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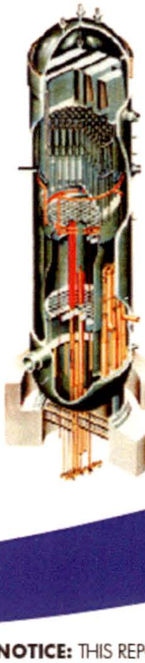
2021 TECHNICAL REPORT

BWRVIP-321NP-A: Boiling Water Reactor Vessel and Internals Project

Plan for Extension of the BWR Integrated Surveillance Program (ISP) Through the Second License Renewal (SLR)



BWRVIP-321NP-A: Boiling Water Reactor Vessel and Internals Project

Plan for Extension of the BWR Integrated Surveillance Program (ISP) Through the Second License Renewal (SLR)

3002020504NP

Final Report, April 2021

EPRI Project Manager
S. Williams

All or a portion of the requirements of the EPRI Nuclear Quality Assurance Program apply to this product.

YES NO

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THE FOLLOWING ORGANIZATIONS, UNDER CONTRACT TO EPRI, PREPARED THIS REPORT:

THE ELECTRIC POWER RESEARCH INSTITUTE (EPRI) PREPARED THIS REPORT.

NOTE

For further information about EPRI, call the EPRI Customer Assistance Center at 800.313.3774 or e-mail askepri@epri.com.

NRC SAFETY EVALUATION

In accordance with an NRC request, the NRC Safety Evaluation immediately follows this page. Other pertinent NRC and BWRVIP correspondence is included in Appendices B through D.

Note: Proprietary information in this Safety Evaluation is indicated by [highlighted, bracketed text].

From: Holonich, Joseph <Joseph.Holonich@nrc.gov>
Sent: Friday, November 20, 2020 6:41 AM
To: McGruder, Wynter <WMcGruder@epri.com>; Rouse, Deborah <drouse@epri.com>
Cc: Morey, Dennis <Dennis.Morey@nrc.gov>; Gonzalez, Hipo <Hipolito.Gonzalez@nrc.gov>; Yee, On <On.Yee@nrc.gov>; Medoff, James <James.Medoff@nrc.gov>
Subject: [EXTERNAL] BWRVIP-321 Final Safety Evaluation

Mr. Tim Hanley, Chairman
ATTN: Debbie Rouse
BWR Vessel and Internals Project
1300 West W.T. Harris Boulevard (Building 1)
Charlotte, NC 28262

Dear Mr. Hanley,

By letter dated March 8, 2019 (Agencywide Documents Access and Management System (ADAMS) Accession No. ML19071A234), the Electric Power Research Institute (EPRI) submitted for U.S. Nuclear Regulatory Commission (NRC) staff review the Topical Report (TR) TR- 3002013097, "BWR [Boiling Water Reactor] Vessel and Internals Project, Plan for Extension of the BWR Integrated Surveillance Program (ISP) Through the Second License Renewal (SLR), (BWRVIP-321)." By email dated October 21, 2020 the NRC staff issued its draft safety evaluations (SEs) (ADAMS Accession No. ML20280A318).

EPRI provided comments on the draft SE by letter dated November 5, 2020 (ADAMS Accession No. ML20318A165). The comments identified proprietary information, made editorial changes, and provided recommendations for clarification of the SE.

The NRC staff has found the TR acceptable for referencing in licensing applications for nuclear power plants to the extent specified and under the limitations delineated in the TR and in the enclosed SE. The final SE defines the basis for our acceptance of the TR. A copy of the final SE, which contains proprietary information, was provided to Ms. Wynter McGruder via the NRC box.com folder.

Our acceptance applies only to material provided in the subject TR. We do not intend to repeat our review of the accepted material described in the TR. When the TR appears as a reference in license applications, our review will ensure that the material presented applies to the specific plant involved. License amendment requests that deviate from this TR will be subject to a plant-specific review in accordance with applicable review standards.

In accordance with the guidance provided on the NRC website, we request that EPRI publish accepted versions of the proprietary and nonproprietary TR within six months of the date of the date of this email. The accepted versions shall incorporate this email and the enclosed SE after the title page.

For the nonproprietary version, EPRI shall redact the proprietary information in the final SE and strike the header and footer to create the nonproprietary version of the SE.

Both this email and the SE have been placed in ADAMS and made Official Agency Records. The SE is declared as nonpublic because it may contain proprietary information. This email is declared public.

Also, the accepted versions must contain historical review information, including NRC requests for additional information (RAIs) and responses. The accepted versions shall include a "-A" (designating approved) following the TR identification symbol.

As an alternative to including the RAIs and RAI responses behind the title page, if changes to the TRs provided to the NRC staff to support the resolution of RAI responses, and the NRC staff reviewed and approved those changes as described in the RAI responses, there are two ways that the accepted version can capture the RAIs:

1. The RAIs and RAI responses can be included as an Appendix to the accepted version.
2. The RAIs and RAI responses can be captured in the form of a table (inserted after the final SE) which summarizes the changes as shown in the accepted version of the TR. The table should reference the specific RAIs and RAI responses which resulted in any changes, as shown in the accepted version of the TR.

If future changes to the NRC's regulatory requirements affect the acceptability of this TR, EPRI will be expected to revise the TR appropriately. Licensees referencing this TR would be expected to justify its continued applicability or evaluate their plant using the revised TR.

If you have any questions, please contact the Project Manager for the review, Joseph J. Holonich at jjh1@nrc.gov.

Dennis Morey, Chief
Licensing Processes Branch
Division of Operating Reactor Licensing
Office of Nuclear Reactor Regulation

Docket No.: 9902016
EPID: L-2019-TOP-0007

FINAL SAFETY EVALUATION

BY THE OFFICE OF NUCLEAR REACTOR REGULATION

ELECTRIC POWER RESEARCH INSTITUTE TOPICAL REPORT

BWRVIP-321: BOILING WATER REACTOR VESSEL AND INTERNALS PROJECT

"PLAN FOR EXTENSION OF THE BWR INTEGRATED SURVEILLANCE PROGRAM (ISP) THROUGH THE SECOND LICENSE RENEWAL (SLR)"

1.0 INTRODUCTION

1.1 Background

By letter dated March 8, 2019 (Ref. 1), the Boiling Water Reactor (BWR) Vessel and Internals Project (BWRVIP) submitted the Electric Power Research Institute (EPRI) Proprietary Report TR-3002013097, "BWR Vessel and Internals Project, Plan for Extension of the BWR Integrated Surveillance Program (ISP) Through the Second License Renewal (SLR), (BWRVIP-321)" dated December 2018, for U. S. Nuclear Regulatory Commission (NRC) staff review. EPRI supplemented the report in letters dated June 8, 2020, July 9, 2020, and July 15, 2020 (Refs. 2 - 4), in response to the NRC staff request for additional information documented in the NRC letter dated October 23, 2019 (Ref. 5).

1.2 Purpose

The staff reviewed the BWRVIP-321 report, including the supplemental information in References 2 through 4, to determine whether it will provide an acceptable reactor pressure vessel (RPV) material surveillance program in accordance with Appendix H to Title 10 of the *Code of Federal Regulations* (10 CFR). The regulation at 10 CFR Part 50, Appendix H, is to support all operating U.S. BWR plants participating in the current ISP for the subsequent period of extended operation (i.e., 60 to 80 years of plant operation). The data from this program will be used to monitor changes in the fracture toughness properties of RPV materials due to irradiation and provide adequate information for required RPV integrity evaluations.

1.3 Regulatory Requirements

The regulation at 10 CFR 50.60 invokes Appendix H that requires licensees to implement an RPV material surveillance program. The purpose of the program is to monitor changes in the fracture toughness properties of ferritic materials in the reactor vessel beltline region, which results from exposure of these materials to neutron irradiation and the thermal environment. In compliance with the requirements of Appendix H, licensees for all operating U.S. BWRs have implemented plant specific RPV material surveillance programs as part of each facility's licensing basis.

However, an alternative to individual plant-specific RPV surveillance programs is addressed in Paragraph III.C of Appendix H. Pursuant to Paragraph III.C. of Appendix H, an RPV ISP may be implemented, with the approval of Director of the Office of Nuclear Reactor Regulation, by two or more facilities with similar design and operating features.

Paragraph III.C of Appendix H also sets forth specific criteria upon which approval of an ISP shall be based. The specified criteria in Paragraph III.C.1 of Appendix H include the following:

a) the reactor in which the materials will be irradiated and the reactor for which the materials are being irradiated must have sufficiently similar design and operating features to permit accurate comparisons of the predicted amount of radiation damage;
b) each reactor must have an adequate dosimetry program;
c) there must be adequate arrangement for data sharing between plants;
d) there must be a contingency plan to assure that the surveillance program for each reactor will not be jeopardized by operation at reduced power level or by an extended outage of another reactor from which data are expected; and,
e) there must be substantial advantages to be gained, such as reduced power outages or reduced personnel exposure to radiation, as a direct result of not requiring surveillance capsules in all reactors in the set.

In addition, Paragraphs III.C.2 and III.C.3 of Appendix H specify the following, respectively:

1. No reduction in the requirements for number of materials to be irradiated, specimen types, or number of specimens per reactor is permitted.
2. After (the effective date of this section), no reduction in the amount of testing is permitted unless previously approved by the Director, Office of Nuclear Reactor Regulation, or Director, Office of New Reactors, as appropriate.

1.4 Applicability

This safety evaluation is applicable to all U.S. BWRs participating in the approved BWRVIP ISP that intend to pursue a renewed operating license to 80-years of operation pursuant to 10 CFR Part 54, and reference BWRVIP-321 in its License Renewal Application.

2.0 SUMMARY

BWRVIP-86, Revision 1-A, "BWR Vessel and Internals Project, Integrated Surveillance Program (ISP) Implementation Plan" (Ref. 6), is the current program plan document for the ISP, which was issued in 2012. This report covers the original license and renewed license periods of BWR participants in the ISP. Plants are currently evaluating the possibility for subsequent license renewal, which would allow for operation to 80 years of plant life. The BWRVIP, in coordination with the EPRI Long Term Operation Program, initiated efforts to address limitations of the current ISP for SLR.

Considerations for extending the current ISP to provide data for 80 years of operation include:

- The total number of plants and which plants will pursue SLR are currently uncertain
- Some current ISP host plants may not pursue SLR

- Plants pursuing SLR may have surveillance materials not representative of other plants and, therefore, are not suitable as host plants
- Current host plants will likely not have additional capsules available for testing following the completion of the current ISP
- Some representative surveillance materials were in the BWR Supplemental Surveillance Program (SSP) capsules only, and no further capsules containing those materials are available to be tested
- Many BWRs, as well as ISP host plants, have lag factors as opposed to lead factors (i.e., capsules are exposed to lower fluence than the peak RPV inside surface fluence)

Given these considerations, EPRI's approach for satisfying the requirements of Appendix H in the SLR period and the Generic Aging Lessons Learned (GALL)-SLR report involves maintaining the existing structure of the BWRVIP ISP. Although some plants (including current host plants) may not pursue SLR, the ideal approach is to ensure that all ISP representative materials have specimens that are irradiated to a fluence that bounds the SLR fluences of all target materials represented by that surveillance material. EPRI explained that this will be accomplished by irradiating, reconstituting, and testing previously tested ISP capsule materials, as necessary, to ensure that any plant which pursues SLR will have appropriate data available for its representative materials. This approach maintains the critical elements of the ISP, particularly the current ISP test matrix, and existing data will be utilized to the extent possible. Where gaps in data exist (i.e., 80-year surveillance data does not exist), previously tested specimens will be reconstituted to generate additional surveillance data.

EPRI explained that this approach has the following advantages:

- This approach is consistent with the current BWRVIP ISP program. The implementation of this approach at individual BWR plant sites would be consistent with the current ISP. There would be no changes to the existing ISP test schedule in BWRVIP-86, Revision 1-A. The responsibilities of utilities to implement ISP data remain unchanged. The only change with respect to the ISP is the addition of 80-year data where such data does not currently exist.

- The representative and target materials, as defined in the approved ISP test matrix, remain unchanged. The program will continue to generate additional surveillance data for the previously tested capsule materials to achieve fluence levels representative of the projected 80-year target vessel fluences. As such, this approach provides an excellent opportunity to trend embrittlement data over time and maintains the philosophy of an ISP as described in Appendix H.

- The reconstitution approach is technically feasible since the methods and techniques for reconstitution are currently available and have been used successfully. American Society for Testing and Materials International (ASTM) E1253-13, "Standard Guide for Reconstitution of Irradiated Charpy-Sized Specimens," addresses procedures for reconstitution of ferritic pressure vessel steels used in nuclear power plant applications, and there is a significant amount of experience with reconstituted specimens to show that the data is reproducible.

- This approach can be implemented in a timeframe that supports all possible applicants for SLR by providing 80-year surveillance data for all ISP materials. As

such, this approach reduces uncertainty associated with not knowing which plants may pursue SLR.

2.1 "Data Investigations" (Section 4 of BWRVIP-321)

Section 4 of BWRVIP-321 evaluated the data needs for SLR by examining the available data from the current BWRVIP ISP program. Extension of the ISP into the SLR period is based on evaluating the extent to which available surveillance specimens can provide additional data to bound 80 years of plant operation. Fluences for 80 years are projected for reactor vessel target materials, and target fluences are compared with fluences of tested capsules. The gaps and additional data requirements to monitor embrittlement to 80 years are identified. The feasibility of planning and implementing SSLR (Supplemental Second License Renewal) capsules is also addressed in Section 4. These investigations include the most recent surveillance capsule and reactor vessel fluence data.

Based on its comparison of fluence values and fluence ratios between the tested/near-term ISP capsules (Table 4-3, "ISP capsule fluence as a % of SLR 1/4T fluence for target plates," and Table 4-4, "ISP capsule fluence as a % of SLR 1/4T fluence for target welds") and yet to be tested ISP(E)[1] capsules (Table 4-6, "Projected ISP(E) capsule fluence as a % of SLR 1/4T fluence for target plates," and Table 4-7, "Projected ISP(E) capsule fluence as a % of SLR 1/4T fluence for target welds"), EPRI determined that many of the capsule fluence as a percentage of 72-Effective Full Power Years (EFPY) fluence ratios increase from less than 100% to greater than 100%.

