**EPRI BWRVIP** BWRVIP-38 No Inspection Required	B-AS-20 B-RG-05
2.10-4 Baffle & Diffuser	SS	SCC: IG/TG RiFP: Env	None	**Water Chemistry** BWRVIP-190 BWRVIP-225 **HWC Technology** BWRVIP-62 BWRVIP-156 BWRVIP-159 BWRVIP-219	**EPRI BWRVIP** BWRVIP-52-A BWRVIP-84	**EPRI BWRVIP** BWRVIP-38 No Inspection Required	B-AS-20

Table A-2 Reactor Vessel Internals (Continued)

Components & ID No.	Material	Degradation Mechanisms	Conseq. of Failure	Mitigation	Repair / Replace	I & E Guidance	Gaps
2.11 Shroud Support Assembly - Pedestal Type							
2.11-1 Support Plate	Ni-Alloy *(A600 with A82/ A182 welds)*	SCC: IG/TG Fat: LC-Env RiFP: Env	B, E, F	**Water Chemistry** BWRVIP-190 BWRVIP-225 **HWC Technology** BWRVIP-62 BWRVIP-156 BWRVIP-159 BWRVIP-219	**EPRI BWRVIP** BWRVIP-52-A BWRVIP-84	**EPRI BWRVIP** BWRVIP-38	B-DM-03 B-DM-06 B-DM-09 B-AS-14 B-AS-27 B-MT-01 B-MT-02 B-MT-04 B-I&E-03 B-RG-05
2.11-2 Shroud Support Cylinder	Ni-Alloy *(A600 with A82/ A182 welds)*	SCC: IG/TG Fat: LC-Env RiFP: Env	B, E, F	**Water Chemistry** BWRVIP-190 BWRVIP-225 **HWC Technology** BWRVIP-62 BWRVIP-156 BWRVIP-159 BWRVIP-219	**EPRI BWRVIP** BWRVIP-52-A BWRVIP-84	**EPRI BWRVIP** BWRVIP-38	B-DM-03 B-DM-06 B-DM-09 B-AS-14 B-AS-27 B-MT-01 B-MT-02 B-MT-04 B-I&E-03 B-RG-05

Table A-2 Reactor Vessel Internals (Continued)

Components & ID No.	Material	Degradation Mechanisms	Conseq. of Failure	Mitigation	Repair / Replace	I & E Guidance	Gaps
2.11-3 Support Legs, Stubs, and Stiffeners	Ni-Alloy *(A600 with A82/ A182 welds)*	SCC: IG/TG Fat: LC-Env RiFP: Env	B, F	**Water Chemistry** BWRVIP-190 BWRVIP-225 **HWC Technology** BWRVIP-62 BWRVIP-156 BWRVIP-159 BWRVIP-219	**EPRI BWRVIP** BWRVIP-52-A BWRVIP-84	**EPRI BWRVIP** BWRVIP-38	B-DM-03 B-DM-06 B-DM-09 B-AS-14 B-AS-27 B-MT-01 B-MT-02 B-MT-04
2.11-4 Support Legs, Stubs, and Stiffeners *(Columbia)*	C&LAS SS Clad	SCC: IG/TG Fat: LC-Env RiFP: Env	B, F	**Water Chemistry** BWRVIP-190 BWRVIP-225 **HWC Technology** BWRVIP-62 BWRVIP-156 BWRVIP-159 BWRVIP-219	**EPRI BWRVIP** BWRVIP-52-A BWRVIP-84	**EPRI BWRVIP** BWRVIP-38	B-DM-06 B-AS-14

Table A-2 Reactor Vessel Internals (Continued)

Components & ID No.	Material	Degradation Mechanisms	Conseq. of Failure	Mitigation	Repair / Replace	I & E Guidance	Gaps
2.12 Shroud Support Assembly - Gusset Type							
2.12-1 Support Plate	Ni-Alloy *(A600 with A82/ A182 welds)*	SCC: IG/TG Fat: LC-Env RiFP: Env	B, E, F	**Water Chemistry** BWRVIP-190 BWRVIP-225 **HWC Technology** BWRVIP-62 BWRVIP-156 BWRVIP-159 BWRVIP-219	**EPRI BWRVIP** BWRVIP-52-A BWRVIP-84	**EPRI BWRVIP** BWRVIP-38	B-DM-03 B-DM-06 B-DM-09 B-AS-14 B-AS-27 B-MT-01 B-MT-02 B-MT-04 B-I&E-03 B-RG-05
2.12-2 Support Plate *(Hatch 2 only)*	C&LAS *(SA508)* Ni-Alloy Clad	SCC: IG/TG Fat: LC-Env RiFP: Env	B, E, F	**Water Chemistry** BWRVIP-190 BWRVIP-225 **HWC Technology** BWRVIP-62 BWRVIP-156 BWRVIP-159 BWRVIP-219	**EPRI BWRVIP** BWRVIP-52-A BWRVIP-84	**EPRI BWRVIP** BWRVIP-38	B-DM-06 B-AS-14 B-I&E-03 B-RG-05

Table A-2 Reactor Vessel Internals (Continued)

Components & ID No.	Material	Degradation Mechanisms	Conseq. of Failure	Mitigation	Repair / Replace	I & E Guidance	Gaps
2.12-3 Gussets	Ni-Alloy *(A600 with A82/ A182 welds)*	SCC: IG/TG Fat: LC-Env RiFP: Env	B, F	**Water Chemistry** BWRVIP-190 BWRVIP-225 **HWC Technology** BWRVIP-62 BWRVIP-156 BWRVIP-159 BWRVIP-219	**EPRI BWRVIP** BWRVIP-52-A BWRVIP-84	**EPRI BWRVIP** BWRVIP-38	B-DM-03 B-DM-06 B-DM-09 B-AS-14 B-AS-27 B-MT-01 B-MT-02 B-MT-04 B-MT-05
2.12-4 Shroud Support Cylinder	Ni-Alloy *(A600 with A82/ A182 welds)*	SCC: IG/TG Fat: LC-Env RiFP: Env	B, E, F	**Water Chemistry** BWRVIP-190 BWRVIP-225 **HWC Technology** BWRVIP-62 BWRVIP-156 BWRVIP-159 BWRVIP-219	**EPRI BWRVIP** BWRVIP-52-A BWRVIP-84	**EPRI BWRVIP** BWRVIP-38	B-DM-03 B-DM-06 B-AS-14 B-AS-27 B-MT-01 B-MT-02 B-MT-04 B-MT-05 B-I&E-03 B-RG-05

Table A-2 Reactor Vessel Internals (Continued)

Components & ID No.	Material	Degradation Mechanisms	Conseq. of Failure	Mitigation	Repair / Replace	I & E Guidance	Gaps
2.13 Shroud Support Access Hole Cover (BWR/3-6)							
2.13-1 Cover Plate, Ledge, Top Hat Ring	Ni-Alloy *(A600 with A82/ A182 welds)*	SCC: IG/TG RiFP: Env	E	**Water Chemistry** BWRVIP-190 BWRVIP-225 **HWC Technology** BWRVIP-62 BWRVIP-156 BWRVIP-159 BWRVIP-219	Replace with Mechanical Design	**EPRI BWRVIP** BWRVIP-180	B-DM-03 B-DM-06 B-DM-09 B-AS-27 B-MT-01 B-MT-02 B-MT-04
2.13-2 Cover Plate, Ledge, Top Hat Ring *(BWR/6)*	SS *(316L)*	SCC: IG/TG RiFP: Env	E	**Water Chemistry** BWRVIP-190 BWRVIP-225 **HWC Technology** BWRVIP-62 BWRVIP-156 BWRVIP-159 BWRVIP-219	Replace with Mechanical Design	**EPRI BWRVIP** BWRVIP-180	B-DM-03 B-DM-06 B-DM-09 B-AS-10 B-AS-27 B-MT-01 B-MT-02 B-MT-04
2.13-3 Replacement Access Hole Cover Components *(Bolting, Retainers, Beams)*	SS *(XM-19)*	SCC: IG/TG Fat: HC, LC-Env RiFP: Env IE: SR	E	**Water Chemistry** BWRVIP-190 BWRVIP-225 **HWC Technology** BWRVIP-62 BWRVIP-156 BWRVIP-159 BWRVIP-219	Replace	**EPRI BWRVIP** BWRVIP-180	B-DM-06 B-DM-09 B-AS-14 B-AS-15 B-AS-19 B-AS-26 B-I&E-09

Table A-2 Reactor Vessel Internals (Continued)

Components & ID No.	Material	Degradation Mechanisms	Conseq. of Failure	Mitigation	Repair / Replace	I & E Guidance	Gaps
2.13-4 Replacement Access Hole Cover Components *(Bolting, Retainers, Beams)*	Ni-Alloy *(X-750)*	SCC: IG/TG Fat: HC, LC-Env RiFP: Env IE: SR	E	**Water Chemistry** BWRVIP-190 BWRVIP-225 **HWC Technology** BWRVIP-62 BWRVIP-156 BWRVIP-159 BWRVIP-219	Replace	**EPRI BWRVIP** BWRVIP-180	B-DM-03 B-DM-06 B-DM-09 B-AS-14 B-AS-15 B-AS-19 B-AS-26 B-MT-04 B-I&E-09 B-RR-05

Table A-2 Reactor Vessel Internals (Continued)

Components & ID No.	Material	Degradation Mechanisms	Conseq. of Failure	Mitigation	Repair / Replace	I & E Guidance	Gaps
2.14 Top Guide/Grid Assembly							
2.14-1 Top Guide Structure Assembly *(Cover Plate, Bottom Plate, Grid Beams, Rim, Reinforcement Blocks, Pins)*	SS *(304, 304L)*	SCC: IG/TG, IA Fat: LC-Env RiFP: Env IE: Emb	F	**Water Chemistry** BWRVIP-190 BWRVIP-225 **HWC Technology** BWRVIP-62 BWRVIP-156 BWRVIP-159 BWRVIP-219	**EPRI BWRVIP** BWRVIP-50-A BWRVIP-84 *(Install Wedge Restraints)*	**EPRI BWRVIP** BWRVIP-26-A BWRVIP-183	B-DM-06 B-DM-09 B-AS-09 B-AS-10 B-AS-11 B-AS-14 B-MT-01 B-MT-02 B-RR-02 B-RR-08 B-RG-05
2.14-2 Aligner Pins and Socket in Top Guide and Shroud	SS *(304, 304L)*	SCC: IG/TG, IA Fat: LC-Env RiFP: Env IE: Emb	F	**Water Chemistry** BWRVIP-190 BWRVIP-225 **HWC Technology** BWRVIP-62 BWRVIP-156 BWRVIP-159 BWRVIP-219	**EPRI BWRVIP** BWRVIP-50-A BWRVIP-84 *(Install Wedge Restraints)*	**EPRI BWRVIP** BWRVIP-26-A	B-DM-06 B-DM-09 B-AS-09 B-AS-10 B-AS-11 B-AS-14 B-MT-01 B-MT-02 B-RR-02 B-RR-08

Table A-2 Reactor Vessel Internals (Continued)

Components & ID No.	Material	Degradation Mechanisms	Conseq. of Failure	Mitigation	Repair / Replace	I & E Guidance	Gaps
2.14-3 Fuel Guard Welds and Bolting *(BWR/3-6)*	SS *(304, 304L)*	SCC: IG/TG, IA Fat: LC-Env RiFP: Env IE: Emb	None	**Water Chemistry** BWRVIP-190 BWRVIP-225 **HWC Technology** BWRVIP-62 BWRVIP-156 BWRVIP-159 BWRVIP-219	**EPRI BWRVIP** BWRVIP-50-A BWRVIP-84	**EPRI BWRVIP** BWRVIP-26-A No Inspection Required	B-AS-20 B-RR-02 B-RR-08
2.14-4 Top Guide Restraining Wedges or Blocks *(BWR/4, 5)*	SS *(304, 304L)*	SCC: IG/TG, IA RiFP: Env IE: Emb	None	**Water Chemistry** BWRVIP-190 BWRVIP-225 **HWC Technology** BWRVIP-62 BWRVIP-156 BWRVIP-159 BWRVIP-219	**EPRI BWRVIP** BWRVIP-50-A BWRVIP-84	**EPRI BWRVIP** BWRVIP-26-A No Inspection Required	B-AS-20
2.14-5 Lateral Support Bracket Assy.	SS *(304, 304L)*	SCC: IG/TG, IA Fat: LC-Env RiFP: Env IE: Emb	None	**Water Chemistry** BWRVIP-190 BWRVIP-225 **HWC Technology** BWRVIP-62 BWRVIP-156 BWRVIP-159 BWRVIP-219	**EPRI BWRVIP** BWRVIP-50-A BWRVIP-84	**EPRI BWRVIP** BWRVIP-26-A No Inspection Required	B-AS-20