Specifically, the previously tested ISP surveillance capsules and near-term planned ISP capsules (i.e., information in Section 4 of BWRVIP-321), bound the projected 72-EFPY 1/4T fluences of nine of the 33 target plate heats and eight of the 33 target weld heats. When ISP(E) capsules are considered (Table 4-6 and Table 4-7), surveillance data are expected to bound the 72-EFPY 1/4T fluences of five additional target plates and eight additional target welds beyond those capsules that are bounded by the capsules that will be tested by the end of the original license period.

EPRI explained that when considering the data from ISP(E) capsules, additional surveillance data is needed for 13 of 15 representative plate heats and 10 of 15 representative weld heats. Thus, EPRI proposed reconstitution, further irradiation, and testing of previously tested Charpy specimens to attain the needed surveillance data. Three groupings of specimens are proposed based on the additional fluence exposure that would be required to catch-up to or bound the corresponding target heats for 80 years of operation.

2.2 "Reconstitution Approach" (Section 5 of BWRVIP-321)

Section 5 of BWRVIP-321 discusses the procedures that will be used in the specimen reconstitution process. As discussed in BWRVIP-321, the proposed approach in obtaining additional surveillance data to bound 80 years of plant operation is to further irradiate material

[1] An ISP capsule designated for withdrawal and testing during the first extended license period (i.e., 40-60 years of plant operation), to differentiate from the ISP capsules withdrawn during the original license period.

from previously tested Charpy specimens and subsequently use that material to reconstitute Charpy specimens. EPRI explained that broken Charpy halves will be retrieved from the ISP repository and machined to remove plastically deformed material or base metal from weld specimens. The resulting material comprises the central portion, or "insert," of the reconstituted Charpy specimen. Inserts from a total of 23 material heats will be placed in 3 newly fabricated SSLR capsules for further irradiation. The capsules will be installed in a host plant reactor vessel using a specially designed holder. After irradiation is complete, reconstituted Charpy specimens will be fabricated by welding end-tabs to the irradiated inserts. The specific representative heats of material identified for reconstitution is dependent on the surveillance data needs for those plants that pursue SLR. The reconstituted specimens will then be subjected to impact testing. The Charpy specimen reconstitution will be delayed until after irradiation of the inserts is complete.

EPRI performed evaluations to confirm that the objectives of the ISP for SLR program can be accomplished with the materials available in the ISP repository. EPRI proposed that its approach for reconstitution and testing of SSLR capsule materials meets ASTM E 1253-13 and ASTM E 185-82, "Standard Practice for Conducting Surveillance Tests for Light-Water Cooled Nuclear Power Reactor Vessels."

2.3 "Fluence and Flux Considerations" and "Schedule for SSLR Capsule Insertion, Withdrawal, and Testing" (Sections 6 and 8 of BWRVIP-321, respectively)

Section 6 of BWRVIP-321 states that the primary objective for obtaining additional surveillance data is to achieve a fluence exposure for representative heats that meets or exceeds target reactor vessel fluence for 80 years of plant operation. These needed catch-up fluences cannot be attained prior to the end of 80 years of operation using typical BWR surveillance capsule flux rates. Given that it is desirable to achieve the required fluences in a reasonable timeframe (~10 years), an accelerated flux rate is needed. EPRI explained that the target flux range for the proposed SSLR capsules has a minimum of 2.4×10^{10} n/cm^2-s and maximum of 4.39×10^{10} n/cm^2-s.

The minimum flux is determined based on the need to attain the maximum catch-up fluence of [[ ]] in a reasonable time, approximately 10 years. The maximum flux is based on a "breakpoint value" for flux of 4.39×10^{10} n/cm^2-s for the embrittlement trend curve in 10 CFR 50.61a. The evaluations performed by EPRI demonstrate that the target flux can be attained for the proposed SSLR capsules at several possible installation locations within the reactor vessel at one of the four candidate host plants in order to obtain the target flux.

Section 8 of BWRVIP-321 assesses the anticipated timeframe for SSLR capsule insertion and withdrawal and compares those times with license periods for BWRs for the three SSLR capsule groupings. As supplemented by letter dated June 8, 2020, EPRI developed three capsule insertion and withdrawal scenarios that consider the minimum, intermediate, and maximum flux values that are expected for the potential host plants, and insertion dates ranging from 2022 to 2024. EPRI included these scenarios in BWRVIP-321 to provide flexibility in the selection of insertion and withdrawal dates. EPRI showed that irradiation of all three SSLR capsules is expected to be complete well before the end of the second period of extended operation (PEO) for all BWRs (i.e., 80-years of operation), and before the end of the first PEO for most BWRs (i.e., 60-years of operation).

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2.4 "Conceptual Design for SSLR Capsules" (Section 7 of BWRVIP-321)

Section 7 of BWRVIP-321 provides the conceptual design features of the SSLR capsules, capsule contents, and capsule holders. EPRI explained that the Charpy inserts for each surveillance material will be contained in a packet, with one packet per material, and that these packets will be contained in three separate SSLR capsules. The SSLR capsules will be contained in a single capsule holder that attaches to the outside surface of the core shroud of the host plant.

2.5 "Administration and Implementation" and "Licensing Aspects of Implementation" (Sections 9 and 10 of BWRVIP-321, respectively)

Section 9 of BWRVIP-321 provides the administration and implementation aspects of the program. Specifically, the project management respons bilities and licensee responsibilities are outlined, and the process for evaluation of capsule data, fluence, and dosimetry. In addition, the details regarding plans for ongoing vessel dosimetry and potential ISP changes, data sharing, and data utilization.

Section 10 of BWRVIP-321 provides the details for implementation of the ISP for SLR program in Plant Technical Specifications or Updated Final Safety Analysis Report, an assessment of the ISP for SLR program's compliance with Appendix H, and NUREG-2191, "Generic Aging Lessons Learned for Subsequent License Renewal (GALL-SLR) Report."

3.0 NRC STAFF EVALUATION

The NRC staff has reviewed the information in the BWRVIP-321 report against the criteria specified in Paragraph III.C. of Appendix H for the establishment of an ISP.

The staff has also reviewed the technical basis for, and comprehensive description of, the proposed program against the objectives of being able to monitor changes in the fracture toughness properties of RPV materials due to irradiation and providing adequate information for required RPV integrity evaluations. Additional details regarding the staff's evaluation of the ISP(E) are provided below.

3.1 Material Selection and Data Investigations (Section 4 of BWRVIP-321)

Section 4 of BWRVIP-321 describes the data investigation performed to determine the data needs for SLR, which involved evaluating available data from the BWRVIP ISP program. EPRI initially projected the neutron fluence at 80 years for the reactor vessel target materials and these target fluences were compared with fluences of tested capsules to identify gaps and additional surveillance data needs to monitor embrittlement to 80 years of plant operation.

The representative surveillance materials and the corresponding target materials in each U.S. BWR reactor vessel, as defined in the ISP test matrix in BWRVIP-86, Revision 1-A, remain unchanged. Using this ISP test matrix, EPRI determined the projected 72-EFPY 1/4T fluences for the target plate and target weld heats in each U.S. BWR reactor vessel. EPRI explained that fluence values were taken from the most recently docketed P-T curve reports or ART tables in the NRC Agencywide Documents Access Management System (ADAMS). However, in some instances where more up-to-date fluence values were available that differed from the latest docketed fluences, the more up-to-date fluences were used. For some plants, more up-to-date

fluences were available in fluence evaluations prepared in conjunction with recently removed ISP capsules. The staff finds the use of the most up-to-date fluences values appropriate because this information is only used by EPRI for planning purposes within BWRVIP-321 to identify the materials that need higher-fluence surveillance data to support 80-year of plant operation for the BWR licensees.

EPRI explained that the neutron fluence at the location of the target heat and corresponding to the 40-years or 60-years of plant operation was utilized (i.e., best available information) and projected for SLR (assumed to be 80 years or 72 EFPY) by extrapolating linearly from fluences provided in source documents for the plant-specific EFPY (typically 32 or 54 EFPY). The staff finds the determination of the projected neutron fluence for SLR (i.e., 72 EFPY) by linear extrapolation to be conservative for determining the needed catch-up fluences of the representative surveillance materials because it is based on the assumption plants will have operated at 90 percent capacity the entire life of the plant (i.e., 80-years of operation).

EPRI explained that projected 1/4T SLR target vessel neutron fluences were then compared to tested and planned surveillance capsule fluence, which shows that some materials are already bounded by existing ISP or projected ISP(E) data. The remaining materials that are not bounded require additional data. EPRI explained that the list of representative material heats that require additional surveillance data, as well as materials for which no additional surveillance data is required, is summarized in Table 4-8, "Summary of representative materials for which additional surveillance data is required," of BWRVIP-321. The NRC staff reviewed Table 4-8 of BWRVIP-321 specifically those materials in which EPRI identified not needing additional surveillance data for the SLR period. The staff reviewed these materials and its evaluation of each material in which no additional surveillance data is required for the SLR period is documented below.

The staff reviewed Tables 4-3 and 4-6 of BWRVIP-321 and noted that for plate material "[[redacted]]" the neutron fluence of the tested ISP capsule and the to be tested ISP(E) capsule is greater than the estimated 72-EFPY 1/4T target fluence for the target vessel (i.e., [[redacted]]). Thus, the staff finds it acceptable that plate material, "[[redacted]]," is not included in BWRVIP-321 and the SSLR capsules.

The staff reviewed Tables 4-3 and 4-6 of BWRVIP-321and noted that plate material "[[redacted]]" the neutron fluence of the tested ISP capsule is greater than the estimated 72-EFPY 1/4T target fluence for the target vessels (i.e., [[redacted]]). Thus, the staff finds it acceptable that the plate material, "[[redacted]]," is not included in BWRVIP-321 and the SSLR capsules.

The staff reviewed Table 4-7 of BWRVIP-321 and noted that for weld material "[[redacted]]" the projected neutron fluence of the to be tested ISP(E) capsule is greater than the estimated 72-EFPY 1/4T target fluence for the target vessel (i.e., [[redacted]]). Thus, the staff finds it acceptable that no additional surveillance data is necessary for the weld material, "[redacted]]," to support the ISP for 60 to 80 years of plant operation. In addition, since [[redacted]] is the only target vessel for weld material "[[redacted]]," the staff finds that an early (potential) shutdown of [[redacted]] (i.e., host plant for the ISP(E) capsule) and the corresponding reduced capsule fluence would have no impact on the ability of any other ISP participant to attain 80-year surveillance data.

The staff reviewed Table 4-7 of BWRVIP-321 and noted that for weld material "[[redacted]]" the projected neutron fluence of the to be tested ISP(E) capsule is greater than the estimated

72-EFPY 1/4T target fluence for the target vessel (i.e., [[ ]]). Thus, the staff finds it acceptable that no additional surveillance data is necessary for the weld material, "[[ ]]," to support the ISP for 60 to 80 years of plant operation. In addition, since [[ ]] is the only target vessel for weld material "[[ ]]," the staff finds that an early (potential) shutdown of [ ] (i.e., host plant for the ISP(E) capsule) and the corresponding reduced capsule fluence would have no impact on the ability of any other ISP participant to attain 80-year surveillance data.

The staff reviewed Tables 4-3 and 4-6 of BWRVIP-321 and noted that weld materials "[ ]]" the neutron fluence of their respective tested ISP capsules are greater than the estimated 72-EFPY 1/4T target fluence for the target vessels (i.e., [[ ]], respectively). Thus, the staff finds it acceptable that the weld materials, "[[ ]]" are not included in BWRVIP-321 and the SSLR capsules.

For the representative surveillance materials that require additional surveillance data to support SLR, EPRI determined the necessary catch-up fluence (i.e., difference between projected 72-EFPY fluence and the fluence from previous capsules). The determination of the necessary catch-up fluence for each representative surveillance material needing additional surveillance data allowed EPRI to categorize the materials into three SSLR capsule groupings. The staff finds this approach to be reasonable because it allows the staggered withdrawal of the SSLR capsules and ensures that these surveillance materials are not irradiated beyond the recommendations in GALL-SLR (i.e., neutron fluence of the capsule between one and two times the peak neutron fluence of interest at the end of the 80-years of plant operation).

The staff reviewed Table 4-13, "Proposed Group 3 reconstituted and irradiated surveillance test specimens," of BWRVIP-321 and noted that the final fluence exposure of plate material [[ ]] under the minimum flux will be slightly less than 72-EFPY projected fluence for one target plant (i.e., [[ ]]). The staff noted that this SSLR capsule will need an irradiation time of 10 or 6 years, under the minimum and maximum neutron flux, respectively. The staff finds it reasonable that the final fluence exposure of plate material [[ ]] will exceed the neutron fluence exposure of the reactor vessel for this target plant because (1) the 72-EFPY projected fluences are a conservative estimate, as discussed above, (2) the neutron flux exposure of the SSLR capsule is expected to be between minimum and maximum values (i.e., not exactly at the minimum flux), and (3) there is a window of three refueling outages for this SSLR capsule to be withdrawn.

As supplemented by letter dated June 8, 2020 (Ref. 2), EPRI explained the plate material [[ ]] will be included in the SSLR capsules, independent of the ISP(E) capsule fluence, because at least one target plant requires additional surveillance data for this material and would not have been bounded by the original projected ISP(E) capsule fluence. Thus, the staff finds the early withdrawal of the Duane Arnold ISP(E) capsule does not impact the other target plants relying on the additional surveillance data for plate material [[ ]]. Further, EPRI explained that the weld heat "[ ]]" has only one target plant, [[ ] which has shut down in 2020. Thus, the staff finds the inclusion of the weld heat "[[ ]]" is not required to support other BWRVIP ISP participants planning to pursue SLR.

As supplemented by letter dated June 8, 2020 (Ref. 2), EPRI explained the tables in Section 4 of BWRVIP-321 were reviewed and discrepancies were identified in Tables 4-3, 4-4, 4-6, and 4-7 (discrepancies were provided in the marked-up pages of BWRVIP-321 in its RAI response). The

fluence and percentage values in the other Section 4 tables are correct. EPRI explained that these discrepancies were due to errors in transcr bing values from calculation worksheets into BWRVIP-321. However, the discrepancies in these report tables did not propagate into subsequent calculations. Consequently, there is no impact to the SSLR capsule projections; therefore, the overall impact of these discrepancies in BWRVIP-321 is minimal. EPRI also confirmed that the ISP(E) data bounds eight additional target welds and that the discrepancy identified by the NRC staff was due to errors in transcribing values from calculation worksheets into BWRVIP-321.

Based on its review, as described above, the NRC staff finds EPRI's determination of the materials that require additional surveillance data for the SLR period, as outlined in Table 4-8 of BWRVIP-321, to be acceptable and will ensure that surveillance data will be obtained for the necessary materials to support all operating U.S. BWR plants participating in the current ISP that chose to pursue SLR.

3.2 Specimen Reconstitution Approach (Section 5 of BWRVIP-321)

EPRI's proposed approach to obtaining additional surveillance data to bound 80 years of plant operation is to further irradiate material from previously tested Charpy specimens and subsequently use that material to reconstitute Charpy specimens. Broken Charpy halves will be retrieved from the ISP repository and machined to remove plastically deformed material or base metal from weld specimens. The resulting material comprises the central portion, or "insert," of the reconstituted Charpy specimen. Inserts from a total of 23 material heats will be placed in three newly fabricated SSLR capsules for further irradiation.

EPRI explained that ASTM E 1253-13 contains procedures for reconstitution of irradiated Charpy specimens and includes requirements on insert size and weld heat input to ensure that reconstituted specimens produce test results equivalent to those of virgin material. The staff noted that ASTM E 1253-13 specifies the use of an insert with a minimum length of 18mm, which is to be welded between two end-tabs (same or similar material). This minimum insert length is based on Charpy-impact specimen testing where the plastic zone is largest and fabricated with a technique where heat input and HAZ sizes are largest.

ASTM E 1253-13 indicates that this dimensional requirement may be relaxed, if it can be shown that the plastic deformation zone in subsequent testing will not extend into the heat affected zones produced by reconstitution and the heat input during welding shall be controlled such that no part of the volume of the central 10mm portion of the reconstituted Charpy-sized specimen exceeds the prior metal irradiation temperature at any time during welding. The staff noted that it is necessary to control the heat input, as described in ASTM E 1253-13, to preclude irradiation damage annealing in the insert; however, this requirement can be relaxed if it can be shown that the plastic deformation zone in subsequent testing will not extend past the zone where irradiation temperature is exceeded.

EPRI investigated the use of smaller insert lengths to determine whether the conditions from ASTM E 1253-13 on insert dimensions and heat input due to the reconstitution process would be fulfilled from the previously tested Charpy specimens in the "ISP Repository." Section 5.2.1 of BWRVIP-321 states that several studies have examined the lengths of inserts that provide acceptable results for reconstituted Charpy specimens. Specifically, an effort in Europe (i.e., RESQUE) as reported in ASTM STP1418, "Small Specimen Test Techniques: Fourth Volume," that provided results for various insert lengths (i.e., 10mm to 20mm) that were

reconstituted used an optimized stud weld process. The results from the RESQUE study indicated that (1) the 12mm inserts were found to lie within standard scatter for Charpy energy in the transition region but differed by 10-15 percent in upper shelf energy and (2) the results for 15mm inserts were found to be within normal scatter in both the transition region and upper shelf region.

In addition, the results of a round robin study on reconstitution as reported in NUREG/CR-6777, "Results and Analysis of The ASTM Round Robin On Reconstitution" (ADAMS Accession No. ML022540225) and ASTM STP-1329, "Small Specimen Test Techniques," indicate that 10mm inserts could be used on the lower shelf or lower transition region of Charpy curves, and there is generally little effect on the use of 14mm inserts for all Charpy energy levels except at high upper shelf energy using a certain load cell geometry. The staff noted that these studies referenced by EPRI support the use of specimen insert lengths less than 18mm, provided that the smaller inserts are tested at the appropriate Charpy energy levels to ensure results equivalent to those of virgin material are produced. The staff noted that the ability to use specimen insert lengths less than 18mm is permitted by ASTM E 1253 and may be necessary due to the availability of specimen inserts for certain materials.

Section 5.2.2 of BWRVIP-321 states that arc stud welding is commonly used for reconstitution of Charpy specimens to meet the heat input requirements of ASTM E 1253 that were discussed previously. EPRI cited work performed by Battelle, in which Argon gas was used with 10mm square end-tabs to potentially eliminate the need for post-weld machining. EPRI also referenced a study documented in ASTM STP 1418 that was performed to determine the risk of annealing the radiation damage during specimen reconstitution. It was noted in this study that annealing is not likely to occur at temperatures of 450°C for a few minutes or 500°C for approximately one minute for irradiated RPV steels. Based on the welding method used in this study (i.e., arc stud welding), the temperature 1.8mm from the weld never exceeded 500°C, and after 5 seconds the specimen had been cooled by over 100°C. The staff noted that this study indicates that that there is little risk of annealing so long as the exposure time at high temperatures is kept to a minimum (i.e., consistent with arc stud welding) and supports the use of specimen insert lengths less than 18mm.

Section 5.4.2 of BWRVIP-321 states that arc stud welding will be used for reconstitution of the SSLR capsule inserts in accordance with the requirements of ASTM E 1253, which permit the use of any welding process provided that the specified heat input and dimensional requirements can be achieved. EPRI explained that the end-tabs will be oversized so that they can be machined via electric discharge machining in plane with the irradiated insert. Further, in accordance with ASTM E 1253 (i.e., requires measurements to demonstrate that the reactor irradiation temperature is not exceeded for a given selection of welding parameters), EPRI indicated that temperature records will be taken using thermocouples during welding of a set of Charpy-sized reconstitution specimens.

The staff finds the use of arc stud welding for joining the end-tabs and the irradiated specimen insert acceptable because (1) the use of this welding process has been demonstrated in studies to be capable of reconstituting irradiated specimen inserts and is consistent with a method used in the development of ASTM E 1253-13, and (2) EPRI will record temperature measurements during the arc stud welding process to preclude irradiation damage annealing. In addition, EPRI confirmed that finite element calculations and testing of arc stud welded specimens will be conducted on representative materials to qualify the methods that will eventually be used on specimens in the SSLR capsules.

Based on its review of these studies, the staff finds the use of specimen insert lengths less than 18mm reconstituted by arc stud welding to be acceptable and capable of producing results equivalent to those of virgin material, provided that the smaller inserts lengths are tested at the appropriate Charpy energy levels in order (i.e., inserts at least 12mm can be tested in the lower shelf to transition region, and inserts at least 15mm can be tested at any region on the transition curve).

As supplemented by letter dated June 8, 2020 (Ref. 2), EPRI explained that the testing of the Peach Bottom Unit 2 30° capsule was completed and the calculated neutron fluence is 9.13×10^{17} n/cm^2 (E>1.0 MeV). Since the Peach Bottom Unit 2 capsule received a higher fluence than originally predicted (i.e., Table 4-7 of BWRVIP-86, Revision 1-A is [[ ]]), which was used in the assessment performed in BWRVIP-321, the staff notes there is no impact to any of the calculations performed to determine the materials selected for the SSLR capsules, as well as their corresponding catch-up fluences. EPRI explained that following completion of the Peach Bottom Unit 2 capsule testing, the broken Charpy specimens of the weld metal and HAZ were etched and it has determined that there are a sufficient number of 18mm inserts for the weld material. Therefore, as supplemented by letter dated June 8, 2020, EPRI revised to Tables 5-1 and 5-2 of BWRVIP-321.

Section 5.3 of BWRVIP-321 states that the materials that will be included in the SSLR capsules are the same materials used in the existing ISP program, but in order to include the existing weld materials, a study was conducted to determine the population of previously tested specimens with adequate weld material to satisfy the recommended insert length in ASTM E 1253-13. EPRI explained that for weld materials, inserts can be fabricated from previously tested weld or heat-affected zone (HAZ) specimens, provided the portion of the specimen consisting of weld material would yield an insert of adequate length. For plate materials, EPRI confirmed that all the needed specimens are available in the ISP repository; thus, no issues were identified in obtaining an adequate number of inserts with the 18mm length.

The staff reviewed the revised Table 5-1, "Summary of weld etch study results," and Table 5-2, "Number of usable weld specimens as a function of insert length," of BWRVIP-321, which contains the summary of weld etch study results and number of usable weld specimens as a function of insert length, respectively. [[ ]]

The staff noted that consistent with ASTM E 1253 and the primary focus to have 10mm of weld in the center of the insert that never exceeded maximum irradiation temperatures during welding, which will allow for a total of 8 mm of length that will potentially be annealed. Therefore, the staff noted that up to 4mm of base metal or HAZ can be used for the weld interface material of the specimen insert during the reconstitution process. EPRI explained that this may increase the number of usable inserts to slightly above the current lengths provided in Table 5-2 of BWRVIP-321, as supplemented by letter dated June 8, 2020. In particular, the staff noted surveillance capsules in current BWRs capsules often contain as few as eight specimens since many existing capsules were designed to earlier versions of ASTM E 185 (i.e., required less than the target of 14 specimens) and high-quality Charpy curves can be developed. As previously discussed, the staff finds the use of specimen insert lengths less than 18mm reconstituted by arc stud welding to be acceptable and capable of producing results equivalent to those of virgin

material, provided that inserts at least 12mm can be tested in the lower shelf to transition region, and inserts at least 15mm can be tested at any region on the transition curve.

Thus, for these three weld materials the staff finds it reasonable that adequate surveillance data will be available to support 80-years of operation for the target plants because (1) up to 4mm of base metal or HAZ can be used for the weld interface material of the specimen insert during the reconstitution process, which may increase the number of usable insert lengths, (2) adequate results can be achieved to characterize the Charpy transition curve with less than the target of 14 specimens when proper experimental and curve fitting techniques are employed, and (3) embrittlement models and data from previously tested surveillance materials will be used to inform the appropriate test temperatures, and the suitable insert specimen sizes will be selected for testing in the regions that will produce results equivalent to those of virgin material.

Section 5.4 of BWRVIP-321 describes the details of the proposed approach for specimen insert fabrication and arc stud welding to ensure that the requirements of ASTM E 1253 are met for reconstituting irradiated Charpy-sized specimens. Section 5.4.1 of BWRVIP-321 states that to meet the condition in ASTM E 1253 that plastic zone size does not extend into the reconstitution weld HAZ, the following approach is being proposed:

- The fracture surface and plastically deformed material from the broken Charpy halves will be machined off to produce the weld reconstitution insert
- For the weld and HAZ specimens, it will also be necessary to machine base metal from the end opposite of the fracture surface for some specimens
- Electric discharge machining will be used to prepare inserts
- Anvil indentations; engraving marks, and other blemishes will be oriented so that they are on the notch surface of the reconstituted specimen

The staff finds that the use of electric discharge machining appropriate because this machining process is precise and does not produce cold worked material, which occurs with the use of conventional milling process. In addition, the staff finds that orienting existing indentations, markings and blemishes such that they are on the notch surface of the reconstituted specimen is appropriate because this practice would minimize adverse effects, if any, on the quality of the surveillance data obtained from Charpy energy measurements and helps ensure that reconstituted specimens produce test results equivalent to those of virgin material.

Section 5.4.3 of BWRVIP-321 indicates that the Charpy-impact tests will be conducted in accordance with ASTM E 185-82. Furthermore, EPRI explained that prior to any testing, the Charpy energy-temperature curve will be predicted using embrittlement models and previous test data. The first test will then be conducted near the middle of the transition region using an 18mm or 15mm insert specimen, and the remaining test temperature decisions will then made based on the test results. Overall, the goal will be to perform two or three tests on the upper shelf, and to use the remaining specimens to characterize the 30 ft-lb (41J) index temperature. For the remaining test temperature selections, the 15mm insert specimens will be tested in the mid and upper transition region, and the 12mm insert specimens will be tested only in the lower shelf region.

The staff finds BWRVIP's approach to conduct Charpy-impact tests in accordance with ASTM E 185-82 to be acceptable and consistent with Section B.III.1 of Appendix H. In addition, the staff finds BWRVIP's approach to determine the appropriate use of the available inserts to be

reasonable because it is based on available embrittlement models and data from previously tested surveillance materials to inform the appropriate test temperatures, and the suitable insert specimen sizes will be selected for testing in the regions that will produce results equivalent to those of virgin material.

3.3 Fluence and Flux Considerations and Schedule for SSLR Capsule Insertion, Withdrawal, and Testing" (Sections 6 and 8 of BWRVIP-321)

EPRI explained the following considerations were taken into account when selecting candidate host plants and to address the contingency planning requirements of Appendix H for cases of plant shutdown and provide flexibility for changes that may occur between the time of program plan development and capsule insertion (i.e., Paragraph III.C.1.d of Appendix H):

- Similarity to Other Plant Designs
- End of 60-year License Dates
- Existing Quality Fluence Model
- Existing ISP Host Plant

Based on its review, the staff finds these considerations for selecting potential candidate host plants to be reasonable and appropriate because (1), if it became necessary, there would be flexibility to transfer the SSLR capsules to another SLR host plant with minimal impact to the program, (2) ensure some level of certainty that SSLR capsules can be installed and obtain the needed fluence levels regardless if the host plant decides to pursue SLR, (3) existing high- quality and up-to-date fluence model facilitates the selected SSLR capsule installation locations will provide the necessary surveillance data in the desired timeframe of approximately 10 years, and (4) the use of an existing ISP host plant ensures there is familiarity with the process and respons bilities of a "host plant."

Section 6.1 of BWRVIP-321 states that the target flux range for the proposed SSLR capsules has a minimum of 2.4×10^{10} n/cm^2-s and maximum of 4.39×10^{10} n/cm^2-s. The minimum flux is determined based on the need to attain the maximum catch-up fluence of [[ ]] in a reasonable time, approximately 10 years. Whereas the maximum flux is based on a "breakpoint value" for flux of 4.39×10^{10} n/cm^2-s for the embrittlement trend curves in 10 CFR 50.61a. EPRI explained that the proposed SSLR capsule flux range is higher than typical BWR capsule flux, which are on the order of 10^8 to 10^9 n/cm^2-s; however, they are on a similar order of magnitude to the flux for some SSP capsules (i.e., flux in the range 8.3×10^9 to 1.9×10^{10} n/cm^2-s). The staff finds that that the target range of fluxes identified by EPRI (i.e., 2.4×10^{10} n/cm^2-s and maximum of 4.39×10^{10} n/cm^2-s) are acceptable for determining the optimal mounting location of the SSLR capsules in the host plant's vessel because the minimum value is representative of previously irradiated SSP capsules used in the development of the BWRVIP ISP, and the maximum value is less than a value at which flux effects may be a concern on irradiation embrittlement.