Table A-2 Reactor Vessel Internals (Continued)

Components & ID No.	Material	Degradation Mechanisms	Conseq. of Failure	Mitigation	Repair / Replace	I & E Guidance	Gaps
2.14-6 Hold-down Assemblies *(Bolting, Locking Bolting, Brackets, Clamps, Keepers)*	SS *(304, 304L)*	SCC: IG/TG, IA Fat: LC-Env RiFP: Env IE: Emb, SR	F	**Water Chemistry** BWRVIP-190 BWRVIP-225 **HWC Technology** BWRVIP-62 BWRVIP-156 BWRVIP-159 BWRVIP-219	**EPRI BWRVIP** BWRVIP-50-A BWRVIP-84	**EPRI BWRVIP** BWRVIP-26-A	B-DM-06 B-DM-09 B-AS-09 B-AS-10 B-AS-11 B-AS-14 B-AS-19 B-MT-01 B-MT-02 B-I&E-09
2.14-7 Miscellaneous Attachments *(Bosses, Eye Bolts, Lifting Lugs)*	SS *(304, 304L)*	SCC: IG/TG, IA Fat: LC-Env RiFP: Env IE: Emb	None	**Water Chemistry** BWRVIP-190 BWRVIP-225 **HWC Technology** BWRVIP-62 BWRVIP-156 BWRVIP-159 BWRVIP-219	**EPRI BWRVIP** BWRVIP-50-A BWRVIP-84	**EPRI BWRVIP** BWRVIP-26-A No Inspection Required	B-AS-20

Table A-2 Reactor Vessel Internals (Continued)

Components & ID No.	Material	Degradation Mechanisms	Conseq. of Failure	Mitigation	Repair / Replace	I & E Guidance	Gaps
2.15 Steam Dryer Assembly							
2.15-1 Steam Dryer Welded Assembly *(Bank Hoods, Hood End Plates, End Skirt and Cover Plate, Outer Plenum End Partitions, Tie Bars, Drain Channels, Steam Dam)*	SS	SCC: IG/TG C&W: Wear Fat: HC RiFP: Env	D	**Water Chemistry** BWRVIP-190 BWRVIP-225 *(Not mitigated by HWC / NMCA / OLNC)* **Mechanical Loads** Strengthen Welds *(vendor controlled)* Modify Geometry to Reduce Acoustic Loads	**EPRI BWRVIP** BWRVIP-181	**EPRI BWRVIP** BWRVIP-139-A BWRVIP-182 BWRVIP-194	B-DM-06 B-DM-09 B-AS-15 B-AS-29
2.15-2 Steam Dryer Welded Assembly *(Bank Hoods, Hood End Plates, End Skirt and Cover Plate, Outer Plenum End Partitions, Tie Bars, Drain Channels, Steam Dam)*	CASS	SCC: IG/TG Fat: HC RiFP: Env	D	**Water Chemistry** BWRVIP-190 BWRVIP-225 *(Not mitigated by HWC / NMCA / OLNC)* **Mechanical Loads** Strengthen Welds *(vendor controlled)* Modify Geometry to Reduce Acoustic Loads	**EPRI BWRVIP** BWRVIP-181	**EPRI BWRVIP** BWRVIP-139-A BWRVIP-182 BWRVIP-194	B-DM-06 B-DM-09 B-AS-15 B-AS-29

Table A-2 Reactor Vessel Internals (Continued)

Components & ID No.	Material	Degradation Mechanisms	Conseq. of Failure	Mitigation	Repair / Replace	I & E Guidance	Gaps
2.15-3 Steam Dryer Interface Components *(Lifting Rods / Attachments, Guide Channels, Guide Rod Followers and Upper Support Ring)*	SS	SCC: IG/TG C&W: Wear Fat: HC RiFP: Env	D	**Water Chemistry** BWRVIP-190 BWRVIP-225 *(Not mitigated by HWC / NMCA / OLNC)* **Mechanical Loads** Strengthen Welds *(vendor controlled)* Modify Geometry to Reduce Acoustic Loads	**EPRI BWRVIP** BWRVIP-181	**EPRI BWRVIP** BWRVIP-139-A BWRVIP-182 BWRVIP-194	B-DM-06 B-DM-09 B-AS-15 B-AS-29

Table A-2 Reactor Vessel Internals (Continued)

Components & ID No.	Material	Degradation Mechanisms	Conseq. of Failure	Mitigation	Repair / Replace	I & E Guidance	Gaps
2.16 Shroud Head and Separators Assembly							
2.16-1 Shroud Head Assembly	SS	SCC: IG/TG Fat: HC RiFP: Env	None	**Water Chemistry** BWRVIP-190 BWRVIP-225 *(Not mitigated by HWC / NMCA / OLNC)*	None	**EPRI BWRVIP** BWRVIP-06-1-A No Inspection Required	B-AS-20
2.16-2 Shroud Head Bolts *(BWR/6)*	Ni-Alloy *(A600)*	SCC: IG/TG C&W: Wear Fat: HC, LC-Env RiFP: Env	None	**Water Chemistry** BWRVIP-190 BWRVIP-225 *(Not mitigated by HWC / NMCA / OLNC)*	None	**EPRI BWRVIP** BWRVIP-06-1-A No Inspection Required	B-AS-20

Table A-2 Reactor Vessel Internals (Continued)

Components & ID No.	Material	Degradation Mechanisms	Conseq. of Failure	Mitigation	Repair / Replace	I & E Guidance	Gaps
2.17 Feedwater Sparger Assembly							
2.17-1 Feedwater Sparger Assembly *(Thermal Sleeve, Spargers / Spray Nozzles, Piping, Pins and Nuts)*	SS *(304, 316L)*	SCC: IG/TG C&W: Wear Fat: HC RiFP: Env	None	**Water Chemistry** BWRVIP-190 BWRVIP-225 *(Not mitigated by HWC / NMCA / OLNC)*	None	**EPRI BWRVIP** BWRVIP-06-1-A No Inspection Required	B-AS-20
2.17-2 Support Bracket Attachments	**Addressed in RPV IMT - Item No. 1.8-6**						

Table A-2 Reactor Vessel Internals (Continued)

Components & ID No.	Material	Degradation Mechanisms	Conseq. of Failure	Mitigation	Repair / Replace	I & E Guidance	Gaps
2.18 Surveillance Capsule Holder Assembly							
2.18-1 Specimen Holder	SS	SCC: IG/TG RiFP: Env	None	**Water Chemistry** BWRVIP-190 BWRVIP-225 **HWC Technology** BWRVIP-62 BWRVIP-156 BWRVIP-159 BWRVIP-219	None	**EPRI BWRVIP** BWRVIP-06-1-A No Inspection Required	B-AS-20
2.18-2 Specimen Holder Support Bracket	**Addressed in RPV IMT - Item No. 1.8-7**						

Table A-2 Reactor Vessel Internals (Continued)

Components & ID No.	Material	Degradation Mechanisms	Conseq. of Failure	Mitigation	Repair / Replace	I & E Guidance	Gaps
2.19 Guide Rod (Non-Safety Related)							
2.19-1 Guide Rod	**Addressed in RPV IMT - Item No. 1.8-8**						

Table A-3 ASME Class 1 Piping, Fittings, and Valves

Components & ID No.	Material	Degradation Mechanisms	Conseq. of Failure	Mitigation	Repair / Replace	I & E Guidance	Gaps
3.1 Reactor Coolant Recirculation							
3.1-1 Recirculation Loop Piping and Fittings *(Piping ≥ NPS 4)*	SS *(304, 304L, 316, 316L, 316NG, 347, 347NG)*	SCC: IG/TG Fat: LC-Env RiFP: Env Ext: IG/TG Pitting	A, G	**Water Chemistry** BWRVIP-190 BWRVIP-225 **HWC Technology** BWRVIP-62 BWRVIP-156 BWRVIP-159 BWRVIP-219 **Stress Improvement** BWRVIP-61 *(Weld Overlay, IHSI, MSIP)*	**ASME Sect. XI** IWA-4000 **Weld Overlay** CC-N-504-2 *(Vendor Controlled)*	**ASME Sect. XI** IWB-2500-1 **RI-ISI** CC-N-716 Reg. Guide 1.200 NUREG-1855 EPRI 1018427 **IGSCC** Generic Letter 88-01 BWRVIP-75-A BWRVIP-222 **LC-Env Fatigue** NUREG-1801-X.M1 NUREG-6260 NUREG-6909	B-DM-06 B-DM-09 B-DM-10 B-AS-07 B-MT-01 B-I&E-05
3.1-2 Flow Nozzle	CASS *(CF3, CF3M, CF8, CF8M)*	SCC: IG/TG RiFP: Env Ext: Pitting	None	**None**	**ASME Sect. XI** IWA-4000 **Weld Overlay** CC-N-504-2 *(Vendor Controlled)*	None	B-AS-20

Table A-3 ASME Class 1 Piping, Fittings, and Valves (Continued)

Components & ID No.	Material	Degradation Mechanisms	Conseq. of Failure	Mitigation	Repair / Replace	I & E Guidance	Gaps
3.1-3 Branch Piping and Fittings *(Piping ≥ NPS 4)* *(RHR Suction and Discharge, RWCU)*	SS *(304, 304L, 316, 316L, 316NG, 347, 347NG)*	SCC: IG/TG Fat: HC, LC-Env RiFP: Env Ext: IG/TG Pitting	A, G	**Water Chemistry** BWRVIP-190 BWRVIP-225 **HWC Technology** BWRVIP-62 BWRVIP-156 BWRVIP-159 BWRVIP-219 **Thermal Fatigue** MRP-235R1 BWRVIP-155 **Stress Improvement** BWRVIP-61 *(Weld Overlay, IHSI, MSIP)*	**ASME Sect. XI** IWA-4000 **Weld Overlay** CC-N-504-2 *(Vendor Controlled)*	**ASME Sect. XI** IWB-2500-1 **RI-ISI** CC-N-716 Reg. Guide 1.200 NUREG-1855 EPRI 1018427 **IGSCC** Generic Letter 88-01 BWRVIP-75-A BWRVIP-222 **HC Thermal Fatigue** MRP-146 MRP-146S BWRVIP-155 BWRVIP-196 **LC-Env Fatigue** NUREG-1801-X.M1 NUREG-6260 NUREG-6909	B-DM-06 B-DM-09 B-DM-10 B-AS-07 B-AS-22 B-MT-01 B-MT-04 B-I&E-05

Table A-3 ASME Class 1 Piping, Fittings, and Valves (Continued)

Components & ID No.	Material	Degradation Mechanisms	Conseq. of Failure	Mitigation	Repair / Replace	I & E Guidance	Gaps
3.1-4 Small Bore Piping and Fittings *(Piping < NPS 4)* *(Includes Vents, Drains, Instrument Lines)*	SS *(304, 304L, 316, 316L, 316NG, 347, 347NG)*	SCC: IG/TG Fat: HC, LC-Env RiFP: Env Ext: IG/TG Pitting	A, G	**Water Chemistry** BWRVIP-190 BWRVIP-225 **HWC Technology** BWRVIP-62 BWRVIP-156 BWRVIP-159 BWRVIP-219 **Thermal Fatigue** MRP-235R1 BWRVIP-155 **Mech. Fatigue** MRP-235R1 EPRI 1007944 EPRI 1003689 *(Strengthen Welds / Modify Geometry)*	**ASME Sect. XI** IWA-4000	**ASME Sect. XI** IWB-2500-1 **RI-ISI** CC-N-716 Reg. Guide 1.200 NUREG-1855 EPRI 1018427 **IGSCC** NUREG-1801 XI.M35 **HC Thermal Fatigue** MRP-146 MRP-146S BWRVIP-155 BWRVIP-196 **LC-Env Fatigue** NUREG-1801-X.M1 NUREG-6260 NUREG-6909	B-DM-06 B-DM-09 B-MT-01 B-MT-04