Section 6.3 of BWRVIP-321 explains that the flux values and flux spectra are based on transport models built for the four plants using the Radiation Analysis Modeling Application (RAMA) fluence methodology. EPRI explained that these calculations were performed using the RAMA, RAFTER, and RAFFLE software packages.

The staff noted that the neutron fluence projections presented by EPRI are not directly used to support a specific plant operating into the SLR period, rather the neutron fluence predictions are

only used to identify candidate locations for the SSLR capsules so the neutron fluence for the specimens will reach the target value within 10 years. The staff noted that an evaluation of capsule fluences will be performed for each of the SSLR capsules as part of the testing and reporting of the capsule. Specifically, the flux wires will be removed from each capsule and analyzed for radioactivity content by gamma spectroscopy. The analysis of dosimeters will be performed using standard, benchmarked methods.

SSLR capsule fluence evaluations will be performed in a consistent manner using an RPV neutron fluence calculational methodology that will meet current NRC staff guidance in NRC Regulatory Guide (RG) 1.190, "Calculational And Dosimetry Methods for Determining Pressure Vessel Neutron Fluence" (ADAMS Accession No. ML010890301). The staff reviewed BWRVIP's analytical methodology for selecting the optimal SSLR capsule installation locations in each of the candidate host plants and determined that the approach used to calculate the neutron fluences is reasonable and consistent with current practices for the RAMA methodology. The staff noted that the neutron fluence methods approved by the NRC staff are unique to the individual licensee's current licensing basis and that any proposal by a BWR facility to change its neutron determination methodology is the responsibility of the individual licensee to meeting all applicable licensing requirements.

Based on this neutron fluence analytical methodology, it was demonstrated by EPRI that the target flux can be attained for the proposed SSLR capsules in four candidate host plants with several possible installation locations to yield the target flux. EPRI stated that the optimal installation locations for the SSLR capsules are found to be (1) several inches radially from the core shroud toward the RPV inside surface, (2) within ±5° of the 0° and 180° positions, which are low flux locations free from jet pump obstructions, and (3) between 60-100" from the bottom of active fuel (BOAF), where the flux profile will be relatively uniform over the height of the capsule.

As supplemented by letter dated June 8, 2020 (Ref. 2), EPRI explained that the proposed mounting location of the SSLR capsules will be several inches (radially) away from the outside diameter core shroud surface (exact dimensions will be determined for the selected host plant to achieve the desired flux and fluence for the three capsule groupings). Irrespective of the exact radial location relative to the shroud outside diameter, EPRI confirmed that the capsules will be exposed to the fluid temperature in the reactor annulus which is typically 525°F to 535°F, depending on the feedwater temperature.

Additionally, the fast flux spectra between the original and proposed locations are comparable; thus, any differences/variations in fast flux and the effect on irradiation temperature are expected to be minor. As such, the SSLR capsules will be exposed to an irradiation temperature that is consistent with original BWR surveillance capsules at the inner diameter surface of the reactor vessel. The design of the SSLR capsules will be similar to those of the original design of BWR surveillance capsules (e.g., overall dimensions, materials of construction, flux wires, etc.) therefore, the current methods to determine surveillance capsule irradiation temperature history will be used.

The staff finds the optimal locations for the SSLR capsules to be reasonable because the SSLR capsules will be exposed to the necessary flux to attain the needed catch-up fluence in a reasonable amount of time to best support any BWR that decides to pursue a SLR. Furthermore, the staff finds that design of the SSLR capsules, including their proposed mounting locations, will be exposed to an irradiation and fluid temperature consistent with original BWR surveillance capsules at the inner diameter surface of the reactor vessel; thus, it is not expected that the SSLR

capsules will produce non-conservative estimates of embrittlement for the materials to be irradiated. As discussed in Section 3.4 of this SE, it is incumbent on host plant that is selected (or the alternate host plant, if needed) to comply and fulfill all design and licensing requirements for implementing the installation of the SSLR capsule holder in accordance with the plant's current licensing basis.

EPRI reiterated in its letter dated June 8, 2020 (Ref. 2), the evaluation in BWRVIP-321 was intended to demonstrate that multiple plants could serve as host plants for the SSLR capsules. The staff finds that regardless of the selected host plant several actions that include but are not limited to (1) determining the radial offset from the core shroud and azimuthal position to achieve the target flux and fluence, (2) verifying projected fluence values, and (3) selecting the withdrawal schedule. In its review of BWRVIP-321, the staff has determined that EPRI has demonstrated the proposed host plants are of similar design and operating features, in accordance with Appendix H and capable of supporting the implementation of the ISP SLR program, such that the SSLR capsules can achieve the target catch-up fluences in a reasonable timeframe.

Section 8 of BWRVIP-321 provides a potential schedule for capsule insertion and withdrawal. These schedules are based on the assessment of flux maps for the four candidate host plants. The flux maps indicate that the target range of 2.4×10^{10} to 4.39×10^{10} n/cm^2-s can be attained if the capsule is located in the annulus region in selected ranges of azimuthal, axial, and radial locations. EPRI further stated that capsules will be irradiated in increments corresponding to 2-year refueling cycles, so the needed irradiation time at the maximum and minimum flux is rounded up to the nearest even whole number. As summarized in Table 4-14, the SSLR capsule irradiation can be completed in 2 years for Group 1, 2-4 years for Group 2, and 6-10 years for Group 3. Based on an assumed installation date of SSLR capsules in the host plant in 2022, EPRI constructed schedules with the anticipated timeframe for SSLR capsule insertion and withdrawal compared with licensed periods of operation and expected subsequent license renewal periods (60 to 80 years of operation) for BWRs for the three SSLR capsule groupings.

As supplemented by letter dated June 8, 2020 (Ref. 2), EPRI developed 3 capsule insertion and withdrawal scenarios that consider the minimum, intermediate, and maximum flux values that are expected for the potential host plants, and insertion dates ranging from 2022 to 2024. EPRI proposed to include these scenarios in BWRVIP-321 to provide flex bility in the selection of insertion and withdrawal dates.

Based on its review of the figures and tables in Section 8 of BWRVIP-321, as supplemented by letter dated June 8, 2020 (Ref. 2), the staff noted that irradiation of all 3 SSLR capsules (i.e., Groups 1 through 3) will be completed well before the end of the second PEO (i.e., 60 to 80 years of operation) for all BWRs, and for nearly all BWRs before the end of the first PEO (i.e., 40 to 60 years of operation) for all scenarios with insertion dates ranging from 2022 to 2024.

The staff noted that there is the possibility that irradiation of the Group 3 SSLR capsule may not be complete before the end of the first PEO for four plants based on the insertion dates ranging from 2022 to 2024. However, this is based on the Group 3 SSLR capsule being irradiated at the minimum target neutron flux (i.e., 2.4×10^{10} n/cm^2-s). The staff noted that if the Group 3 SSLR capsule is exposed to the maximum neutron target flux range, the irradiation of all three SSLR capsules (i.e., Group 1s through 3) will be completed roughly at the end of the first PEO (i.e., 40 to 60 years of operation) for the US BWR fleet.

The staff finds the proposed withdrawal schedules (i.e., insertion dates ranging from 2022 to 2024) for the SSLR capsules in Groups 1, 2, and 3 acceptable because the necessary surveillance data to assess reactor vessel integrity for plant operation through 80-years will available for the majority of ISP participants well in advance of entering the subsequent PEO. Furthermore, for the four plants in Group 3 identified above, the staff finds the proposed withdrawal schedules (i.e., insertion dates ranging from 2022 to 2024) reasonable because the necessary surveillance data to assess reactor vessel integrity for plant operation through 80-years will available to the applicable target plants at the onset of the subsequent PEO period.

Therefore, based on the target range of fluxes (i.e., 2.4×10^{10} to 4.39×10^{10} n/cm^2-s) and installation date of the SSLR capsules in the host plant, based refueling outage schedule, ranging from 2022 to 2024, the staff finds the proposed withdrawal schedule for the SSLR capsules (Groups 1, 2, and 3) in BWRVIP-321, as supplemented by letter dated June 8, 2020 (Ref. 2), to be acceptable. The staff noted that any withdrawal schedule beyond those proposed in BWRVIP-321, as supplemented by letter dated June 8, 2020 (Ref. 2) (i.e., Table 8-1, "Scenario 1: Insertion and Withdrawal Dates for Minimum Flux of 2.4E10 n/cm^2-s," Table 8-2, "Scenario 2: Insertion and Withdrawal Dates for Minimum Flux of 3.4E10 n/cm^2-s," and Table 8-3, "Scenario 3: Insertion and Withdrawal Dates for Minimum Flux of 4.39E10 n/cm^2-s), must be submitted with a technical justification and approved by the NRC staff prior to implementation, in accordance with Paragraph III.B.3 of Appendix H.

3.4 SSLR Capsule Design (Section 7 of BWRVIP-321)

Section 7.1.1 of BWRVIP-321 states that positive identification of the materials must be maintained throughout the insert preparation, encapsulation, irradiation, weld reconstitution, and post-irradiation testing. EPRI explained that all previously tested ISP and SSP Charpy specimens are currently in the EPRI specimen repository in individual containers that are marked with the plant and capsule identification. This inventory list is carefully maintained and reviewed annually so that every broken Charpy specimen is known and easily retrievable. Based on BWRVIP's current practices for accounting of previously tested ISP and SSP Charpy specimens, the staff finds it reasonable that the appropriate materials, including number of specimens, will be installed in the proper SSLR capsule (i.e., Groups 1, 2, or 3); thus, ensuring the proper materials accumulate the necessary catch-up fluence to support plant operation to 80 years.

EPRI stated that positive identification of the reconstitution inserts will be maintained during the irradiation period by only including one material in each packet. Positive identification during packet fabrication will be ensured by only having one material worked on at a time during the machining, packet loading, and packet weld closure operation and each packet will be marked on the end-tab with both lettering and with a binary code. EPRI indicated that it is possible to mark each insert; however, the staff finds that creating any marking on the specimen inserts is not desirable because it would adversely affect the post-irradiation reconstitution and testing, and the quality of surveillance data obtained. The staff noted that positive identification will be maintained by only opening one Charpy packet at a time. The staff finds this practice of only opening one Charpy packet at a time after irradiation ensures that the unmarked reconstitution inserts are accurately identifiable so that the correct surveillance data is available to a BWR ISP participant pursuing SLR and avoids any possible confusion with different surveillance materials.

[

[redacted]]].

[[[redacted]]] The staff noted that the selection of dosimeter wires is generally consistent with those contained in existing BWR surveillance capsules and EPRI has demonstrated experience in obtaining the necessary dosimetry measurements. The staff finds that these conceptual design features for the SSLR capsules are reasonable and ensure that EPRI will be capable of identifying, testing, and obtaining the proper dosimetry measurements and surveillance data for a BWR ISP participant when it is determined to be necessary to support plant operation in the subsequent PEO.

Section 7.2 of BWRVIP-321 provides the following characteristics for the specialized holder for the SSLR capsule so that the materials can achieve the necessary range of fluence needed to catch-up to the target reactor vessel fluence (i.e., 72-EFPY) in a reasonable amount of time (i.e., approximately 10 years):

- Single holder capable of containing three SSLR capsules (i.e., Groups 1, 2, and 3)
- Allows for the removal of a single capsule from the holder independently
- Allows for the removal and transfer of the capsules to an alternate host plant, if needed
- Attaches to the outside surface of the core shroud to enable capsules to achieve target flux range
- Does not restrict access to in-vessel visual inspections, or if so, is able to easily be relocated and reinstalled to allow for these activities
- Requires minimal modification to the host plant
- Withstands host plant seismic conditions (and for the alternate host plant, should the capsule need to be moved)
- Not susceptible to flow-induced vibration

EPRI also states that the following conceptual capsule holder designs have been developed and evaluated for the candidate host plants that will be mounted to the shroud outside surface using mechanical methods so that weldability of irradiated materials is not an issue. A detailed capsule holder design effort will be conducted after NRC approval of the ISP for SLR program plan. Appropriate design and licensing requirements for implementing the installation of the holder will be met.

The staff finds the considerations identified by EPRI to be reasonable and appropriate because (1) the proposed conceptual design would cause minimal modification and disruption to the host

plant meeting its existing current licensing basis requirements (e.g., inspections), (2) there is flexibility to ensure the continuation of this program with an alternate host plant, and (3) withstands applicable loads of the host plant (e.g., seismic and flow-induced vibration loads). Nevertheless, the staff finds that it is incumbent on the host plant that is selected (or the alternate host plant, if needed) to comply and fulfill all design and licensing requirements for implementing the installation of the SSLR capsule holder in accordance with the plant's current licensing basis. Therefore, the NRC staff's review and approval of BWRVIP-321 is not associated with the approval of the design of the SSLR capsule holder and does not obviate the host plant's responsibility for design and licensing requirements of the SSLR capsule holder.

3.5 Administration and Implementation (Section 9 of BWRVIP-321)

Section 9.1 of BWRVIP-321, defines EPRI's responsibilities as the program manager for implementing the ISP for SLR program on behalf of the industry licensees that may adopt it into their licensing bases. With the exception of the submittal of capsule reports, the staff finds these responsibilities/activities for EPRI to be acceptable because they are consistent to those defined for the currently approved version of the ISP in Chapter 5.1 of BWRVIP-86, Revision 1-A report. The staff's evaluation related to the submittal of capsule reports for BWRVIP-321 is discussed in Section 3.5 of this SE.