Table A-3 ASME Class 1 Piping, Fittings, and Valves (Continued)

Components & ID No.	Material	Degradation Mechanisms	Conseq. of Failure	Mitigation	Repair / Replace	I & E Guidance	Gaps
3.1-5 Small Bore Piping and Fittings *(Piping < NPS 4)* *(Includes Vents, Drains, Instrument Lines)*	C&LAS *(Carbon Steel)*	C&W: FAC Fat: HC, LC-Env RiFP: Env Ext: Pitting	A, G	**Water Chemistry** BWRVIP-190 BWRVIP-225 **Thermal Fatigue** MRP-235R1 BWRVIP-155 **Mech. Fatigue** MRP-235R1 EPRI 1007944 EPRI 1003689 *(Strengthen Welds / Modify Geometry)*	**ASME Sect. XI** IWA-4000	**ASME Sect. XI** IWB-2500-1 **RI-ISI** CC-N-716 Reg. Guide 1.200 NUREG-1855 EPRI 1018427 **FAC Program** NSAC 202L **HC Thermal Fatigue** MRP-146 MRP-146S BWRVIP-155 BWRVIP-196 **LC-Env Fatigue** NUREG-1801-X.M1 NUREG-6260 NUREG-6909	B-DM-06
3.1-6 Valve Bodies	SS *(304, 304L, 316, 316L, 316NG, 347, 347NG)*	SCC: IG/TG RiFP: Env Ext: IG/TG Pitting	A, G	**Water Chemistry** BWRVIP-190 BWRVIP-225 **HWC Technology** BWRVIP-62 BWRVIP-156 BWRVIP-159 BWRVIP-219	**ASME Sect. XI** IWA-4000	**ASME Sect. XI** IWB-2500-1	B-DM-06 B-DM-09 B-I&E-05

Table A-3 ASME Class 1 Piping, Fittings, and Valves (Continued)

Components & ID No.	Material	Degradation Mechanisms	Conseq. of Failure	Mitigation	Repair / Replace	I & E Guidance	Gaps
3.1-7 Valve Bodies	CASS *(CF3, CF3M, CF8, CF8M)*	SCC: IG/TG RiFP: Env Ext: Pitting	A, G	**None**	**ASME Sect. XI** IWA-4000	**ASME Sect. XI** IWB-2500-1	B-DM-06 B-DM-09 B-I&E-05 B-I&E-06
3.1-8 Valve Bonnets	SS *(304, 304L, 316, 316L, 316NG, 347, 347NG)*	RiFP: Env Ext: IG/TG Pitting	A, G	**Water Chemistry** BWRVIP-190 BWRVIP-225 **HWC Technology** BWRVIP-62 BWRVIP-156 BWRVIP-159 BWRVIP-219	**ASME Sect. XI** IWA-4000	**ASME Sect. XI** IWB-2500-1	B-DM-06 B-DM-09
3.1-9 Flanges / Seals *(Clean-out Connections, ECP Autoclaves)*	SS *(304, 304L, 316, 316L, 316NG, 347, 347NG)*	SCC: IG/TG Fat: LC-Env RiFP: Env Ext: IG/TG Pitting	A, G	**Water Chemistry** BWRVIP-190 BWRVIP-225 **HWC Technology** BWRVIP-62 BWRVIP-156 BWRVIP-159 BWRVIP-219 **Bolting Integrity** EPRI 1018959 EPRI NP-5769 NUREG-1339 NUREG-1801	**ASME Sect. XI** IWA-4000	**ASME Sect. XI** IWB-2500-1	B-DM-06 B-DM-09

Table A-3 ASME Class 1 Piping, Fittings, and Valves (Continued)

Components & ID No.	Material	Degradation Mechanisms	Conseq. of Failure	Mitigation	Repair / Replace	I & E Guidance	Gaps
3.1-10 Thermowells	SS	SCC: IG/TG Fat: LC-Env RiFP: Env Ext: IG/TG Pitting	A	**Water Chemistry** BWRVIP-190 BWRVIP-225 **HWC Technology** BWRVIP-62 BWRVIP-156 BWRVIP-159 BWRVIP-219	**ASME Sect. XI** IWA-4000	**ASME Sect. XI** IWB-2500-1	B-DM-06 B-DM-09

Table A-3 ASME Class 1 Piping, Fittings, and Valves (Continued)

Components & ID No.	Material	Degradation Mechanisms	Conseq. of Failure	Mitigation	Repair / Replace	I & E Guidance	Gaps
3.2 Feedwater							
3.2-1 Feedwater Piping and Fittings & Branch Piping and Fittings *(HPCI & RCIC Supply, RWCU)* *(Piping ≥ NPS 4)*	C&LAS *(Carbon Steel)*	SCC: IG/TG C&W: FAC Fat: HC, LC-Env RiFP: Env Ext: Pitting	A	**Water Chemistry** BWRVIP-190 BWRVIP-225 **Thermal Fatigue** MRP-235R1 BWRVIP-155	**ASME Sect. XI** IWA-4000	**ASME Sect. XI** IWB-2500-1 **RI-ISI** CC-N-716 Reg. Guide 1.200 NUREG-1855 EPRI 1018427 **FAC Program** NSAC 202L **HC Thermal Fatigue** MRP-146 MRP-146S BWRVIP-155 BWRVIP-196 **LC-Env Fatigue** NUREG-1801-X.M1 NUREG-6260 NUREG-6909	B-DM-06 B-DM-07 B-I&E-05

Table A-3 ASME Class 1 Piping, Fittings, and Valves (Continued)

Components & ID No.	Material	Degradation Mechanisms	Conseq. of Failure	Mitigation	Repair / Replace	I & E Guidance	Gaps
3.2-2 Small Bore Piping and Fittings *(Piping < NPS 4)* *(Includes Vents, Drains, Instrument Lines)*	SS *(304, 304L, 316, 316L, 316NG, 347, 347NG)*	SCC: IG/TG Fat: HC, LC-Env RiFP: Env Ext: IG/TG Pitting	A	**Water Chemistry** BWRVIP-190 BWRVIP-225 **HWC Technology** BWRVIP-62 BWRVIP-156 BWRVIP-159 BWRVIP-219 **Thermal Fatigue** MRP-235R1 BWRVIP-155 **Mech. Fatigue** MRP-235R1 EPRI 1007944 EPRI 1003689 *(Strengthen Welds / Modify Geometry)*	**ASME Sect. XI** IWA-4000	**ASME Sect. XI** IWB-2500-1 **RI-ISI** CC-N-716 Reg. Guide 1.200 NUREG-1855 EPRI 1018427 **IGSCC** NUREG-1801 XI.M35 **HC Thermal Fatigue** MRP-146 MRP-146S BWRVIP-155 BWRVIP-196 **LC-Env Fatigue** NUREG-1801-X.M1 NUREG-6260 NUREG-6909	B-DM-06 B-DM-09

Table A-3 ASME Class 1 Piping, Fittings, and Valves (Continued)

Components & ID No.	Material	Degradation Mechanisms	Conseq. of Failure	Mitigation	Repair / Replace	I & E Guidance	Gaps
3.2-3 Small Bore Piping and Fittings *(Piping < NPS 4)* *(Includes Vents, Drains, Instrument Lines)*	C&LAS *(Carbon Steel)*	C&W: FAC Fat: HC, LC-Env RiFP: Env Ext: Pitting	A	**Water Chemistry** BWRVIP-190 BWRVIP-225 **Thermal Fatigue** MRP-235R1 BWRVIP-155 **Mech. Fatigue** MRP-235R1 EPRI 1007944 EPRI 1003689 *(Strengthen Welds / Modify Geometry)*	**ASME Sect. XI** IWA-4000	**ASME Sect. XI** IWB-2500-1 **RI-ISI** CC-N-716 Reg. Guide 1.200 NUREG-1855 EPRI 1018427 **FAC Program** NSAC 202L **HC Thermal Fatigue** MRP-146 MRP-146S BWRVIP-155 BWRVIP-196 **LC-Env Fatigue** NUREG-1801-X.M1 NUREG-6260 NUREG-6909	B-DM-06
3.2-4 Valve Bodies	C&LAS	RiFP: Env Ext: Pitting	A	**Water Chemistry** BWRVIP-190 BWRVIP-225	**ASME Sect. XI** IWA-4000	**ASME Sect. XI** IWB-2500-1	B-DM-06 B-I&E-05

Table A-3 ASME Class 1 Piping, Fittings, and Valves (Continued)

Components & ID No.	Material	Degradation Mechanisms	Conseq. of Failure	Mitigation	Repair / Replace	I & E Guidance	Gaps
3.2-5 Valve Bodies	SS *(304, 304L, 316, 316L, 316NG, 347, 347NG)*	SCC: IG/TG RiFP: Env Ext: IG/TG Pitting	A	**Water Chemistry** BWRVIP-190 BWRVIP-225 **HWC Technology** BWRVIP-62 BWRVIP-156 BWRVIP-159 BWRVIP-219	**ASME Sect. XI** IWA-4000	**ASME Sect. XI** IWB-2500-1	B-DM-06 B-DM-09 B-I&E-05
3.2-6 Valve Bonnets	C&LAS	RiFP: Env Ext: Pitting	A	**Water Chemistry** BWRVIP-190 BWRVIP-225	**ASME Sect. XI** IWA-4000	**ASME Sect. XI** IWB-2500-1	B-DM-06
3.2-7 Valve Bonnets	SS *(304, 304L, 316, 316L, 316NG, 347, 347NG)*	RiFP: Env Ext: IG/TG Pitting	A	**Water Chemistry** BWRVIP-190 BWRVIP-225 **HWC Technology** BWRVIP-62 BWRVIP-156 BWRVIP-159 BWRVIP-219	**ASME Sect. XI** IWA-4000	**ASME Sect. XI** IWB-2500-1	B-DM-06 B-DM-09
3.2-8 Flanges / Seals	C&LAS	Fat: LC-Env RiFP: Env Ext: Pitting	A	**Water Chemistry** BWRVIP-190 BWRVIP-225 **Bolting Integrity** EPRI 1018959 EPRI NP-5769 NUREG-1339 NUREG-1801	**ASME Sect. XI** IWA-4000	**ASME Sect. XI** IWB-2500-1	B-DM-06

Table A-3 ASME Class 1 Piping, Fittings, and Valves (Continued)

Components & ID No.	Material	Degradation Mechanisms	Conseq. of Failure	Mitigation	Repair / Replace	I & E Guidance	Gaps
3.3 Main Steam							
3.3-1 Main Steam Piping and Fittings & Branch Piping and Fittings *(HPCI & RCIC Steam Supply)* *(Piping ≥ NPS 4)*	C&LAS *(Carbon Steel)*	SCC: IG/TG Fat: HC, LC-Env RiFP: Env Ext: Pitting	A	**Water Chemistry** BWRVIP-190 BWRVIP-225	**ASME Sect. XI** IWA-4000	**ASME Sect. XI** IWB-2500-1 **FAC Program** NSAC 202L	B-DM-06 B-DM-07 B-I&E-05
3.3-2 Flow Restrictor	CASS *(CF3, CF3M, CF8, CF8M)*	SCC: IG/TG RiFP: Env Ext: Pitting	H	**Water Chemistry** BWRVIP-190 BWRVIP-225	None	None	B-DM-06 B-DM-09

Table A-3 ASME Class 1 Piping, Fittings, and Valves (Continued)