Section 9.2 of BWRVIP-321 defines the activities and responsibilities of licensees that plan to implement the ISP for SLR program. Specifically, it indicates that it is the licensee's responsibility to update the fluences values and percentages reported in Tables 4-3, 4-4, 4-6, and 4-7 of BWRVIP-321 using the latest fluence projections for its plant(s) at the time that the Subsequent License Renewal Application is submitted. The staff noted that the process for performing these activities is given in Figure 9-1 of BWRVIP-321.

As supplemented by letter dated June 8, 2020 (Ref. 2), EPRI stated that Figure 9-1 of BWRVIP-321 has been amended to include an additional verification step "to ensure that the actual tested capsule fluence has been accounted for in determining if additional surveillance data is needed for SLR." The staff finds the revision to Figure 9-1 of BWRVIP-321 establishes an acceptable process for licensees to verify whether additional surveillance data from the SSLR capsules will be needed for the RPV target materials during a proposed PEO, based on the actual capsule fluence from the ISP for License Renewal (i.e., BWRVIP-86, Revision 1-A). Thus, the staff finds that the methodology in Figure 9-1 of BWRVIP-321, as supplemented by letter dated June 8, 2020 (Ref. 2), to be an acceptable methodology for performing this confirmatory activity because it adequately addresses the licensee responsibilities for updating relevant fluences and percentages in BWRVIP-321 for SLR (e.g., 72 EFPY), and includes necessary steps to confirm the as-tested capsule fluence from the ISP for License Renewal (i.e., BWRVIP-86, Revision 1-A).

Section 9.3 of BWRVIP-321 provides the methodology that will be used to perform evaluations of capsule specimen Charpy-impact test results. The staff finds the methods described in Section 9.3 of BWRVIP-321 acceptable because they are either consistent with those approved in BWRVIP-86, Revision 1-A, or those defined in RG 1.99, Revision 2, "Radiation Embrittlement of Reactor Vessel Materials" (ADAMS Accession No. ML031430205).

Sections 9.4 and 9.5 of BWRVIP-321 provides the methodology that will be used to perform capsule neutron fluence and dosimetry assessments using benchmarked standards and calculational methods that will conform to the guidance for neutron fluence calculations in RG 1.190. Section 9.6 of BWRVIP-321 provides the criteria that will be used by EPRI for data

sharing, which states that EPRI will coordinate, exchange, and share the applicable surveillance data with all BWR utilities participating in the ISP for SLR program. The staff finds these criteria in these Sections 9.4 and 9.6 of BWRVIP-321 to be acceptable because they are consistent with those previously approved in BWRVIP-86, Revision 1-A. The staff finds the options for non-host plant dosimetry and fluence assessments in Section 9.5 of the BWRVIP-321 report to be acceptable because they are consistent with those approved for non-host plant facilities in Section 5.4 of BWRVIP-86, Revision 1-A, and with RG 1.190.

Section 9.7 of BWRVIP-321 provides the criteria that will be used by EPRI for data utilization. EPRI stated that Option 1 is used for situations when the heat of material does not specifically match the limiting heat of beltline material for that vessel, and Option 2 is used when two or more surveillance data sets with matching heat numbers are available for the limiting beltline material. As supplemented by letter dated June 8, 2020 (Ref. 2), EPRI indicated that the evaluation and application of surveillance data will continue to follow the established methodology documented in RG 1.99, Revision 2, and BWRVIP-86, Revision 1-A. EPRI also explained that if (1) there are not two or more credible data points per RG 1.99, Revision 2, Position 2.1 or (2) the surveillance material is not a heat match to the vessel, the surveillance data will only be used for assessment of embrittlement trend correlations. The staff finds that EPRI's response provides a sufficient demonstration that its methodology for data utilization described in Section 9.7 of BWRVIP-321 is consistent with the guidance in RG 1.99, Revision 2.

Section 9.8 of BWRVIP-321 discusses EPRI's contingency plan for the ISP for SLR program and the potential situations that may arise when implementing this program. EPRI stated that it will monitor the progress of the ISP for SLR program, coordinate future actions (such as withdrawals and testing of SSLR capsules), and identify additional programmatic needs. EPRI also stated that it will identify and implement minor changes to the program as the need arises, such as changes to the insertion location, withdrawal, and testing schedule of the SSLR capsule. The staff noted that it is incumbent on EPRI to assess these potential changes to determine whether it deviates from what is approved in this SE or warrants prior approval in accordance with Appendix H.

3.6 Licensing Aspects of Implementation (Section 10 of BWRVIP-321)

The staff's evaluation of compliance of the ISP for SLR program in accordance with Paragraph III.C.1 of Appendix H is documented below:

(1) *ISP Similarity of Plant Design and Operating Environments Requirement*.
For this requirement, the staff finds that the ISP for SLR program will meet Criterion 1 for ISPs in Paragraph III.C.1 of Appendix H, even if a BWR facility's site-specific basis for implementing the ISP is updated to include the ISP for SLR for its BWR RPV target plate and weld materials.

(2) *ISP Use of Site-Specific Neutron Dosimetry Program Requirement*.
For this requirement, the staff finds that the ISP for SLR program has been updated to adequately address neutron fluence calculation and dosimetry needs for both host plant facilities or non-host plant facilities during the SLR period and that the BWRVIP ISP will meet Criterion 2 for ISPs in Paragraph III.C.1 of Appendix H, even if a BWR facility's site-specific basis for implementing the ISP is updated to include the ISP for SLR.

(3) *ISP Data Sharing Requirement*.
For this requirement, the staff noted that the data sharing basis for the host plants and non-host plants participating in the ISP for SLR program is the same as that developed and approved for the ISP in the BWRVIP-86, Revision 1-A. Therefore, the staff also finds that the BWRVIP ISP will meet Criterion 3 for ISPs in Paragraph III.C.1 of Appendix H, even if a BWR facility's site-specific basis for implementing the ISP is updated to include the ISP for SLR.

(4) *ISP Programmatic Contingency Plan Requirement*.
For this requirement, EPRI stated that the ISP in BWRVIP-86, Revision 1-A already includes appropriate contingency options to account for changes in power or prolonged shutdowns of the host reactor facilities. EPRI also states that the existing ISP already includes several options that may be taken in the event of capsule damage or loss or indefinite shutdowns of a host reactor facility, and that the contingency plans for the ISP in BWRVIP-86, Revision 1-A carry over into the ISP for SLR program.

The staff has evaluated the potential contingencies that may result as a result of BWRVIP's implementation of the ISP for SLR program in the staff's evaluation of Section 9.8 of BWRVIP-321, as given in Section 3.5 of this SE. The staff evaluates how potential contingencies may impact compliance with other requirement provisions in Paragraph III.C of Appendix H, later in this SE section. However, the staff finds that the ISP for SLR program meets the criterion Paragraph III.C.1 of Appendix H, for inclusion of a programmatic contingency plan because the plan is provided and has been adequately defined in Section 9.8 of BWRVIP-321.

(5) *ISP Requirement – Demonstration of Substantial Advantages to Be Gained Through Implementation of an ISP*.
For this requirement, the staff noted that the advantages to be gained by implementing the ISP for SLR program are the same as those for implementing the ISP in accordance with BWRVIP-86, Revision 1-A. Therefore, the staff finds that the BWRVIP ISP will meet Criterion 5 for ISPs in Paragraph III.C.1 of Appendix H, even if a BWR facility's site-specific basis for implementing the ISP is updated to include the ISP for SLR.

Section 10.2.1 of BWRVIP-321discusses how the ISP for SLR program is consistent with the guidance in GALL-SLR AMP XI.31, "Reactor Vessel Materials Surveillance." Section 10.2.2 of BWRVIP-321 discusses how the ISP for SLR program may create the alternative criteria to the requirements for ISPs in Appendix H, or alternative criteria to the program elements for ISPs in GALL-SLR AMP XI.M31. The staff evaluates BWRVIP's alternate criteria in the following subsections:

(1) *Paragraph IV.A of Appendix H to 10 CFR Part 50 – Capsule Test Reporting Deadline*.
EPRI stated that, when a SSLR capsule is withdrawn under the ISP for SLR, all RPV surveillance specimens from the capsule will be placed into storage until it is determined that data for a given material are needed. The staff's evaluation of this alternate criteria is documented in its assessment of Sections 10.3.1 and 10.3.2 of BWRVIP-321.

(2) *Paragraph III.C.2 of Appendix H to 10 CFR Part 50 – Reduction in Number of Specimens*.
EPRI stated that establishment of the ISP does not result in a reduction in the number of material being irradiated, number of specimen types, or number of specimens per reactor being tested. Furthermore, all capsules credited under the current ISP will be withdrawn and tested according to the schedule established in BWRVIP-86, Revision1-A and that no ISP capsules will be deferred to the SLR period. However, EPRI stated that it is unknown whether there will be a reduction in the number of specimens being tested in the ISP for SLR program because, at this time, it is unknown which plants will pursue SLR and which material specimens will need to be tested.

Paragraph III.C.3 to Appendix H states that, "no reduction in the amount of testing is permitted unless previously authorized by the Director, Office of Nuclear Reactor Regulation." As such, once it is known which plants will pursue SLR and whether there is a reduction in the number of specimens, it is incumbent upon the licensee, if necessary, to request authorization for a reduction in the amount of testing as part of the ISP for SLR program.

(3) *GALL-SLR – Capsule Fluence Criteria*.
EPRI indicated that GALL-SLR recommends the withdrawal and testing of at least one capsule addressing the subsequent POE with a neutron fluence of one and two times the peak neutron fluence of interest at the end of the subsequent PEO. EPRI indicated that this criterion is met for the target plant that is the host plant for the SSLR capsule and is generally met for the target plant that has the highest 72-EFPY fluence needs for a given representative material. However, for other target plants, the SSLR capsule will generally exceed this fluence criterion, which is an inherent part of data sharing in an ISP and is relevant to some materials in the approved ISP.

Since it is unknown which plants will pursue SLR and which material specimens will need to be tested, the staff noted that it is unknown how many and which plants will exceed this fluence criterion described in GALL-SLR. As such, it is incumbent upon the licensee submitting an SLRA, if necessary, to identify and justify an exception to the guidance in the GALL-SLR, if it chooses to reference this document. The staff noted that its review and acceptance of BWRVIP-321 may serve as a basis for an exception to this fluence criterion described in GALL-SLR.

Section 10.3.1 of BWRVIP-321 states that the following information will need to be forwarded to the NRC when the following ISP for SLR program details have been confirmed:

1. Notification of the final host plant for SLR selection
2. Notification of the planned SSLR capsule insertion and withdrawal schedule
3. Notification of any changes to the SSLR capsule withdrawal schedule
4. Notification of SSLR capsule withdrawals
5. Notification of materials to be reconstituted and tested, and the timeline for reporting test results

With respect to Notification #1, #2, #3 and #4, the staff's review documented in Section 3.3. of this SE identified 4 host plants, and a range of insertion and withdrawal dates for the SSLR capsules

that provides EPRI flexibility in implementing the ISP for SLR program. Thus, as long as the final host plant, and planned SSLR capsule location, and insertion and withdrawal schedule are consistent with BWRVIP-321, the staff finds Notifications #1 through #4, are for informational purposes only. However, if EPRI changes the SSLR capsule location, and insertion and withdrawal schedule beyond what is identified in BWRVIP-321, the staff noted that prior approval in accordance with Paragraph III.B.3 of Appendix H to 10 CFR Part 50 is required.

Notification #5, as discussed in Section 10.3.2 of BWRVIP-321, addresses the timing of needed SSLR capsule report submittals. Since it is unknown which plants will pursue SLR, the staff noted that the following situations could occur if a licensee needs additional surveillance data to support SLR and decides to adopt BWRVIP-321 in its current licensing basis:

1. SSLR capsule is withdrawn before a plant is approved for SLR
2. SSLR capsule is withdrawn after a plant is approved for SLR

As supplemented by July 15, 2020 (Ref. 4), EPRI stated that the timing for the reporting of the SSLR capsule test report would commence "at the time of SLR application approval for capsules withdrawn prior to the approval" or "immediately following withdrawal of the capsule when the SLR applicant has already been approved." EPRI confirmed that the capsule reports would be submitted in accordance with the timeframe required by Paragraph IV of Appendix H and that the reports would include all data required by ASTM E 185-82 to the extent practicable for the configuration of the specimens in the capsule.

The staff finds the timing for submittal of SSLR capsule reports, as supplemented by letter dated July 15, 2020 (Ref. 4), acceptable because it will be in accordance with the reporting requirements in Paragraph IV.A of Appendix H. Specifically, if the SSLR capsule is withdrawn ***after*** a plant is approved for SLR, the capsule report will be submitted in accordance with the timeframe in Appendix H upon withdrawal of the capsule. Additionally, if the SSLR capsule is withdrawn ***before*** a plant is approved for SLR, the capsule report will be submitted in accordance with the timeframe in Appendix H to 10 CFR Part 50 upon the issuance of the renewed license for the SLRA (i.e., SSLR capsule is relied upon for aging management for SLR).

3.7 Appendix A of BWRVIP-321

Appendix A in BWRVIP-321 provides EPRI's RPV surveillance capsule representative material selection assessments for BWR target weld and target plates materials in the ISP. This information is analogous to those previously included in BWRVIP-86, Revision 1-A report. The staff acknowledges that EPRI amended the target material assessments in BWRVIP-321 to include the projected ¼-T neutron fluence estimates of the target materials through 80-years of licensed plant operation. EPRI did not amend any of the RPV surveillance material-to-target material relationships in BWRVIP-321; thus, the staff considers any changes to the information in BWRVIP-321 to be administrative edits of the information. As a result, the staff's review of BWRVIP-321 did not include an evaluation of the RPV surveillance material-to-target material relationships assessments performed for designated RPV target materials in Appendix A of BWRVIP-321.

4.0 LIMITATIONS AND CONDITIONS

There are no limitations or conditions identified by the staff.

5.0 USE AND REFERENCING OF THE TR

As addressed in BWRVIP-321 and in this SE, the use and referencing of BWRVIP-321 is an acceptable alternative to all existing BWR plant-specific RPV surveillance programs for the purpose of maintaining compliance with the requirements of Appendix H through the end of current facility 80-year extended operating licenses. The staff noted that for plants intending to implement BWRVIP-321, including this SE, will do so by submitting requests to the NRC as part of the Subsequent License Renewal Application or license amendment process.