Components & ID No.	Material	Degradation Mechanisms	Conseq. of Failure	Mitigation	Repair / Replace	I & E Guidance	Gaps
3.3-3 Small Bore Piping and Fittings *(Piping < NPS 4)* *(Includes Vents, Drains, Instrument Lines)*	SS *(304, 304L, 316, 316L, 316NG, 347, 347NG)*	SCC: IG/TG Fat: HC, LC-Env RiFP: Env Ext: IG/TG Pitting	A	**Water Chemistry** BWRVIP-190 BWRVIP-225 *(Not mitigated by HWC / NMCA / OLNC)* **Mech. Fatigue** MRP-235R1 EPRI 1007944 EPRI 1003689 *(Strengthen Welds / Modify Geometry)*	**ASME Sect. XI** IWA-4000	**ASME Sect. XI** IWB-2500-1 **RI-ISI** CC-N-716 Reg. Guide 1.200 NUREG-1855 EPRI 1018427 **IGSCC** NUREG-1801 XI.M35 **HC Thermal Fatigue** MRP-146 MRP-146S BWRVIP-155 BWRVIP-196	B-DM-06 B-DM-09
3.3-4 Small Bore Piping and Fittings *(Piping < NPS 4)* *(Includes Vents, Drains, Instrument Lines)*	C&LAS *(Carbon Steel)*	Fat: HC, LC-Env RiFP: Env Ext: Pitting	A	**Water Chemistry** BWRVIP-190 BWRVIP-225 **Mech. Fatigue** MRP-235R1 EPRI 1007944 EPRI 1003689 *(Strengthen Welds / Modify Geometry)*	**ASME Sect. XI** IWA-4000	**ASME Sect. XI** IWB-2500-1 **FAC Program** NSAC 202L **HC Thermal Fatigue** MRP-146 MRP-146S BWRVIP-155 BWRVIP-196	B-DM-06
3.3-5 Valve Bodies *(Includes MSIVs, SRVs)*	C&LAS	RiFP: Env Ext: Pitting	A	**Water Chemistry** BWRVIP-190 BWRVIP-225	**ASME Sect. XI** IWA-4000	**ASME Sect. XI** IWB-2500-1	B-DM-06 B-I&E-05

Table A-3 ASME Class 1 Piping, Fittings, and Valves (Continued)

Components & ID No.	Material	Degradation Mechanisms	Conseq. of Failure	Mitigation	Repair / Replace	I & E Guidance	Gaps
3.3-6 Valve Bodies *(Includes MSIVs, SRVs)*	SS *(304, 304L, 316, 316L, 316NG, 347, 347NG)*	SCC: IG/TG RiFP: Env Ext: IG/TG Pitting	A	**Water Chemistry** BWRVIP-190 BWRVIP-225 *(Not mitigated by HWC / NMCA / OLNC)*	**ASME Sect. XI** IWA-4000	**ASME Sect. XI** IWB-2500-1	B-DM-06 B-DM-09 B-I&E-05
3.3-7 Valve Bonnets	C&LAS	RiFP: Env Ext: Pitting	A	**Water Chemistry** BWRVIP-190 BWRVIP-225	**ASME Sect. XI** IWA-4000	**ASME Sect. XI** IWB-2500-1	B-DM-06
3.3-8 Valve Bonnets	SS *(304, 304L, 316, 316L, 316NG, 347, 347NG)*	RiFP: Env Ext: IG/TG Pitting	A	**Water Chemistry** BWRVIP-190 BWRVIP-225 *(Not mitigated by HWC / NMCA / OLNC)*	**ASME Sect. XI** IWA-4000	**ASME Sect. XI** IWB-2500-1	B-DM-06 B-DM-09
3.3-9 Flanges / Seals	C&LAS	Fat: LC-Env RiFP: Env Ext: Pitting	A	**Water Chemistry** BWRVIP-190 BWRVIP-225 **Bolting Integrity** EPRI 1018959 EPRI NP-5769 NUREG-1339 NUREG-1801	**ASME Sect. XI** IWA-4000	**ASME Sect. XI** IWB-2500-1	B-DM-06

Table A-3 ASME Class 1 Piping, Fittings, and Valves (Continued)

Components & ID No.	Material	Degradation Mechanisms	Conseq. of Failure	Mitigation	Repair / Replace	I & E Guidance	Gaps
3.4 Core Spray & Low Pressure Coolant Injection Piping							
3.4-1 Piping and Fittings *(Piping ≥ NPS 4)*	SS *(304, 304L, 316, 316L, 316NG, 347, 347NG)*	SCC: IG/TG Fat: HC, LC-Env RiFP: Env Ext: IG/TG Pitting	A	**Water Chemistry** BWRVIP-190 BWRVIP-225 *(Not mitigated by HWC / NMCA / OLNC)* **Thermal Fatigue** MRP-235R1 BWRVIP-155 **Stress Improvement** BWRVIP-61 *(Weld Overlay, IHSI, MSIP)*	**ASME Sect. XI** IWA-4000 **Weld Overlay** CC-N-504-2 *(Vendor Controlled)*	**ASME Sect. XI** IWB-2500-1 **RI-ISI** CC-N-716 Reg. Guide 1.200 NUREG-1855 EPRI 1018427 **IGSCC** Generic Letter 88-01 BWRVIP-75-A BWRVIP-222 **HC Thermal Fatigue** MRP-146 MRP-146S BWRVIP-155 BWRVIP-196 **LC-Env Fatigue** NUREG-1801-X.M1 NUREG-6260 NUREG-6909	B-DM-06 B-DM-09 B-DM-10 B-AS-07 B-MT-01 B-I&E-05
3.4-2 Piping and Fittings *(Piping ≥ NPS 4)*	C&LAS *(Carbon Steel)*	Fat: HC, LC-Env RiFP: Env Ext: Pitting	A	**Water Chemistry** BWRVIP-190 BWRVIP-225	**ASME Sect. XI** IWA-4000	**ASME Sect. XI** IWB-2500-1	B-DM-06 B-AS-07 B-I&E-05

Table A-3 ASME Class 1 Piping, Fittings, and Valves (Continued)

Components & ID No.	Material	Degradation Mechanisms	Conseq. of Failure	Mitigation	Repair / Replace	I & E Guidance	Gaps
3.4-3 Small Bore Piping and Fittings *(Piping < NPS 4)* *(Includes Vents, Drains, Instrument Lines)*	SS *(304, 304L, 316, 316L, 316NG, 347, 347NG)*	SCC: IG/TG Fat: HC, LC-Env RiFP: Env Ext: IG/TG Pitting	A	**Water Chemistry** BWRVIP-190 BWRVIP-225 *(Not mitigated by HWC / NMCA / OLNC)* **Thermal Fatigue** MRP-235R1 BWRVIP-155 **Mech. Fatigue** MRP-235R1 EPRI 1007944 EPRI 1003689 *(Strengthen Welds / Modify Geometry)*	**ASME Sect. XI** IWA-4000	**ASME Sect. XI** IWB-2500-1 **RI-ISI** CC-N-716 Reg. Guide 1.200 NUREG-1855 EPRI 1018427 **IGSCC** NUREG-1801 XI.M35 **HC Thermal Fatigue** MRP-146 MRP-146S BWRVIP-155 BWRVIP-196	B-DM-06 B-DM-09 B-MT-01
3.4-4 Small Bore Piping and Fittings *(Piping < NPS 4)* *(Includes Vents, Drains, Instrument Lines)*	C&LAS *(Carbon Steel)*	Fat: HC, LC-Env RiFP: Env Ext: Pitting	A	**Water Chemistry** BWRVIP-190 BWRVIP-225 **Thermal Fatigue** MRP-235R1 BWRVIP-155 **Mech. Fatigue** MRP-235R1 EPRI 1007944 EPRI 1003689 *(Strengthen Welds / Modify Geometry)*	**ASME Sect. XI** IWA-4000	**ASME Sect. XI** IWB-2500-1 **RI-ISI** CC-N-716 Reg. Guide 1.200 NUREG-1855 EPRI 1018427 **HC Thermal Fatigue** MRP-146 MRP-146S BWRVIP-155 BWRVIP-196	B-DM-06

Table A-3 ASME Class 1 Piping, Fittings, and Valves (Continued)

Components & ID No.	Material	Degradation Mechanisms	Conseq. of Failure	Mitigation	Repair / Replace	I & E Guidance	Gaps
3.4-5 Valve Bodies	C&LAS	RiFP: Env Ext: Pitting	A	**Water Chemistry** BWRVIP-190 BWRVIP-225	**ASME Sect. XI** IWA-4000	**ASME Sect. XI** IWB-2500-1	B-DM-06 B-I&E-05
3.4-6 Valve Bodies	SS *(304, 304L, 316, 316L, 316NG, 347, 347NG)*	RiFP: Env Ext: IG/TG Pitting	A	**Water Chemistry** BWRVIP-190 BWRVIP-225 *(Not mitigated by HWC / NMCA / OLNC)*	**ASME Sect. XI** IWA-4000	**ASME Sect. XI** IWB-2500-1	B-DM-06 B-DM-09 B-I&E-05
3.4-7 Valve Bonnets	C&LAS	RiFP: Env Ext: Pitting	A	**Water Chemistry** BWRVIP-190 BWRVIP-225	**ASME Sect. XI** IWA-4000	**ASME Sect. XI** IWB-2500-1	B-DM-06
3.4-8 Valve Bonnets	SS *(304, 304L, 316, 316L, 316NG, 347, 347NG)*	RiFP: Env Ext: IG/TG Pitting	A	**Water Chemistry** BWRVIP-190 BWRVIP-225 *(Not mitigated by HWC / NMCA / OLNC)*	**ASME Sect. XI** IWA-4000	**ASME Sect. XI** IWB-2500-1	B-DM-06 B-DM-09
3.4-9 Flanges / Seals	C&LAS	Fat: LC-Env RiFP: Env Ext: Pitting	A	**Water Chemistry** BWRVIP-190 BWRVIP-225 **Bolting Integrity** EPRI 1018959 EPRI NP-5769 NUREG-1339 NUREG-1801	**ASME Sect. XI** IWA-4000	**ASME Sect. XI** IWB-2500-1	B-DM-06

Table A-3 ASME Class 1 Piping, Fittings, and Valves (Continued)

Components & ID No.	Material	Degradation Mechanisms	Conseq. of Failure	Mitigation	Repair / Replace	I & E Guidance	Gaps
3.5 Reactor Pressure Vessel Head Vent, Spray, and Bottom Drains							
3.5-1 RPV Drain Line Piping *(Piping < NPS 4)*	C&LAS *(Carbon Steel)*	C&W: FAC Fat: LC-Env RiFP: Env Ext: Pitting	A, G	**Water Chemistry** BWRVIP-190 BWRVIP-225 **Mech. Fatigue** MRP-235R1 EPRI 1007944 EPRI 1003689 *(Strengthen Welds / Modify Geometry)*	**ASME Sect. XI** IWA-4000	**ASME Sect. XI** IWB-2500-1 **RI-ISI** CC-N-716 Reg. Guide 1.200 NUREG-1855 EPRI 1018427 **EPRI BWRVIP** BWRVIP-205	B-DM-06 B-I&E-07 B-RR-06
3.5-2 RPV Head Vent Piping *(Piping < NPS 4)*	C&LAS *(Carbon Steel)*	Fat: LC-Env RiFP: Env Ext: Pitting	A	**Water Chemistry** BWRVIP-190 BWRVIP-225 **Mech. Fatigue** MRP-235R1 EPRI 1007944 EPRI 1003689 *(Strengthen Welds / Modify Geometry)*	**ASME Sect. XI** IWA-4000	**ASME Sect. XI** IWB-2500-1	B-DM-06
3.5-3 RPV Head Spray Piping *(Piping < NPS 4)*	C&LAS *(Carbon Steel)*	Fat: LC-Env RiFP: Env Ext: Pitting	A	**Water Chemistry** BWRVIP-190 BWRVIP-225 **Mech. Fatigue** MRP-235R1 EPRI 1007944 EPRI 1003689 *(Strengthen Welds / Modify Geometry)*	**ASME Sect. XI** IWA-4000	**ASME Sect. XI** IWB-2500-1	B-DM-06

Table A-3 ASME Class 1 Piping, Fittings, and Valves (Continued)

Components & ID No.	Material	Degradation Mechanisms	Conseq. of Failure	Mitigation	Repair / Replace	I & E Guidance	Gaps
3.6 Bolting							
3.6-1 Closure Bolting *(Bolts, Studs, Nuts)*	C&LAS *(HSLA Steels 193, Gr B7, SA-540, Gr B22 & B23)*	SCC: IG/TG C&W: Pitting Fat: LC-Env	A	**Bolting Integrity** EPRI 1018959 EPRI NP-5769 NUREG-1339 NUREG-1801	**ASME Sect. XI** IWA-4000	**ASME Sect. XI** IWB-2500-1	None
3.6-2 Closure Bolting *(Bolts, Studs, Nuts)*	SS	SCC: IG/TG C&W: Pitting Fat: LC-Env	A	**Bolting Integrity** EPRI 1018959 EPRI NP-5769 NUREG-1339 NUREG-1801	**ASME Sect. XI** IWA-4000	**ASME Sect. XI** IWB-2500-1	None

Table A-4 Reactor Recirculation Pump

Components & ID No.	Material	Degradation Mechanisms	Conseq. of Failure	Mitigation	Repair / Replace	I & E Guidance	Gaps
4.1 Reactor Recirculation Pump							
4.1-1 Recirculation Pump Casing	CASS *(CF3, CF3M, CF8, CF8M)*	SCC: IG/TG RiFP: Env Ext: Pitting	A, G	**Water Chemistry** BWRVIP-190 BWRVIP-225	**ASME Sect. XI** IWA-4000	**ASME Sect. XI** IWB-2500-1	B-DM-06 B-DM-09 B-I&E-06
4.1-2 Recirculation Pump Cover	SS *(304, 304L, 316, 316L, 316NG, 347, 347NG)*	RiFP: Env Ext: IG/TG Pitting	A, G	**Water Chemistry** BWRVIP-190 BWRVIP-225	**ASME Sect. XI** IWA-4000	**ASME Sect. XI** IWB-2500-1 **Vendor** GE SIL 459	B-DM-06 B-DM-09
4.1-3 Recirculation Pump Cover	CASS	SCC: IG/TG RiFP: Env Ext: Pitting	A, G	**Water Chemistry** BWRVIP-190 BWRVIP-225	**ASME Sect. XI** IWA-4000	**ASME Sect. XI** IWB-2500-1	B-DM-06 B-DM-09
4.1-4 Recirculation Pump Seal Flange	SS *(304, 304L, 316, 316L, 316NG, 347, 347NG)*	SCC: IG/TG RiFP: Env Ext: IG/TG Pitting	A, G	**Water Chemistry** BWRVIP-190 BWRVIP-225	**ASME Sect. XI** IWA-4000	**ASME Sect. XI** IWB-2500-1	B-DM-06 B-DM-09
4.1-5 Recirculation Pump Cover Thermal Barrier	CASS	SCC: IG/TG RiFP: Env Ext: Pitting	A, G	**Water Chemistry** BWRVIP-190 BWRVIP-225	**ASME Sect. XI** IWA-4000	**ASME Sect. XI** IWB-2500-1	B-DM-06 B-DM-09

Table A-4 Reactor Recirculation Pump (Continued)

Components & ID No.	Material	Degradation Mechanisms	Conseq. of Failure	Mitigation	Repair / Replace	I & E Guidance	Gaps
4.1-6 Pump Flange Closure Bolting	C&LAS *(HSLA Steels 193, Gr B7, SA-540, Gr B22 & B23)*	SCC: IG/TG C&W: Pitting	A; G	**Bolting Integrity** EPRI 1018959 EPRI NP-5769 NUREG-1339 NUREG-1801 Reg. Guide 1.65	**ASME Sect. XI** IWA-4000	**ASME Sect. XI** IWB-2500-1	None

B

GAP CLOSURE

Table B-1 provides a historical listing of closed BWR IMT gaps, regardless of when the gap was closed. Table B-2 presents the R&D gaps that have been closed since revision 1 of the BWR IMT Report, along with a basis for closure of the gap. See EPRI Report BWRVIP-167NP, Revision 1 (EPRI 1018111) for gap descriptions and closure bases for gaps closed in revision 1 of the BWR IMT.

Table B-1 Historical Listing of Closed Gaps

R&D Gap Identifier	R&D Gap Title	Closure Revision
B-DM-01	Environmentally Assisted Cracking: LAS	Revision 2 (2010 Version)
B-DM-02	SCC of "Resistant" Stainless Steel Materials	Revision 2 (2010 Version)
B-DM-04	NMCA Plant Corrosion Products	Revision 1 (2008 Version)
B-DM-05	Thermal Embrittlement of Nickel Alloys	Revision 1 (2008 Version)
B-AS-01	RAMA Code Validation *[NOTE: Gap re-categorized as a program requirement (RQMT B-03)*]	Revision 1 (2008 Version)
B-AS-02	RPV Axial Welds Inspection Coverage	Revision 1.1 (2009 Interim Version)
B-AS-03	Alternate ASME Section XI Appendix G Methodology	Revision 1.1 (2009 Interim Version)
B-AS-04	Thermal Embrittlement of C&LAS	Revision 1 (2008 Version)
B-AS-06	Neutron Embrittlement of Nozzle Forgings	Revision 1 (2008 Version)
B-AS-08	High Cycle Fatigue: RPV Locations	Revision 1 (2008 Version)
B-AS-13	Assess the Impact of High Fluence on Nickel-Base Alloys	Revision 2 (2010 Version)

Table B-1 Historical Listing of Closed Gaps (Continued)

R&D Gap Identifier	R&D Gap Title	Closure Revision
B-AS-16	Loose Parts Assessment	Revision 1.1 (2009 Version)
B-AS-21	Assess Adequacy of FAC Modeling for RPV Drain Line & Bottom Head Nozzle	Revision 1 (2008 Version)
B-AS-23	Mechanical (Vibratory) Fatigue - Small Bore Piping	Revision 1 (2008 Version)
B-AS-24	Corrosion of C&LAS Piping Locations	Revision 1 (2008 Version)
B-AS-25	TGSCC of Cladding via Hydrogen Embrittlement Mechanism	Revision 1 (2008 Version)
B-MT-03	High Fluence Effect on HWC and NMCA [*NOTE: Gap merged into B-AS-09.*]	Revision 1 (2008 Version)
B-MT-06	NMCA Durability & Long Term Effectiveness	Revision 2 (2010 Version)
B-I&E-04	I&E Guidance: AHCs	Revision 1 (2008 Version)
B-RR-01	Roll / Expansion Repair Technique Approval	Revision 1 (2008 Version)
B-RR-03	Access Hole Cover (AHC) Repair Design Criteria (RDC)	Revision 1.1 (2009 Interim Version)
B-RR-04	Steam Dryer Repair Design Criteria	Revision 1 (2008 Version)
B-RR-07	ICMH Roll / Expansion Repair Technique Approval	Revision 1.1 (2009 Interim Version)
B-RR-09	Improved Jet Pump Restrainer Bracket Design	Revision 2 (2010 Version)
B-RG-01	IGSCC & High-Cycle Thermal Fatigue of Small Bore Piping (SBP)	Revision 2 (2010 Version)
B-RG-02	Thermal Embrittlement of CASS Piping	Revision 1 (2008 Version)
B-RG-03	Top Guide License Renewal Assessment	Revision 1 (2008 Version)
B-RG-04	Integrated Surveillance Program (ISP) Maintenance [*NOTE: Gap re-categorized as a program requirement (RQMT B-03)*]	Revision 1 (2008 Version)

Table B-1 Historical Listing of Closed Gaps (Continued)

R&D Gap Identifier	R&D Gap Title	Closure Revision
B-RG-06	Reactor Internals NDE Qualification	Revision 2 (2010 Version)
B-RG-07	Flaw Sizing Criteria	Revision 1.1 (2009 Interim Version)

Table B-2 Closed Gaps - Gap Descriptions and Closure Basis

R&D Gap Description
B-DM-01 - Environmentally Assisted Cracking: LAS **Revision 1 IMT Gap Description:** *Develop an improved understanding regarding the potential for environmentally assisted cracking of clad low alloy steel materials in the BWR water environment. More data is needed regarding intermediate temperature effects, ripple loading effects, and possible chloride effects. Additionally, some concerns remain regarding cracking of LAS materials exposed to the CANDU reactor heavy water environment. Also included within the scope of this gap is the possibility that the effects of neutron fluence could exacerbate SCC of low alloy steel vessel materials.* *However field experience is good. To date, there have been no documented instances of environmentally assisted cracking of any domestic BWR RPV alloy steel material. All cracking observed has been in cladding, and most of the cracking was the result of a manufacturing or fabrication defect. Even when limited environmentally assisted corrosion has been observed in vessel cladding, it has arrested at the vessel-clad interface. Laboratory data illustrate that crack initiation and growth is extremely difficult. The result indicates that the consideration of possible SCC growth into LAS is likely conservative. Additionally, HWC is expected to mitigate this degradation mechanism completely.* **Basis for Closure:** BWRVIP-233 provides an update of the BWRVIP-60-A disposition lines for predicting LAS SCC CGRs in BWR vessels. The results of this study reveal that low alloy steel RPVs are extremely tolerant to SCC crack growth of postulated flaws emanating from attachment welds or weld metal cladding. The field and laboratory data illustrate that crack initiation and growth is difficult and that no significant SCC growth has been observed in BWR vessel components. Near term issues including intermediate temperature effects and ripple loading effects are considered to be resolved by this study. As a result, gap B-DM-01 is closed. There are two open issues regarding low alloy steel crack growth rates. The first is related to the effect of chlorides, even at concentrations below the EPRI BWR Water Chemistry Guideline action level 1. The second is related to potential 80-year fluence effects on alloy steel CGRs (IASCC). These issues are addressed by new gaps B-DM-07 and B-DM-08, respectively. **References:** BWRVIP-233, BWRVIP-60, BWRVIP-190

Table B-2 Closed Gaps - Gap Descriptions and Closure Basis (Continued)

R&D Gap Description
B-DM-02 - SCC of "Resistant" Stainless Steel Materials **Revision 1 IMT Gap Description:** *Cracking occurred in early BWRs under normal water chemistry. Hydrogen water chemistry mitigates many locations, but recent degradation observed in Japan and elsewhere indicate that SCC susceptibility remains a possible event for unsensitized material. Presently, SCC concerns are focused on high local strain at weld fusion lines and on locations with surface cold work. Assessment is needed to determine if the presence of these aggravating conditions could result in stress corrosion cracking of materials that were previously thought to be resistant to SCC, e.g. un-sensitized stainless steels and 316NG stainless steels.* *These concerns have basis in field experiences. SCC of these "resistant" materials has been identified in a number of Japanese plants. Locations include Recirculation piping and horizontal core shroud welds. In core shrouds, the cracking has been circumferential for ring welds and radial for shell welds. In Recirculation system piping, the cracking has been circumferentially oriented and close to the weld fusion line. These experiences in Japan and elsewhere have shown that cold work surface layers of low carbon 304/316 can initiate stress corrosion cracking, typically as transgranular cracks. Once initiated, these cracks can, and do, transition into intergranular stress corrosion cracks, given the presence of sufficient local tensile stresses.* *Factors possibly influencing cracking include weld residual stresses; high local ECP in creviced regions; and strain hardening via surface machining, grinding, or welding. It is observed that weld heat affected zones of stainless steel welds retain a significant level of residual strain (on the order of 20% near the fusion line). Cracks initiated in a surface cold worked layer are observed to grow readily in this strained material. Surface cold work can be introduced by a variety of common and necessary fabrication processes such as machining, grinding, and roll forming.* *Resolution of this gap includes development of an improved mechanistic understanding of SCC occurring in unsensitized and low carbon (304L, 316L) or nuclear grade (316NG) stainless steels.* **Closure Basis:** At this time, these near term concerns are deemed to have been sufficiently investigated and no additional specific, near-term research is considered necessary. Extensive studies conducted by the Japanese have shown that crack initiation is promoted by surface cold work from heavy machining or other sources. Once initiated, IGSCC will propagate in the weld strained material of the heat affected zone. However, long-term concerns remain, including late life SCC initiation and long term stress stability of surface mitigation techniques. In particular, the long term susceptibility of weld strained material in the absence of surface cold work is unknown. New gap B-DM-09 will address these concerns. **References:** S. Suzuki, "BWR Materials Research for Ageing Management in TEPCO", International Symposium on the Ageing Management and Maintenance of Nuclear Power Plants, February 22, 2007. 2010 MDM (Notes b1-1c, b1-1d)