6.0 CONCLUSION

The staff has reviewed BWRVIP-321 including the supplemental information, and based on the evaluation in Section 4 of this SE, finds BWRVIP-321, as supplemented by letters dated June 8, 2020 (Ref. 2), July 9, 2020 (Ref. 3), and July 15, 2020 (Ref. 4), and this SE, provides an acceptable means to adequately address the need for surveillance data for BWR licensees through the end of a facility's 80-year operating license, if SLR is pursued by licensees. Accordingly, BWRVIP-321, as supplemented by letters dated June 8, 2020 (Ref. 2), July 9, 2020 (Ref. 3), and July 15, 2020 (Ref. 4), and this SE, is acceptable for referencing to satisfy the requirements of Appendix H for BWR licensees through the end of the facility's 80-year operating license, if SLR is pursued by licensees.

7.0 REFERENCES

1. EPRI BWR Vessel and Internals Project (BWRVIP) Proprietary Letter No. 2020-021, "Transmittal of BWRVIP-321: BWR Vessel and Internals Project, Plan for Extension of BWR Integrated Surveillance Program (ISP) Through the Second License Renewal (SLR)," March 8, 2019 (ADAMS Accession No. ML19071A248 for the package; a non- proprietary version of the report is available to members of the general public at ADAMS Accession No. ML19071A235).

2. EPRI BWRVIP Proprietary Letter No. 2020-046, "BWRVIP Docket No. 99902016 – BWRVIP Response to BWRVIP-321 Request for Additional Information (RAIs)," June 8, 2020 (ADAMS Accession No. ML20188A355 for the package; non-proprietary version of the RAI response set is available to members of the general public at ADAMS Accession No. ML20188A357).

3. EPRI BWRVIP Proprietary Letter No. 2020-054, "BWRVIP Docket No. 99902016 – Revised BWRVIP Response for RAI-10 to the NRC Request for Additional Information on BWRVIP-321," July 9, 2020 (ADAMS Accession No. ML20191A268).

4. EPRI BWRVIP Proprietary Letter No. 2020-058, "BWRVIP Docket No. 99902016 – Revised BWRVIP Response for RAI-10 to the NRC Request for Additional Information on BWRVIP-321," July 15, 2020 (ADAMS Accession No. ML20206K867).

5. Email from Joseph J. Holonich (NRC) to Wynter McGruder (EPRI BWRVIP), "BWRVIP-321 Requests for Additional Information," October 23, 2019 (ADAMS Accession No. ML19288A052).

6. EPRI BWRVIP, "Updated BWR Integrated Surveillance Program (ISP) Implementation Plan," BWRVIP-86, Revision 1-A, June 2013 (ADAMS Accession No. ML131760082).

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BWRVIP-321: Boiling Water Reactor Vessel and Internals Project: Plan for Extension of the BWR Integrated Surveillance Program (ISP) Through the Second License Renewal (SLR). EPRI, Palo Alto, CA: 2018. 3002013097.

This publication is a corporate document that should be cited in the literature in the following manner:

BWRVIP-321NP-A: Boiling Water Reactor Vessel and Internals Project: Plan for Extension of the BWR Integrated Surveillance Program (ISP) Through the Second License Renewal (SLR). EPRI, Palo Alto, CA: 2021. 3002020504NP.

ABSTRACT

10CFR50 Appendix H requires that reactor vessels that will exceed a neutron fluence of 1×10^{17} n/cm^2 (E>1 MeV) by the end of license have a material surveillance program to monitor changes in the fracture toughness properties, which result from exposure to neutron irradiation and the thermal environment. Since 2002, the U.S. boiling water reactor (BWR) fleet has relied on an integrated surveillance program (ISP) to satisfy the requirements on 10CFR50 Appendix H. The U.S. Nuclear Regulatory Commission approved the program plan for the ISP: *BWRVIP-86, Revision 1-A: BWR Vessel and Internals Project, Updated BWR Integrated Surveillance Program (ISP) Implementation Plan* (1025144), designed to support the surveillance needs of the U.S. BWR fleet through 60 years of operation. Plants are currently evaluating the potential for a second license renewal (SLR), which would allow for operation to 80 years of plant life. This report provides a plan to extend the ISP for an SLR using a combination of existing data and the irradiation, reconstitution, and testing of previously tested surveillance specimens.

This report (3002020504NP) incorporates changes requested by the NRC Safety Evaluation of the report. For the NP version of the technical report, all EPRI proprietary information is marked out with either yellow highlighting or [[double brackets with yellow highlighting]].

Keywords
Boiling water reactor
Charpy testing
Mechanical properties
Radiation embrittlement
Reactor pressure vessel integrity
Reactor vessel surveillance program

ELECTRIC POWER RESEARCH INSTITUTE

EXECUTIVE SUMMARY

Deliverable Number: 3002020504NP

Product Type: Technical Report

Product Title: BWRVIP-321NP-A: Boiling Water Reactor Vessel and Internals Project: Plan for Extension of the BWR Integrated Surveillance Program (ISP) Through the Second License Renewal (SLR)

PRIMARY AUDIENCE: Plant engineers responsible for reactor vessel integrity

SECONDARY AUDIENCE: Utility staff responsible for boiling water reactor (BWR) extended operations assessments

KEY RESEARCH QUESTION

10CFR50 Appendix H requires that reactor vessels that will exceed a neutron fluence of $1x10^{17}$ n/cm^2 (E>1 MeV) by the end of license have a material surveillance program to monitor changes in the fracture toughness properties, which result from exposure to neutron irradiation and the thermal environment. Since 2002, the U.S. BWR fleet has relied on an integrated surveillance program (ISP) to satisfy the requirements on 10CFR50 Appendix H. The U.S. Nuclear Regulatory Commission approved the program plan for the ISP: *BWRVIP-86, Revision 1-A: BWR Vessel and Internals Project, Updated BWR Integrated Surveillance Program (ISP) Implementation Plan* (1025144), designed to support the surveillance needs of the U.S. BWR fleet through 60 years of operation. Plants are currently evaluating the potential for a second license renewal (SLR) which would allow for operation to 80 years of plant life. To continue to meet the requirements of 10CFR50 Appendix H in the SLR period, an extension to the ISP is needed.

RESEARCH OVERVIEW

Researchers projected the 80-year fluence values for the reactor vessels in the U.S. BWR fleet and compared them with the fluence values of surveillance data already provided by the ISP. Where ISP data were not able to bound the 80-year reactor vessel fluence values, a plan was formulated to irradiate material from previously tested surveillance specimens in a set of specially designed surveillance capsules. These irradiated materials would then be available for reconstitution and testing at a later date so that surveillance data could be provided for BWR plants pursuing an SLR. To ensure that a suitable amount of material existed to support the reconstitution approach, the previously tested specimens were etched and detailed measurements were taken. Neutron flux investigations were performed to determine the optimal placement of the specialized surveillance capsules within the RV annulus and to estimate the irradiation time needed for the materials to reach fluence values that bounded the 80-year reactor vessel fluence values. Conceptual designs were developed for the specialized surveillance capsules and their holder.

KEY FINDINGS

- The ISP can be extended to support the SLR by using a combination of existing data supplemented with the irradiation, reconstitution, and testing of previously tested surveillance specimens.
- Additional surveillance data are needed for 13 of the 15 ISP representative plate heats and 10 of the 15 ISP representative weld heats.
- Based on the results of the etching study, a suitable amount of material can be obtained from previously tested specimens to support the proposed irradiation, reconstitution, and testing approach.

- By locating the specialized surveillance capsules offset several inches from the core shroud outer wall at the 0° or 180° position, neutron flux values can be obtained that will enable the materials to reach the needed fluence values in 10 years or less.
- Conceptual designs have been developed for the specialized surveillance capsule and holder. It has been determined that these designs can be installed in the desired positions based on the flux investigations, and design constraints can be satisfied.

WHY THIS MATTERS

An extension to the ISP is necessary for plants to continue to implement the program in the SLR period. Without this extension, plants would need to reestablish plant-specific programs to satisfy the requirements of 10CFR50 Appendix H. Implementation of plant-specific programs is less cost-effective than an integrated program. Furthermore, it is possible that the use of a plant-specific program may reintroduce technical issues that originally motivated the development and implementation of the ISP.

HOW TO APPLY RESULTS

Requirements for implementation of this report are provided in Section 9.

LEARNING AND ENGAGEMENT OPPORTUNITIES

- The program plan for the current BWRVIP ISP is contained in the technical report, BWRVIP-86, Revision 1-A: BWR Vessel and Internals Project, Updated BWR Integrated Surveillance Program (ISP) Implementation Plan (1025144).
- The feasibility of options for extending or replacing the ISP was evaluated in technical report BWRVIP-295: Boiling Water Reactor Vessel and Internals Project, Reactor Vessel Material Surveillance for U.S. BWRs During the Second License Renewal: Feasibility Evaluation (3002007041).
- Data investigations recommended in BWRVIP-295 were performed and documented in the technical report, *BWRVIP-313, BWR Vessel and Internals Project: Data Investigations to Support the ISP for SLR* (3002010409).
- This current report was prepared in collaboration with the EPRI Long-Term Operations (LTO) Program.

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PROGRAM: Boiling Water Reactor Vessel and Internals Project, 41.01.03, and Long Term Operations, 41.10.01

IMPLEMENTATION CATEGORY: Category 1 – Regulatory

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ACRONYMS, ABBREVIATIONS, AND DEFINITIONS

10CFR50 Appendix G	Appendix G to Part 50 of Title 10 of the Code of Federal Regulations, “Fracture Toughness Requirements”
10CFR50 Appendix H	Appendix H to Part 50 of Title 10 of the Code of Federal Regulations, “Reactor Vessel Material Surveillance Program Requirements”
1/4T	One-quarter of the vessel wall thickness as measured from the clad-to-base metal interface at the vessel inner surface
Adjusted reference temperature	(ART) The reference temperature adjusted for irradiation effects by adding to the initial RT_{NDT} the transition temperature shift (due to irradiation) and an appropriate margin
ASME B&PV Code	American Society of Mechanical Engineers Boiler and Pressure Vessel Code
ASTM E185	American Society for Testing and Materials E185, “Standard Practice for Conducting Surveillance Tests for Light-Water Cooled Nuclear Power Reactor Vessels”
BWR	Boiling water reactor
BWROG	BWR Owners’ Group
BWRVIP	BWR Vessel and Internals Program
EFPY	Effective full power year
ESW	Electroslag welding
EOL	End-of-license
EOLE	End-of-license, extended
Existing Surveillance Program	The set of surveillance capsules that were installed originally when each BWR was licensed. The surveillance capsules typically include specimens for plate, weld, and HAZ materials. The test results from the specimens are to be used for monitoring radiation embrittlement for the plant.

Full Charpy curve	A Charpy curve based on Charpy V-notch tests of 8 or more specimens that are tested over a broad range of temperatures so as to properly characterize the upper shelf and the ductile-to-brittle transition behavior of the material.
GALL	U.S. NRC NUREG-1801, Revision 2, "Generic Aging Lessons Learned (GALL) Report"
GALL-SLR	U.S. NRC NUREG-2191, Volumes 1 and 2, "Generic Aging Lessons Learned for Subsequent License Renewal (GALL-SLR) Report"
HAZ	Heat affected zone
ISP	BWRVIP Integrated Surveillance Program
ISP(E)	An ISP capsule designated for withdrawal and testing during the first extended license period, to differentiate from the ISP capsules withdrawn during the original license period
Limiting material	The reactor vessel beltline material judged most likely to be controlling with regard to radiation embrittlement, based on a calculation of the adjusted reference temperature (ART) defined by Reg. Guide 1.99 using best estimate chemistries and projected EOL and/or EOLE fluence estimates
LWR	Light water reactor
MLE	Mils lateral expansion
PEO	Period of extended operation
PWR	Pressurized water reactor
Reg. Guide 1.99	U.S. NRC Regulatory Guide 1.99, Revision 2, "Radiation Embrittlement of Reactor Vessel Materials"
Representative material	A plate or weld material that is selected from among existing surveillance programs or the SSP to represent the corresponding target plate or weld material in a plant
Representative data set	The data set from the Charpy impact test of the representative material that consists of three Charpy curves: (1) unirradiated, (2) first irradiated, and (3) second irradiated
RPV	Reactor pressure vessel
SAW	Submerged arc weld
SLR	Second license renewal
SMAW	Shielded metal arc weld

SRM	Standard Reference Material is a material used to provide an independent check on the measurement of irradiation conditions for the surveillance materials. Also, sometimes referred to as *Correlation Monitor Material (CMM).*
SSLR	BWR Supplemental SLR capsules
SSP	BWR Supplemental Surveillance Program
Target material	A target weld or plate material is the specific vessel material to which the ISP test matrix assigns a representative surveillance material
USE	Upper shelf energy

RECORD OF REVISIONS

Revision Number	Revisions
BWRVIP-321	Original Report (3002103097)
BWRVIP-321-A	The report as originally published (3002103097) was revised to incorporate changes proposed by the BWRVIP in responses to NRC Requests for Additional Information, recommendations in the NRC Safety Evaluation (SE), and other necessary revisions identified since the last issuance of this report. All changes, except corrections to typographical errors, are marked with margin bars. In accordance with an NRC request, the SE is included here in the report frontmatter and the BWRVIP report number includes a "A" indicating the version of the report accepted by the NRC staff. Non-essential format changes were made to comply with the current EPRI publication guidelines. Appendix B added: NRC Request for Additional Information Appendix C added: BWRVIP Response to NRC Request for Additional Information Appendix D added: Revised BWRVIP Response for RAI-10 to the NRC Request for Additional Information Details of the revisions can be found in Appendix E.
BWRVIP-321NP-A	This report (3002020504NP) incorporates changes requested by the NRC Safety Evaluation of the report. For the NP version of the technical report, all EPRI proprietary information is marked out with either yellow highlighting or [[double brackets with yellow highlighting]].

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1 INTRODUCTION

Operating nuclear power plants in the U.S must meet the requirements of 10CFR50 Appendix H [1]. Appendix H requires that reactor vessels which will exceed a neutron fluence of 1×10^{17} n/cm^2 (E >1 MeV[1]) by the end of license (EOL) have a material surveillance program in order to monitor changes in the fracture toughness properties which result from exposure to neutron irradiation and the thermal environment. Fracture toughness test data are obtained from material specimens exposed in surveillance capsules, which are withdrawn periodically from the reactor pressure vessel (RPV). The data obtained from this material surveillance program are then used to demonstrate the vessel continues to meet the fracture toughness requirements of 10CFR50 Appendix G [2]. Of significance for boiling water reactors (BWRs), Appendix G provides the procedures by which the operating pressure-temperature (P-T) limit curves and leak test temperature are determined.

Each U.S. BWR was designed and built with a surveillance capsule program and until 2002, compliance with 10CFR50 Appendix H was demonstrated by each plant individually. Since 2002, the U.S. BWR fleet has relied on an integrated surveillance program (ISP) to provide fracture toughness data for RPV materials in lieu of plant specific programs [3]. The ISP uses select plant surveillance capsules to provide valuable data to support the ISP and to satisfy the requirements of 10CFR50 Appendix H. The current ISP, developed and managed by the Boiling Water Reactor Vessel and Internals Project (BWRVIP), was designed to support the surveillance needs of the BWR fleet through 60 years of operation (EOLE), which was the maximum license period foreseen at the time of its development [4]. Plants are currently evaluating the potential for a second license renewal (SLR) which would allow for operation to 80 years of plant life.

Recognizing the need to satisfy the requirements of 10CFR50 Appendix H in the SLR period, while also recognizing the limitations of the existing ISP for meeting those requirements, options for the SLR period were evaluated. This report incorporates the findings of those evaluations and provides a comprehensive program plan for extension of the ISP for the SLR period.

1.1 Implementation Requirements

The results documented in this report will be utilized by the BWRVIP ISP and by individual utilities to demonstrate compliance with 10CFR50 Appendix H Reactor Vessel Material Surveillance Program Requirements. Therefore, the implementation requirements of 10CFR50 Appendix H govern and the implementation requirements of Nuclear Energy Institute (NEI) 03-08, Guideline for the Management of Materials Issues, are not applicable.

[1] Neutron fluence and flux values identified in this report are for E>1MeV unless stated otherwise

2
BACKGROUND

2.1 Historical Background of the BWRVIP ISP

An RPV surveillance program is intended to monitor the changes in vessel material properties due to neutron irradiation. In July 1973, the Code of Federal Regulations, 10CFR50, Appendix H, established the first legal requirements for comprehensive surveillance programs in nuclear plants. Plants already licensed prior to that time had installed irradiation test samples using the guidance of the 1961 (tentative), 1962, 1966, 1970 or the then-emerging 1973 version of ASTM E185[2] [5]. Today, RPVs that exceed a peak neutron fluence of 1 x 10^{17} n/cm^2 at the end-of-license are required to have an RPV material surveillance program that monitors radiation embrittlement in accordance with 10CFR50 Appendix H.

Each BWR plant was built with a surveillance program that included weld, heat-affected zone (HAZ), and plate materials. However, many plant surveillance programs did not have surveillance materials that represented the limiting plate and/or weld material of the RPV. There are two reasons for this. First, many of the surveillance programs were implemented prior to the establishment of 10CFR50 Appendix H, and there were no specific requirements to choose materials that represent the limiting beltline material for plants built prior to 1973. Second, for some plants, multiple revisions to Regulatory Guide 1.99, the latest of which is Revision 2 [6], resulted in a change in the limiting beltline material for that vessel.

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[2] The current version of 10CFR50, Appendix H [1], cites the 1982 version of ASTM E185 [5].

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2.2 Limitations of Current ISP for Providing Data for SLR

Plants are currently evaluating the potential for SLR, which would allow for operation to 80 years of plant life. In 2015, the BWRVIP, in coordination with the EPRI Long Term Operation (LTO) Program, initiated efforts to address limitations of the ISP for SLR.

In order to evaluate the potential for extending the ISP through a SLR, it is important to identify the requirements in 10CFR50 Appendix H for an ISP. Furthermore, it is also important to understand the NRC's expectations for SLR applications in NUREG-2191, "Generic Aging Lessons Learned for Subsequent License Renewal (GALL-SLR) Report" [10].

Per the GALL-SLR report [10], an ISP may be considered for a set of reactors that have similar design and operating features, in accordance with 10CFR50 Appendix H, allowing for the use of the ISP in the SLR period. At least one dedicated capsule addressing the subsequent period of extended operation (PEO) must be tested, with capsule neutron fluence of one to two times the vessel neutron fluence of interest at the end of the subsequent PEO. The GALL-SLR report acknowledges that additional surveillance capsules may be needed for the subsequent PEO, suggesting that standby capsules or reconstitution of previously tested specimens and reinsertion to accumulate additional fluence may be used to obtain the needed test data.

Considerations for extending the current ISP to provide data for 80 years of operation include:

- The total number of plants and which plants will pursue SLR are currently uncertain.
- Some current ISP host plants may not pursue SLR.
- Plants pursuing SLR may have surveillance materials not representative of other plants and, therefore, are not suitable as host plants.

- Current host plants will likely not have additional capsules available for testing following the completion of the current ISP.
- Some representative surveillance materials were in the SSP capsules only, and no further capsules containing those materials are available to be tested.
- Many BWRs, as well as ISP host plants, have lag factors as opposed to lead factors (i.e., capsules are exposed to lower fluence than the peak RPV inside surface fluence).

2.3 Proposed Approach for Extending ISP for SLR

Recognizing the need to satisfy the requirements of 10CFR50 Appendix H in the SLR period, the BWRVIP evaluated options and feasibility for providing BWR RPV surveillance data for SLR. The recommended approach maintains the critical elements of the ISP, as discussed in Section 3 of this report. In order to determine whether such an approach was possible, further investigations of available data are summarized in Section 4 of this report. Sections 5 through 7 of this report provide further technical details of the ISP for SLR program, while Sections 8 through 10 address programmatic and licensing aspects of the program.

3 ISP FOR SLR APPROACH

Given the considerations and uncertainties discussed in the previous section, the optimum approach for satisfying the requirements of 10CFR50 Appendix H in the SLR period and the GALL-SLR report is to maintain the existing structure of the BWRVIP ISP. The ISP test matrix, as approved, provides adequate and appropriate surveillance data for all U.S. BWRs. Although some plants (including some host plants) may not pursue SLR, the ideal approach is to ensure that all ISP representative materials have specimens that are irradiated to a fluence that bounds the SLR fluences of all target materials represented by that surveillance material. This will be accomplished by irradiating, reconstituting, and testing previously-tested ISP capsule materials as necessary to ensure that any plant which pursues SLR will have appropriate data available for its representative materials.

This approach maintains the critical elements of the ISP, particularly the current ISP test matrix. Existing data will be utilized to the extent possible. For some materials, specimens from many capsules that were exposed to a wide range of fluence levels have been tested. Some tested specimens, such as SSP capsules which had higher lead factors than typical BWR capsules, have attained fluences exceeding 80-year projected reactor vessel fluences. Where gaps in data exist (i.e., 80-year surveillance data does not exist), previously tested specimens will be reconstituted to generate additional surveillance data.

3.1 Reconstitution Approach

When all remaining capsules are tested under the ISP, the current set of representative material specimens will have been fully used, with the exception of potential existing reconstituted capsules. For materials which require additional surveillance data, previously tested specimens from the BWRVIP ISP repository will be used for reconstitution. New Charpy test specimens will be fabricated by machining an insert, or central portion of the test specimen, from the broken Charpy halves and welding end tabs to the insert. Prior to reconstitution, the specimen inserts will be placed into specially designed Supplemental SLR (SSLR) capsules and be reinserted into a host reactor vessel to continue to irradiate the specimens to accumulate sufficient fluence to meet or exceed 80-year projected reactor vessel fluences. All SSLR capsules can be irradiated in one host plant. After irradiation is complete, reconstituted specimens will be fabricated and tested only for those materials that are needed by BWRs pursuing SLR. Details of the reconstitution procedures are discussed in Section 5. Figure 3-1 illustrates the sequence of steps in preparing a reconstituted Charpy specimen.

Irradiation of inserts prior to welding of end tabs has several advantages for the ISP for SLR program. More specimens can be placed in a single capsule, and the cost of completing specimen fabrication is deferred until after irradiation. Depending on which BWRs ultimately pursue SLR, it is possible that specimens for some materials will not need to be reconstituted and tested, resulting in saved cost. Irradiating inserts prior to specimen fabrication may increase the dose during the reconstitution process, however, dose is still expected to be lower than typical PWR levels and specimen reconstitution has been successful at those fluence levels.

The ISP test matrix approved in BWRVIP-86, Revision 1-A [4] will remain unchanged for the ISP for SLR program. The program will still consist of 15 representative plate heats and 15 representative weld heats, the limiting target materials for the BWR vessels will not be reevaluated, and the mapping of representative heats to target heats will be unchanged. This will maximize the usefulness of the available representative surveillance materials that are in the existing ISP program, which are well-characterized materials with applicable baseline and irradiated Charpy data.

New materials will not be added to the ISP for SLR program to address materials now considered as part of the extended beltline or changes in limiting materials as a result of potential changes in embrittlement trend curves (ETC). The guidance of ASTM E185-82 [5] does not require the ISP to maintain a dynamic test matrix in which the target material changes if the reactor vessel limiting material changes. Doing so would derive no technical benefit, and this would detract from the long-term effectiveness of the ISP, which is enhanced by maintaining the same target materials and associated representative surveillance materials and monitoring specific high-value surveillance materials over a long period of time. The intent of the ISP for SLR program is to trend the embrittlement behavior of the materials in the ISP. Adding a new material for the SLR period and obtaining a single surveillance data point would not allow for trending of embrittlement. This approach is consistent with implementation requirements approved by the NRC in the existing ISP and PWR plant-specific surveillance programs through 60 years of operation. Generally, the content of LWR surveillance programs have not changed regardless of the potential for a new material to become limiting based on updated projections of fluence, revised material chemistry factors and adjusted reference temperature (ART) values, or changes in regulatory requirements. The ability to predict the embrittlement of materials for which surveillance data does not exist is provided by the ETC and the margins required in its application. Adequate margins of safety are provided by the pressure-temperature limit curves developed in accordance with 10CFR50 Appendix G [2].

3.2 Benefits of the Proposed Approach

There are several advantages of the reconstitution approach:

1. *Consistency with Current BWRVIP ISP Program*

   This approach is consistent with the current BWRVIP ISP program. The implementation of this approach at individual BWR plant sites would be consistent with the current ISP. There would be no changes to the existing ISP test schedule in BWRVIP-86, Revision 1-A. The responsibilities of utilities to implement ISP data remain unchanged. The only change with respect to the ISP is the addition of 80-year data where such data does not currently exist.

2. *Maintains Trending of Embrittlement Data*

   The representative and target materials, as defined in the approved ISP test matrix, remain unchanged. The program will continue to generate additional surveillance data for the previously tested capsule materials to achieve fluence levels representative of the projected 80-year target vessel fluences. As such, this approach provides an excellent opportunity to trend embrittlement data over time and maintains the philosophy of an ISP as described in 10CFR50 Appendix H [1].

3. *Technical Feasibility*

   The reconstitution approach is technically feasible since the methods and techniques for reconstitution are currently available and have been used successfully. ASTM E1253-13 [11] addresses procedures for reconstitution of ferritic pressure vessel steels used in nuclear power plant applications, and there is a significant amount of experience with reconstituted specimens to show that the data is reproducible [12].

4. *Supports BWR SLR Applications*

   This approach can be implemented in a timeframe that supports all possible applicants for SLR by providing 80-year surveillance data for all ISP materials. As such, this approach reduces uncertainty associated with not knowing which plants may pursue SLR.

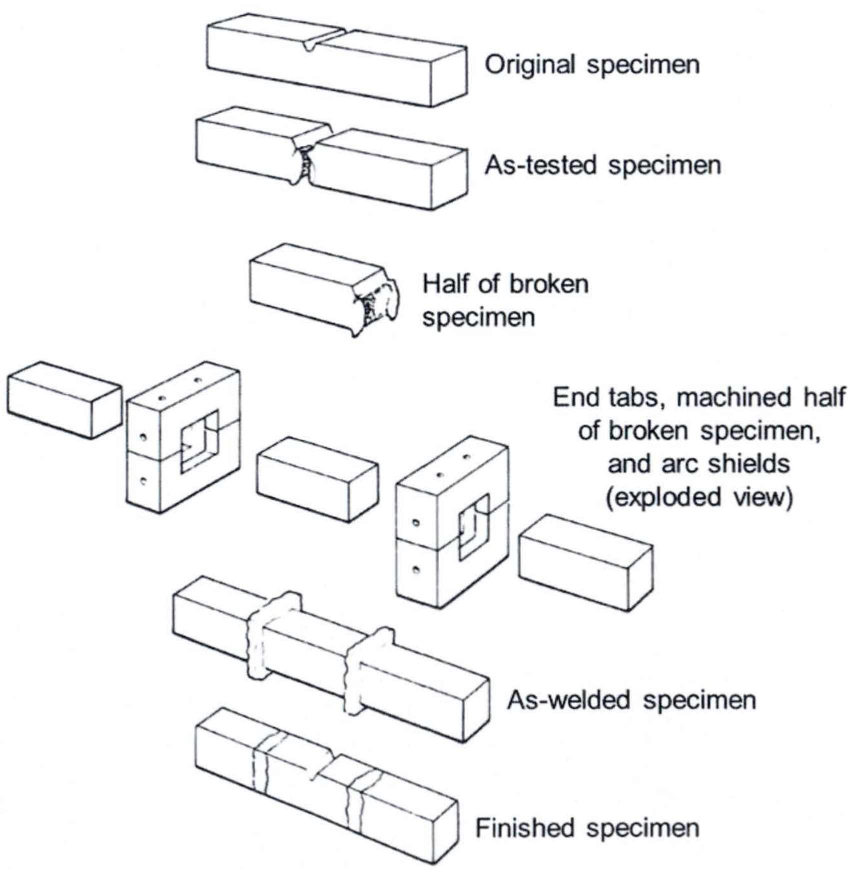

Figure 3-1
Sequence of stages in preparing a reconstituted Charpy specimen

4
DATA INVESTIGATIONS

In this section, data needs for SLR are determined by evaluating available data from the BWRVIP ISP program. Extension of the ISP into the SLR period is based on evaluating the extent to which available surveillance specimens can provide additional data to bound 80 years of plant operation. Fluences for 80 years are projected for reactor vessel target materials, and target fluences are compared with fluences of tested capsules. Gaps and additional data requirements to monitor embrittlement to 80 years are identified. The feasibility of planning and implementing SSLR capsules is also discussed. These investigations include the most recent surveillance capsule and reactor vessel fluence data.