Table B-2 Closed Gaps - Gap Descriptions and Closure Basis (Continued)

R&D Gap Description
B-AS-02 - RPV Axial Welds Inspection Coverage **Revision 1 IMT Gap Description:** *BWRVIP-05 and related correspondence provided the technical justification to eliminate the inspection of BWR RPV circumferential welds. However, the NRC safety evaluation required essentially 100% inspection coverage of the axial welds. Utility experience regarding inspection of the axial welds is showing that many welds cannot be fully inspected, i.e., coverage much less than 100%. Several utilities have performed plant-specific analyses to determine the minimum coverage that satisfies the risk criteria in the NRC SE. These analyses are submitted to NRC to support relief requests or technical alternative to the regulations.* *Resolution of the gap will include generic probabilistic fracture mechanics evaluations, similar to BWRVIP-05, to determine the required minimum allowable inspection coverage of the axial welds to satisfy the risk criteria. A technical report will be produced that documents the results of the work. The results of this work will be submitted to the NRC. Utilities will reference this report as the technical basis to support relief requests for reduced inspection coverage of the axial welds.* **Closure Basis:** This gap is closed based on BWRVIP-203. This report provides a process to determine the acceptability of specific inspection coverages for the axial welds. A diagram is provided in the report to determine acceptable inspection coverage considering 30, 40, 50, and 60 years of crack growth. The appropriate wall thickness curve is selected along with the actual inspection coverage that can be obtained. If adjusted reference temperature (ART) lies below the curve, inspection coverage is adequate to satisfy the acceptance criteria. **References:** BWRVIP-05, BWRVIP-203 Generic Letter 98-05

Table B-2 Closed Gaps - Gap Descriptions and Closure Basis (Continued)

R&D Gap Description
B-AS-03 -Alternate ASME Section XI Appendix G Methodology **Revision 1 IMT Gap Description:** *The procedures required by Appendix G (Fracture Toughness Criteria for Protection Against Failure) of ASME Boiler and Pressure Vessel Code Section XI are based on fracture mechanics methods. These methods constitute a flaw tolerance approach to vessel integrity where the margin on pressure, postulated flaw size, and material toughness ensure that the material in the reactor vessel maintains a consistent and acceptable tolerance for flaws that might exist in the RPV. Excessive conservatisms exist in these procedures such that severe restrictions in operating flexibility are being imposed on operating plants. Significant enhancements have been made in the fracture mechanics and nondestructive evaluation (NDE) technologies embedded in the Appendix G methodology. Development of an improved methodology is necessary to take advantage of these enhancements and thereby reduce operating limitations.* *NRC is planning to issue a revision to Reg. Guide 1.99, Revision 2. The new embrittlement trend curves are expected to be more conservative for BWRs due to the inclusion of a flux effect (lower flux produces larger embrittlement) which increases* RT_{NDT} *for BWRs. The resulting methodology will offset an expected increase in predicted vessel material embrittlement from R.G. 1.99, Rev. 3.* *The resulting methodology will allow for a greatly increased operating flexibility and will allow for reduced outage time. Completion of this activity should remove RPV heatup/cooldown as an RPV integrity issue through license renewal.* **Closure Basis:** This gap is closed based on the near-term planned publishing of BWRVIP-215NP. **References:** ASME Section XI MRP-250, BWRVIP-215NP NRC R.G. 1.99 Rev. 2

Table B-2 Closed Gaps - Gap Descriptions and Closure Basis (Continued)

R&D Gap Description
B-AS-13 - Assess the Impact of High Fluence on Nickel-Base Alloys This gap is closed - neutron fluence issues are being consolidated with SCC concerns in gaps B-AS-26 and B-AS-27. **Revision 1 IMT Gap Description:** *There remains a need for additional data in order to better understand and characterize the impact of significant neutron fluence on nickel-base alloys, especially the potential for IASCC. Data development would be aimed at understanding the differences in irradiated material behavior between nickel alloys and stainless steels.* *Associated BWR reactor internals components include wrought nickel alloy tie rods, jet pump beams, core plate wedge retainers, and shroud repair hardware. Fluence effects are also possible for some internals welds.* ***References:*** *2008 MDM (Note b2-14)* **Closure Basis:** There are concerns with both Alloy 182 (riser brace welds) and X-750 (jet pump beams and shroud repair hardware). However, these two materials are quite different and the nature of the degradation concerns and associated resolution approaches are different. A more efficient approach is to address all Alloy 182 degradation issues in a single gap (B-AS-27) and all high strength alloy issues in a separate gap (B-AS-26). Open issues associated with B-AS-13 will be incorporated into B-AS-26 and B-AS-27.
B-AS-16 - Loose Parts Assessment **Revision 1 IMT Gap Description:** *BWRVIP-06-A provides a loose part assessment from a safety-related view point. This gap is related to the potential need for assessment of non-safety related impacts on BWR vessel internals due to loose parts generation. Presently, the most significant concerns are focused on the steam dryers, where significant generation of loose parts has occurred in a number of events.* **Closure Basis:** A revision to BWRVIP-06 addresses the potential impact of loose parts on the BWR primary system. **References:** BWRVIP-06 Revision 1-A, BWRVIP Correspondence 2006-301

Table B-2 Closed Gaps - Gap Descriptions and Closure Basis (Continued)

R&D Gap Description
B-MT-06 - NMCA Durability & Long Term Effectiveness **Revision 1 IMT Gap Description:** *It is important to document the long term effectiveness and durability of NMCA to ensure protection of vessel internals and to justify inspection relief. This work will help to minimize any unexpected results from NMCA (for example, the high main steam line and shutdown radiation fields observed at some plants immediately after NMCA). Work includes collection of data on the long term effectiveness and durability of NMCA including durability coupon data, re-deposition data, and re-application experiences.* *<u>Hydrolasing</u>:* *Some inspection vendors use hydrolasing at high pressures to clean the surfaces of BWR internals before performing visual (EVT-1) examinations. Hydrolasing at 3000 psig was performed at Perry on the bottom portion of the stainless steel surveillance capsule. The hydrolasing removed the noble metal from this surface (BWRVIP-159).* *Therefore, for NMCA plants, this process is likely to remove the noble metal from the surface and leave it unprotected during subsequent operation. It is possible that re-deposition during operation may not be sufficient to protect the hydrolased surfaces, but further study is needed.* *<u>Power Washing</u>:* *Power washing at pressures < 1000 psi has been typically used to remove loose crud from nozzle locations. It is likely that noble metal deposited on the crud is also removed during this process. For creviced weld locations associated with thermal sleeves, crud blockage and low flow conditions are likely to preclude sufficient noble metal deposition to mitigate IGSCC.* *Resolution of this gap involves development of a comprehensive understanding of noble metal durability in service and guidance regarding the use of cleaning techniques to support in-vessel visual inspections.* **Closure Basis:** Previously, evaluations were focused on NMCA technologies and application of cleaning techniques such as hydrolasing and power washing. This work is now considered complete, with hydrolasing (3000 psig) generally found to remove noble metal deposits from surfaces and power washing (< 1000 psig) generally found not to remove noble metal deposits, provided that appropriate process controls are implemented. With development and now adoption of On-line NobleChem™ (OLNC), focus has now shifted toward investigation of OLNC deposition and durability under various flow conditions. There is ongoing BWRVIP work to monitor OLNC deposition immediately after OLNC application and again after 3-4 months of operation under various flow conditions. The results will be used to adjust the OLNC deposition model and to improve the understanding of OLNC durability in varying flow conditions. However, issues associated with resolution of OLNC performance are addressed by gap B-MT-04. As a result, gap B-MT-06 is considered to be resolved. **References:** BWRVIP-159, BWRVIP-190, BWRVIP-193, BWRVIP-201, BWRVIP-204

Table B-2 Closed Gaps - Gap Descriptions and Closure Basis (Continued)

R&D Gap Description
B-RR-03 - Access Hole Cover (AHC) Repair Design Criteria (RDC) **Revision 1 IMT Gap Description:** *Plants are currently performing inspections of Access Hole Covers (AHC) in accordance with GE SILs and will be performing inspections in accordance with the recently published BWRVIP AHC inspection and evaluation guidelines (BWRVIP-180). If relevant indications are found during inspections, repairs may be required.* *The BWRVIP has developed Repair Design Criteria for most critical internal components. Development of Access Hole Cover Repair Design Criteria would provide guidance on acceptable methods for repair of this component and would reduce the effort required to design a repair. If repairs are designed in accordance with these guidelines, utilities are not required, in most cases, to obtain specific approval of the design and installation from the NRC. As with previous criteria documents, it would include guidance on material selection, design considerations, fabrication processes and inspection and testing.* *A number of units have already installed replacement access hole covers. The repair design criteria may also include a description of the design concepts that have been successfully implemented in the industry.* **Closure Basis:** This gap is closed based on the near-term planned publishing of BWRVIP-217, which provides repair design criteria for the access hole cover. **References:** BWRVIP-84, BWRVIP-160, BWRVIP-180, BWRVIP-217 GE SIL 462, Revision 1

Table B-2 Closed Gaps - Gap Descriptions and Closure Basis (Continued)

R&D Gap Description
B-RR-07 - ICMH Roll / Expansion Repair Technique Approval **Revision 1 IMT Gap Description:** *This R&D gap addresses the need to develop and issue a revision to Code Case N-730 to include rolling of an in-core monitor housing (ICMH) as an acceptable means of permanent repair. A technical basis for the revision will be prepared and documented in a technical report. No additional testing is envisioned to justify the adequacy of a roll repair for the ICMH. The test data for CRDs was to demonstrate that the rolled joint could withstand upward-directed loads from a scram with a failed buffer. Those loads do not exist for the ICMH. The Code Case assumes that the downward-directed loads for CRDs (and ICMHs) are reacted by the remaining weld ligament. Thus, the friction of the rolled joint is not required to resist loads in that direction.* *In 2006, Code Case N-730, "Roll Expansion of Class 1 Control Rod Drive Bottom Head Penetrations in BWRs" was approved by ASME for publication in Supplement 11 to Nuclear Code Cases. The Code Case allows the use of roll-expansion for the permanent repair of leaking CRD housings in BWRs. A revision to this Code Case for ICMHs would provide a repair method for all bottom head penetrations and make this cost-effective approach available to all BWRs on a generic basis.* *Plant experience has shown that rolling is a cost-effective alternative to other methods (e.g., welding) of repairing CRD housing leaks. A successful revision to the Code Case would provide a repair method for all bottom head penetrations and make this cost-effective approach available to all BWRs on a generic basis.* *This gap is economic in nature since no significant safety concern exists.* **Closure Basis:** BWRVIP-214NP contains a technical basis for the ICMH roll / expansion repair technique. This report has been published and transmitted to the NRC. **References:** BWRVIP-146NP, BWRVIP-214NP ASME CC-N-730

Table B-2 Closed Gaps - Gap Descriptions and Closure Basis (Continued)

R&D Gap Description
B-RR-09 - Improved Jet Pump Restrainer Bracket Design **Revision 1 IMT Gap Description:** *Development of improved restrainer designs is needed to ensure jet pump vibration issues are resolved. Resolution of this repair gap is closely related to the successful closure of assessment gap B-AS-18.* *There have been a number of recent occurrences of wedge wear and/or movement, and wedge rod wear related primarily to flow-induced vibrations. This degradation, if not controlled, could cause cracking in locations such as the riser brace attachment to the RPV. Presently, a number of units have implemented jet pump assembly repairs or auxiliary restraints (e.g. auxiliary wedges, slip joint clamps) in an effort to mitigate jet pump vibration issues. There is growing evidence that these auxiliary restraints are not fully mitigating wedge and rod wear.* ***References:*** *BWRVIP-160, BWRVIP-165* **Closure Basis:** BWRVIP-207 and BWRVIP-210 document a number of conceptual designs developed by AREVA NP and MPR Associates and by XGEN Engineering for modification of BWR jet pump restrainer brackets. Designs proposed in these reports provide alternatives for ensuring the integrity of the jet pump assembly by resolving the potential for wear of moving parts within the restrainer bracket assembly. Based on these completed design reports, this gap is closed. **References:** BWRVIP-207, BWRVIP-210

Table B-2 Closed Gaps - Gap Descriptions and Closure Basis (Continued)

R&D Gap Description
B-RG-01 – IGSCC & High-Cycle Thermal Fatigue of Small Bore Piping (SBP) **Revision 1 IMT Gap Description:** *Develop NRC Staff approved alternative to one-time inspection of BWR small bore piping to detect SCC.* *NUREG-1801, Section XI.M35 outlines a staff requirement that license renewal applicants commit to volumetric examination of small bore piping (< NPS 4). The staff concern relates to IGSCC and high cycle thermal fatigue (turbulence penetration and thermal stratification). Further discussion with the staff could potentially eliminate this pre-emptive examination requirement.* *IGSCC is not a significant mechanism for small bore piping as demonstrated by operating experience. Further, the number of small bore piping locations where a break could result in leakage exceeding make-up capability is expected to be small.* *Subsequent to development of Revision 0 of the BWR IMTs, the relative importance of this gap has been diminished by two factors:* *1. High-cycle thermal fatigue has occurred in PWR small bore piping, but has been managed by effective screening to determine when examination is recommended (MRP-146). Recently issued BWRVIP-155 addresses this issue for BWR configurations, providing a similar screening process for BWR piping geometries. Recent NRC reviews of PWR license renewal applications have accepted the use of screening to manage high-cycle thermal fatigue.* *2. The NRC has agreed with the industry that performing volumetric examinations of socked weld connections NPS 2 and smaller represents an unusual difficulty, without providing any meaningful increase in the level or quality of safety.* **Closure Basis:** In an effort to simplify gaps, open issues associated with license renewal are being tracked in a single gap, B-RG-08. **References:** NUREG-1801 (Section IV.C1 & XI.M35) BWRVIP-155 MRP-146 NRC Safety Evaluation Related to the Fourth 10-Year Interval Inservice Inspection Program, Surry Power Station, Unit 2 - Virginia Electric and Power Company - Docket No. 50-281, U.S. Nuclear Regulatory Commission: August 2005. Vogtle Electric Generating Plant License Renewal Application

Table B-2 Closed Gaps - Gap Descriptions and Closure Basis (Continued)

R&D Gap Description
B-RG-06 ~ Reactor Internals NDE Qualification **Revision 1 IMT Gap Description:** *In June 2006, the NRC staff transmitted a set of requests for additional information regarding Rev. 6 of BWRVIP-03. In this transmittal, the NRC staff questioned the BWRVIP processes for qualification of examination techniques specified in BWRVIP-03, including qualification of examiners, and uncertainties associated with flaw measurements. NRC questions lead toward expectations of medium rigor examinations instead of low rigor.* *In May 2007, the BWRVIP transmitted responses to the NRC staff requests for additional information. The BWRVIP responses elaborated on rationales and bases supporting the BWRVIP positions and processes regarding qualification of examination techniques and examination personnel contained in BWRVIP-03. The BWRVIP position is that current processes remain adequate.* *As of February 2008, no formal response from the staff had been received by the BWRVIP. Until additional staff correspondence on the issue is received, there are no practical actions that can be taken to address this issue. Based on the staff's response, this gap item may either be resolved, or some additional work may be required.* **Closure Basis:** A safety evaluation on BWRVIP-03R6 has now been received from the NRC. Based on this safety evaluation, concerns related to NDE qualification of volumetric examinations appear to be resolved. Current open items with the NRC are focused on reliability of visual examination methods. Open IMT gap B-RG-05 addresses NRC concerns associated with visual examinations. As a result, this gap can now be closed. **References:** BWRVIP-03R6 and BWRVIP-03R12 BWRVIP Correspondence 2006-322, 2007-144, 2008-186.

Table B-2 Closed Gaps - Gap Descriptions and Closure Basis (Continued)

R&D Gap Description
B-RG-07 - Flaw Sizing Criteria **Revision 1 IMT Gap Description:** *For some component inspections, current ASME Section XI Appendix VIII RMS flaw sizing values represent a hardship in terms of qualifying techniques which pass the criteria. Current ASME Section XI Appendix VIII applies fixed RMS flaw sizing acceptance criteria. In some cases, this approach presents significant challenges to inspection because the achievable RMS flaw sizing error is related to component geometry. Of particular concern is the current Appendix VIII 0.125" RMS criterion for dissimilar metal weld depth sizing. For thicker wall components, this fixed criterion becomes progressively difficult to meet.* *An alternative approach is implementation of dimensionless flaw sizing criteria. Implementation of this technique results in a normalized acceptance criterion based on component geometry and achieves a more consistent standard of flaw sizing accuracy.* *Resolution of this gap involves development of technical bases to support implementation of dimensionless flaw sizing criteria and acceptance of the approach by ASME Code and by the NRC. The primary benefit of resolution of this gap is decreased costs associated with qualification of inspection techniques without a decrease in the overall level of safety.* **Closure Basis:** Further investigation determined that this concern is not applicable to BWRs. Difficulties in meeting the 0.125" RMS criterion for dissimilar metal welds is limited to examinations performed from the piping inner diameter where resolution of flaw sizes is more difficult. Different than PWRs, BWR welds can be inspected from the piping outside diameter because access for UT is generally better and surface contour/geometry is better than for PWRs. **References:** None

C

REVISION LOG

Table C-1 Revision Log

Revision	Description of Changes
Revision 0	Initial Issue
Revision 1	Important changes to R&D Gaps from Revision 0 are summarized in items 1 through 4 below. 1. The following gaps were closed: B-DM-04, B-DM-05, B-AS-04, B-AS-06, B-AS-08, B-AS-21, B-AS-23, B-AS-24, B-AS-25, B-I&E-04, B-RR-01, B-RR-04, B-RG-02, B-RG-03 2. The following new gaps were added: B-DM-06, B-AS-26, B-AS-27, B-AS-28, B-I&E-08, B-I&E-09, B-RR-05, B-RR-06, B-RR-07, B-RR-08, B-RR-09, B-RG-05, B-RG-06, B-RG-07 3. A category for program requirements was added. The following gaps were effectively closed and moved into the requirements category: B-AS-01, B-RG-04 4. Gap B-MT-03 was merged into B-AS-09. A number of minor changes to the IMTs and formatting changes are also included in this Revision 1 report (EPRI 1018111). Tables E-1 and E-2 of Appendix E to EPRI 1018111 provide a comprehensive list of the revisions.

Table C-1 Revision Log (Continued)

Revision	Description of Changes
Revision 1.1	Based on completed work and updated prioritization by the BWRVIP Integration Committee, an interim revision to IMT gaps was made in mid-2009 (referred to as Revision 1.1). Revision 1.1 of the BWR IMTs refers to BWRVIP Correspondence 2009-216, "Interim Revision to BWR Issue Management Tables to Include New, Revised, and Re-Ranked R&D Gaps." This correspondence added new R&D Gaps, re-ranked some R&D Gaps, and revised the content of some R&D Gaps. The BWR IMT Report was not re-published in 2009 to reflect these changes. The important changes to R&D Gaps from Revision 1 of the IMT Report are summarized in items 1 through 6 below. 1. The following gaps were closed based on new information: B-AS-02, B-AS-03, B-AS-16, B-RG-07, B-RR-03, B-RR-07. 2. Gap B-AS-15 was amended to remove Steam Dryer High Cycle Fatigue Evaluation Methodology issues. These steam dryer issues are now addressed separately in a new gap (B-AS-29). This change separates steam dryer high-cycle fatigue issues from other FIV concerns for reactor internals. 3. The following gaps changed from medium priority to high priority: B-DM-06, B-RR-02 4. The following gaps changed from high priority to medium priority: B-RG-05, B-AS-27, B-AS-28 5. The following gaps changed from low priority to medium priority: B-RR-08, B-AS-20 6. The following gap changed from medium priority to low priority: B-I&E-05.

Table C-1 Revision Log (Continued)

Revision	Description of Changes
Revision 2	Revision 2 of the BWR IMTs addresses consideration of long term operations (LTO). A majority of long term operation issues are associated with the 2010 MDM panel results. Consideration of LTO results in the identification of several new gaps and significantly affects a number of other gaps. Gaps created by or affected by LTO are indicated as such in Table 3-1. The most significant changes to R&D Gaps from Revision 1 are summarized in items 1 through 5 below. 1. The following gaps were closed: B-DM-01, B-DM-02, B-AS-13, B-MT-06, B-RR-09, B-RG-01, B-RG-06. 2. The following new gaps were added: B-DM-07, B-DM-08, B-DM-09, B-DM-10, B-AS-30, B-AS-31, B-AS-32, B-RG-08, B-RG-09. New gaps are identified in Table 3-1. 3. Gaps B-AS-09 and B-AS-10 have been restructured such that all crack growth rate data needs are addressed in B-AS-09 and fracture toughness data needs are addressed in B-AS-10. 4. Gap B-AS-26 has been modified to address all high strength alloy issues, for both unirradiated and irradiated applications. Outstanding issues associated with irradiated X-750 previously captured in gap B-AS-13 have been incorporated into this gap. 5. Gap B-AS-27 has been modified to address all Alloy 182 / creviced Alloy 600 SCC issues, for both unirradiated and irradiated applications. Outstanding issues associated with irradiated Alloy 182 weld metal previously captured in gap B-AS-13 have been incorporated into this gap. 6. Most of the open R&D Gaps have been extensively revised to reflect the current state of industry knowledge. See Table D-1 for additional information. A number of other changes to the BWR IMTs and formatting changes are also included in this Revision 2 report. Tables D-1 and D-2 of Appendix D provide a comprehensive list of revisions.

D

DETAILED LISTING OF CHANGES IN REVISION 2

Revision 2 to the BWRVIP IMTs includes a number of significant changes to the report.

Table D-1 describes the major revisions to R&D Gaps in Revision 2 of the IMT Report. This listing of changes is not intended to be exhaustive in nature. Most all R&D gap descriptions were revised to reflect comments received or new information. However, only significant changes to gaps are noted in Table D-1 (i.e. major shifts in gap focus or content, major LTO impacts, closed gaps, and new gaps).

Table D-2 lists other significant changes to the IMT report.

Table D-1 Changes to R&D Gaps

Gap No.	Gap Title	Description of Change
B-DM-01	Environmentally Assisted Cracking: LAS	GAP CLOSED Table B-2 provides a basis for gap closure.
B-DM-02	SCC of "Resistant" Stainless Steel Materials	GAP CLOSED Table B-2 provides a basis for gap closure.
B-DM-03	Low Temperature Crack Propagation	This gap was extensively revised to address new EPRI data and the results of the 2010 MDM expert panel meeting.
B-DM-06	Environmental Effects on Fracture Resistance	This gap was extensively revised to address new EPRI data and the results of the 2010 MDM expert panel meeting.
B-DM-07	Chloride Transient Effects on Low Alloy Steel Crack Growth Rates	NEW GAP This new gap addresses concerns noted during the 2010 MDM expert panel meeting.
B-DM-08	Long Term Neutron Fluence Effect on Low Alloy Steel Cracking Susceptibility	NEW GAP This new gap addresses concerns noted during the 2010 MDM expert panel meeting. This gap is specifically related to LTO.
B-DM-09	Long Term SCC Susceptibility (Late Life SCC Initiation)	NEW GAP This new gap addresses concerns noted during the 2010 MDM expert panel meeting. This gap is specifically related to LTO.

Table D-1 Changes to R&D Gaps (Continued)

Gap No.	Gap Title	Description of Change
B-DM-10	Long Term Stress Stability (LTO Based Gap)	NEW GAP This new gap addresses concerns noted during the 2010 MDM expert panel meeting. This gap is specifically related to LTO.
B-AS-02	RPV Axial Welds Inspection Coverage	GAP CLOSED Gap closed in interim revision 1.1 (2009). Table B-2 provides a basis for gap closure.
B-AS-03	Alternate ASME Section XI Appendix G Methodology	GAP CLOSED Gap closed in interim revision 1.1 (2009). Table B-2 provides a basis for gap closure.
B-AS-05	Assess Neutron Dose Rate Effects on Embrittlement of C&LAS	This gap was revised to address LTO concerns.
B-AS-07	Environmental Effects on Fatigue Life: Pressure Boundary Components	This gap was revised to address LTO concerns, the results of the 2010 MDM expert panel meeting, and recent experience with NRC application of R.G. 1.207 for new plant designs.
B-AS-09	Assess the Impact of High Fluence on Fracture Toughness	This gap was extensively revised to address LTO and to acknowledge that current fracture toughness data needs are focused on weld and HAZ materials.
B-AS-10	Assess the Impact of High Fluence and HWC Mitigation Technologies on SCC Crack Growth Rates	This gap was extensively revised to address LTO and recently completed and ongoing research projects.
B-AS-11	Assess Non BWR Reactor Irradiated Materials Data Applicability to the BWR Environment	This gap was revised to address LTO.
B-AS-12	Thermal & Irradiation Embrittlement: Synergistic Effects (on CASS BWR Reactor Internals)	This gap was revised to acknowledge recently completed screening of BWR internals CASS components indicating that embrittlement is not a concern through 60-year operation. This gap remains open to address LTO (80-year assessment).
B-AS-13	Assess the Impact of High Fluence on Nickel-Base Alloys	GAP CLOSED Table B-2 provides a basis for gap closure.
B-AS-14	Environmental Effects on the Fatigue Life of Reactor Internals	This gap was revised to reflect LTO.

Table D-1 Changes to R&D Gaps (Continued)

Gap No.	Gap Title	Description of Change
B-AS-15	FIV and High Cycle Fatigue Assessment: Reactor Internals	This gap was extensively revised to address the current state of industry knowledge and to remove content associated with steam dryers (now addressed by open gap B-AS-29).
B-AS-16	Loose Parts Assessment	GAP CLOSED Gap closed in interim revision 1.1 (2009). Table B-2 provides a basis for gap closure.
B-AS-17	Evaluate Hidden Weld Locations	This gap was extensively revised to highlight recent BWRVIP activity to implement an alternative, non risk-based approach to inspection of hidden welds.
B-AS-18	Jet Pump Degradation Management	This gap was extensively revised to reflect BWRVIP jet pump testing program progress and recent operating experience.
B-AS-19	Assess In-Vessel Fastener Loosening	This gap was revised to reflect additional concerns associated with LTO.
B-AS-22	High-Cycle Thermal Fatigue: Piping Locations	This gap was revised to address industry progress related to modeling and assessment of high-cycle thermal fatigue in primary piping systems.
B-AS-26	High Strength Alloys	This gap was extensively revised to incorporate all high strength alloy issues for both XM-19 and X-750 into a single gap. Previously irradiated materials issues associated with nickel alloys were addressed in gap B-AS-13. In this revision, irradiated materials concerns associated with both X-750 and XM-19 are addressed in this gap.
B-AS-27	Alloy 182 / Creviced Alloy 600 SCC Susceptibility & Irradiation Effects	This gap was extensively revised to address irradiated materials concerns associated with Alloy 182 weld material.
B-AS-28	Impact of BWR Nozzle Penetrations on Pressure-Temperature Limit Curves	This gap was revised to address LTO.
B-AS-29	Steam Dryer Evaluation Methodology	This gap was added in 2009 in an interim revision of the BWR IMTs. This new gap comprehensively addresses remaining steam dryer high-cycle vibration and fatigue issues.

Table D-1 Changes to R&D Gaps (Continued)

Gap No.	Gap Title	Description of Change
B-AS-30	Material Surveillance Program Implementation for 80 Year Service Lives	NEW GAP This new gap addresses the need for a review of the BWRVIP ISP to ensure LTO is adequately addressed.
B-AS-31	BWRVIP-47-A (CRGT) Re-Inspection Requirements	NEW GAP This new gap notes the need for reassessment of CRGT inspection requirements.
B-AS-32	Assessment of Core Plate Rim Hold Down Bolts	NEW GAP This new gap addresses the potential for resolution of core plate rim hold down bolt NDE needs by engineering assessment, rather than development of NDE technologies.
B-MT-01	Development of Alternative Mitigation Technologies	This gap was extensively revised to address the results of BWRVIP research since 2008.
B-MT-02	Demonstrate Improved ECP Model	This gap was extensively revised to address the results of BWRVIP research since 2008.
B-MT-04	Noble Metal Catalyst-Based Mitigation Technology Improvement	This gap was extensively revised to address the results of BWRVIP research since 2008.
B-MT-05	Startup & Shutdown Chemistry	This gap was extensively revised to address the results of BWRVIP research since 2008.
B-MT-06	NMCA Durability & Long Term Effectiveness	GAP CLOSED Table B-2 provides a basis for gap closure.
B-I&E-05	Appendix VIII Compliance	This gap was revised to focus the gap only on remaining ASME Section XI, Appendix VIII implementation issues for BWR plants.
B-I&E-07	NDE Capability: RPV Bottom Head Drain Line	This gap was extensively revised to address the results of BWRVIP research since 2008.
B-RR-02	Welding Processes for Repair of Irradiated Material	This gap was extensively revised to address the results of BWRVIP research since 2008.
B-RR-03	Access Hole Cover (AHC) Repair Design Criteria (RDC)	GAP CLOSED Gap closed in interim revision 1.1 (2009). Table B-2 provides a basis for gap closure.
B-RR-07	ICMH Roll / Expansion Repair Technique Approval	GAP CLOSED Gap closed in interim revision 1.1 (2009). Table B-2 provides a basis for gap closure.
B-RR-08	Availability of Laser Welding for Repairs to Highly Irradiated Components	This gap was revised to address current research plans for development of laser welding technologies.

Table D-1 Changes to R&D Gaps (Continued)

Gap No.	Gap Title	Description of Change
B-RR-09	Improved Jet Pump Restrainer Bracket Design	GAP CLOSED Table B-2 provides a basis for gap closure.
B-RG-01	IGSCC & High-Cycle Thermal Fatigue of Small Bore Piping (SBP)	GAP CLOSED Table B-2 provides a basis for gap closure.
B-RG-05	Evaluation of EVT-1	This gap was extensively revised to focus the gap only on resolution current NRC staff concerns regarding the effectiveness of EVT-1.
B-RG-06	Reactor Internals NDE Qualification	GAP CLOSED Table B-2 provides a basis for gap closure.
B-RG-07	Flaw Sizing Criteria	GAP CLOSED Gap closed in interim revision 1.1 (2009). Table B-2 provides a basis for gap closure.
B-RG-08	Reactor Pressure Vessel Material Surveillance Program Implementation for 80-Year Service Lives	NEW GAP This new gap addresses LTO issues associated with regulatory implementation of reactor vessel material surveillance programs.
B-RG-09	Management of License Renewal Issues	NEW GAP This new gap captures current license renewal issues in a single gap, rather than in multiple regulatory gaps.

Table D-2 List of Significant Changes to the IMTs (excluding changes to gaps)

ID	Report Section	Description of Change
1	Cover Section	A list of definitions was added to clarify the meaning of specific technical words and phrases used in the IMT report. The addition of these definitions aligns this report with the PWR IMT report and various advanced reactor design MMT reports which also contain a definition section.
2	Section 2, Methodology	The methodology section has been streamlined to remove detailed discussion regarding the application of degradation mechanisms from the MDM. The text has also been edited to be more concise.
3	Section 3, Table 3-1	Table 3-1, "R&D Gap Priority Results" now lists gaps in sequential order rather than in order of priority. The priority for each gap is listed in a new column. Priority columns are included for Revision 2 (2010), Revision 1.1 (interim 2009 version), and Revision 1 (2008). As this table is often used as a master list of gaps with links to gap descriptions, sequential order is more useful in locating specific gap information than the previous order by priority.
4	Table 3-9 and Appendix B	A number of R&D Gaps have been closed based on newly available data. Closed gaps are noted as closed in R&D Gap Tables 3-2 through 3-7. Additionally, Table 3-9 contains an historical listing of all closed gaps and Appendix B, Table B-1 includes a brief discussion of the basis for closure of each R&D Gap closed in this revision to the IMTs. Changes to specific gaps are outlined in Table D-1 above.
5	Section 4	EPRI References now have links to the appropriate EPRI download web page for the report.

Table D-2 List of Significant Changes to the IMTs (excluding changes to gaps) (Continued)

ID	Report Section	Description of Change
6	BWRVIP References added to the IMTs (Tables A-1 thru A-4)	BWRVIP-190 Latest water chemistry guidance added to water chemistry mitigation block. Supersedes BWRVIP-130. BWRVIP-196 This thermal fatigue susceptibility guidance was added to the high-cycle thermal fatigue block. BWRVIP-200 This implementation plan for two-sided inspection of shroud welds was added to applicable shroud I&E management blocks. BWRVIP-203 RPV axial weld inspection coverage evaluation report was added to I&E guidance for RPV shells. BWRVIP-207 Jet pump restrainer bracket repair design report was added to applicable jet pump repair blocks. BWRVIP-208 This report for bottom head drain line replacement criteria was added to RPV the drain nozzle repair block. BWRVIP-210 Jet pump restrainer bracket repair design report was added to applicable jet pump repair blocks. BWRVIP-219 This report concerning On-Line NobleChem™ was added to the mitigation block for applicable components. BWRVIP-222 Accelerated inspection program for category C DM welds was added to applicable IGSCC I&E blocks. BWRVIP-225 The BWR startup and shutdown chemistry sourcebook was added to the water chemistry mitigation block.

Table D-2 List of Significant Changes to the IMTs (excluding changes to gaps) (Continued)

ID	Report Section	Description of Change
7	BWRVIP References modified in the IMTs (Tables A-1 thru A-4)	BWRVIP-06-A Updated to BWRVIP-06 Revision 1-A. BWRVIP-18 Updated to Revision 1. BWRVIP-42 Updated to Revision 2. BWRVIP-86-A Updated to Revision 1. BWRVIP-135 Updated to Revision 1.
8	Non-BWRVIP References added to the IMTs	The following new references were added to the I&E guidance block for risk-informed inservice inspection: EPRI 1018427, CC-N-716, NUREG -1855, Reg. Guide 1.200. These references replace EPRI TR-112657 and ASME Code Cases N-560, N-577, and N-578. Updated the bolting integrity block to include the following references: EPRI 1018959, NP-5769, NUREG - 1339. Added NUREG-6909 to the I&E guidance block for LC-Env fatigue and removed NUREG-6583 and NUREG-5704. MRP-146S Added this supplemental guidance to the high-cycle thermal fatigue block. MRP-235 The fatigue management handbook was added to the thermal fatigue mitigation block. CC-N-769 This ASME code case was added to the in-core housing repair block.

Table D-2 List of Significant Changes to the IMTs (excluding changes to gaps) (Continued)

ID	Report Section	Description of Change
9	Formatting in Tables A-1 thru A-4	The IMTs have been reformatted to take advantage of information linking available in an "e-document" format and to align with the formatting of the PWR IMT and recent advanced reactor design MMTs. • The keys at the end of each IMT was removed. This information was presented as a table key for earlier revisions as an aid when viewing the tables in print form. As this report is now presented as an e-document, links to the appropriate section or item is more useful, and therefore the keys were removed. • EPRI References now have links to the appropriate EPRI web page with the abstract information for that report. • Gaps are now linked to the gap description found in Section 3 of this report. • Component identification numbers are now fully numerical, rather than the alpha-numerical approach used previously.
10	Was App. B	The Gap to Component Applicability Table was removed. The usefulness was deemed limited in comparison with the effort necessary to maintain the table.
11	Was App. C	Gap Responsibility Table was removed. Gap applicability is provided for each gap in the gap description tables.

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