4.1 Assessment of 72 EFPY 1/4T Fluence for BWR Fleet Target Materials

BWRVIP-86, Revision 1-A [4], defines the ISP test matrix: the representative surveillance materials assigned to each reactor vessel (Table 4-4 in [4]) and the corresponding target materials in each reactor vessel (Tables 4-1 and 4-2 in [4]).

This section presents projected 72-EFPY 1/4T fluences for the target plate and target weld heats in each U.S. BWR reactor vessel. Projected 1/4T SLR target fluences are then compared with the highest fluences attained for tested (previously tested and planned to be tested) surveillance capsules.

Projected 1/4T fluences for 72 EFPY were developed for each target heat and are presented in Table 4-1 and Table 4-2 for plates and welds, respectively. Fluence values are plotted in Figure 4-1 and Figure 4-2. Fluence values were taken from the most recently docketed P-T curve reports or ART tables in the NRC Agencywide Documents Access Management System (ADAMS). Where more up-to-date fluence values were available that differed from the latest docketed fluences, the more up-to-date fluences were preferred. For some plants, more up-to-date fluences were available in fluence evaluations prepared in conjunction with recently removed ISP capsules. Fluence at the location of the target heat and corresponding to EOL or EOLE was utilized in the present evaluation based on the best available information.

Fluences were projected for SLR (assumed to be 80 years or 72 EFPY) by extrapolating linearly from fluences provided in source documents for the plant-specific reference EFPY, either EOL or EOLE (typically 32 or 54 EFPY). This was performed by multiplying the fluence at the reference EFPY by the ratio of the SLR EFPY to the reference EFPY. As shown in Figure 4-1 and Figure 4-2, most plants have projected target 1/4T SLR fluences that fall within a similar range, between 1×10^{18} and 5×10^{18} n/cm^2. A few plants are projected to have much lower fluence than the rest of the BWR fleet, on the order of 4×10^{17} n/cm^2, while several plants are projected to have much higher fluence, on the order of 6 to 9×10^{18} n/cm^2.

4.2 Identification of Data Needs for Extending the ISP for SLR

The objective of this evaluation is to identify, for each reactor vessel, whether surveillance data credited under the current ISP will bound the projected 72-EFPY 1/4T fluence.

The current ISP provides comprehensive surveillance coverage for the BWR fleet by using surveillance data from thirteen ISP host plants and nine capsules from the SSP. Thirteen license renewal capsules from the thirteen ISP host plants are earmarked for testing during the extended license period (60 years). The ISP capsule withdrawal schedules for the original license period and license renewal period are presented in BWRVIP-86, Revision 1-A [4].

These two sets of capsules are considered separately in the following sections: (1) capsules that have been tested or will be tested in the near term and (2) capsules designated for withdrawal and testing during the extended license period, termed "ISP(E)" capsules, to differentiate them from the ISP capsules withdrawn during the original license period.

4.2.1 Previously-Tested and Near-Term Capsules

For each target heat, the projected SLR 1/4T fluence was compared with the highest fluence attained for tested or near-term surveillance capsules. ISP capsule fluence as a percentage of target material 72-EFPY 1/4T fluence is presented in Table 4-1 and Table 4-2 for each heat.

Fluences for previously tested surveillance capsules were obtained from capsule fluence evaluations. A total of 30 capsules have been tested under the ISP and individual plant programs, and 9 capsules were tested under the SSP, providing data for 15 representative plate heats and 15 representative weld heats. Fluence for all ISP and SSP capsules has been evaluated using the RAMA fluence methodology [13] in accordance with the requirements of Regulatory Guide 1.190 [14]. Projected fluence for one capsule scheduled to be withdrawn under the ISP in 2018 is obtained from BWRVIP-86, Revision 1-A [4]. Hence, Table 4-1 and Table 4-2 consider fluences of previously tested capsules but also consider the projected fluences of capsules scheduled to be withdrawn and tested in the near term, as the higher fluence of these near-term capsules and known availability of specimens makes them more attractive for reconstitution.

Table 4-1 and Table 4-2 provide this evaluation organized by plant and target heat, while Table 4-3 and Table 4-4 show the same information organized by surveillance heat to facilitate comparison to the evaluation of the ISP(E) capsule test schedule presented in Tables 7-2 and 7-3 of BWRVIP-86, Revision 1-A [4].

4.2.2 ISP(E) Capsules

From Table 4-8 of BWRVIP-86, Revision 1-A [4], thirteen ISP(E) capsules are designated for testing under the ISP during the license renewal period. The withdrawal schedule for the 13 ISP(E) capsules with approximate withdrawal dates and projected capsule fluence is shown in Table 4-5 [4]. One additional ISP capsule is scheduled to be withdrawn in 2025 during the host plant's original license period [4], but that capsule fluence is bounded by the corresponding ISP(E) capsule fluence. Table 4-6 and Table 4-7 compare the projected fluence of the ISP(E) capsules to the projected SLR 1/4T fluences, for plates and welds respectively. For representative heats only irradiated in SSP capsules, no ISP(E) capsule is scheduled to be withdrawn, and Table 4-6 and Table 4-7 present the highest tested capsule fluence for those heats. Fluences for previously tested ISP and SSP capsules and projected fluences for ISP(E) capsules for the representative materials for each target plant are provided in Appendix A.

4.3 Results

Based on the evaluations presented in Table 4-1 through Table 4-4, the previously tested ISP surveillance capsules and near-term planned ISP capsules bound the projected 72-EFPY 1/4T fluences of a nine of the 33 target plate heats and eight of the 33 target weld heats.

When ISP(E) capsules are considered (Table 4-6 and Table 4-7), surveillance data are expected to bound the 72-EFPY 1/4T fluences of five additional target plates and eight additional target welds beyond those capsules that are bounded by the capsules that will be tested by the end of the original license period. Therefore, the capsules that will be tested under the ISP prior to the end of the 60-year license renewal period will bound a total of 14 of 33 target plates and 16 of 33 target welds.

The 72-EFPY 1/4T fluences for the remaining target heats will not be bounded by existing surveillance data. These plants will require additional higher fluence surveillance data for SLR, which may be obtained using reconstituted specimens.

Continuation of the ISP for SLR depends on a number of factors including the testing of prior capsules, planned testing of future capsules during the extended period of plant operation, and availability of capsule materials for additional use.

All previously tested and planned to be tested capsules in the ISP and SSP program are summarized for each plant in Appendix A. The availability of tested surveillance specimens for reconstitution is also summarized for each plant in Appendix A.

4.4 Proposed Material Groupings and Catch Up Fluences for SSLR Capsules

Comparison of tested and planned surveillance capsule fluence and projected 72-EFPY target reactor vessel fluence shows that some materials are already bounded by existing ISP or projected ISP(E) data. The remaining materials needing additional data and the organization of these materials into new SSLR capsules are discussed in this section.

The matrix of materials requiring additional test data at higher fluences can be determined from the low fluence ratios (< 100%) projected from the fluence values in Table 4-6 and Table 4-7. A list of representative material heats which require additional surveillance data, as well as materials for which no additional surveillance data is required, is summarized in Table 4-8. This table was developed based on comparing 72-EFPY 1/4T target fluences to the projected fluences of ISP(E) capsules in BWRVIP-86, Rev. 1-A [4]. According to Table 4-8, additional surveillance data is required for 13 of 15 representative plate heats and 10 of 15 representative weld heats.

Details of plate and weld materials for which additional surveillance data are needed for SLR is given in Table 4-9 and Table 4-10. These materials can be grouped by the range of fluence needed to catch up to the target reactor vessel fluence. Three "Supplemental SLR" or SSLR capsules are proposed to contain the materials for further irradiation to meet the required catch up fluence for each grouping. Details of the three groupings are shown in Table 4-11, Table 4-12, and Table 4-13.

For each representative plate and weld material needing additional data, the catch up fluence is determined as follows:

1. The tested capsule having the highest fluence is identified.
2. For each representative surveillance material, all target vessel materials represented by that surveillance material are reviewed, and the highest 72-EFPY 1/4T fluence is identified.
3. The needed catch up fluence for each representative heat is the difference between the bounding 72-EFPY target fluence and the highest tested capsule fluence.

This evaluation assumed that new SSLR capsules would be fabricated from previously tested ISP specimens and ISP specimens to be tested in the near-term, while ignoring the ISP(E) capsules that would be tested farther in the future, so as not to delay the start of the program. All specimens needed for the SSLR capsules would be drawn from the archive of ISP and SSP specimens (known as the ISP repository) – no specimens would be required from plant-specific programs predating the ISP. A survey of the availability of previously tested surveillance specimens is summarized for each BWR in Appendix A. The findings of that survey indicate that all representative material heats requiring additional data will have at least one capsule available in the ISP repository for use in preparing reconstituted specimens for SSLR capsules. Specimen availability is discussed in more detail in Section 5.

Table 4-11, Table 4-12, and Table 4-13 show projected final fluence exposures for the materials in the three SSLR capsule groupings. The SSLR capsule design and location are still to be finalized, hence, the neutron flux for the SSLR capsules is defined by a target range. The target maximum flux is 4.39×10^{10} n/cm^2-s based on the "breakpoint" value for flux in the ETC in 10CFR50.61a [15]. A minimum flux of at least 2.4×10^{10} n/cm^2-s is needed for SSLR capsule irradiation to attain catch up fluences in a reasonable amount of time, approximately 10 years. Capsules will be irradiated in increments corresponding to 2-year refueling cycles, so the needed irradiation time at the maximum and minimum flux is rounded up to the nearest even whole number. As summarized in Table 4-14, the SSLR capsule irradiation can be completed in 2 years for Group 1, 2-4 years for Group 2, and 6-10 years for Group 3.

The comparison of projected SSLR capsule fluence levels as a percent of the 72-EFPY 1/4T fluence values for target plates and welds is shown in Table 4-15 and Table 4-16, respectively. For representative heats where existing ISP or projected ISP(E) capsule fluence bounds the 72-EFPY 1/4T target fluence, the ISP/ISP(E) capsule fluence is presented. This comparison is based on the conservative projected 1/4T fluence values for each reactor vessel based on an upper bound for 80 years of plant operation. It is possible that additional RPV fluence calculations projected for the 80-year life may be lower than the conservative extrapolations used here and, therefore, the need may diminish for all capsule materials to be reconstituted, irradiated and tested to catch up to the maximum SLR reactor vessel fluence values shown in these tables.

4.5 Discussion

The conceptual design of the ISP for SLR is based on providing surveillance data for all existing plants in the BWR fleet for SLR even though some plants may not pursue SLR.

In comparing the fluence values and fluence ratios between the tested/near-term ISP capsules (Table 4-3 and Table 4-4) and yet to be tested ISP(E) capsules (Table 4-6 and Table 4-7), many of the capsule fluence as a % of 72-EFPY fluence ratios increase from less than 100% to greater than 100%. In fact, the representative plate and weld materials in ISP(E) capsules are projected to bound the estimated 72-EFPY 1/4T fluence values for five additional target plates and eight additional target welds. Although these data have not yet been obtained or credited for the program, they are in the ISP(E) test matrix and will continue to be irradiated in the host plants and tested in the future. The remainder of the capsule materials with less than 100% of the target reactor vessel fluence levels (shown in Table 4-6 and Table 4-7) is significantly fewer, and in many cases the ratio still exceeds 80% of the target reactor vessel fluence values, indicating that the current ISP(E) test program is well planned.

Additional surveillance data is needed for 13 of 15 representative plate heats and 10 of 15 representative weld heats. Reconstitution, further irradiation, and testing of previously tested Charpy specimens is proposed to attain the needed data, with three groupings of specimens proposed based on the additional fluence exposure that would be required to catch up to or bound the corresponding target heats for 80 years of operation. Details of the reconstitution procedures, capsule placement to achieve needed flux levels, capsule design, and insertion and withdrawal schedules are discussed in the following sections.

Table 4-1
Projected SLR 1/4T fluences for BWR target plate heats [[

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Table 4-1 (continued)
Projected SLR 1/4T fluences for BWR target plate heats

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Table 4-2
Projected SLR 1/4T fluences for BWR target weld heats [[

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Table 4-2 (continued)
Projected SLR 1/4T fluences for BWR target weld heats

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Table 4-3
ISP capsule fluence as a % of SLR 1/4T fluence for target plates [[

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Table 4-4
ISP capsule fluence as a % of SLR 1/4T fluence for target welds [[

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Table 4-5
ISP(E) capsule test schedule [4, Tables 7-1 and 7-2] [[

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Table 4-6
Projected ISP(E) capsule fluence as a % of SLR 1/4T fluence for target plates [[

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Table 4-7
Projected ISP(E) capsule fluence as a % of SLR 1/4T fluence for target welds [[

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Table 4-8
Summary of representative materials for which additional surveillance data is required [[

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Table 4-9
Identification of additional reconstituted surveillance capsule plate materials needed for ISP for SLR [[

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Table 4-9 (continued)
Identification of additional reconstituted surveillance capsule plate materials needed for ISP for SLR [[

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Table 4-10
Identification of additional reconstituted surveillance capsule weld materials needed for ISP for SLR [[

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Table 4-10 (continued)
Identification of additional reconstituted surveillance capsule weld materials needed for ISP for SLR

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Table 4-11
Proposed Group 1 reconstituted and irradiated surveillance test specimens [[

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Table 4-12
Proposed Group 2 reconstituted and irradiated surveillance test specimens [[

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Table 4-13
Proposed Group 3 reconstituted and irradiated surveillance test specimens [[

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Table 4-14
Summary of proposed SSLR capsule groupings [[

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Table 4-15
Projected ISP(E) or SSLR capsule fluence as a % of SLR 1/4T fluence for target plates [[

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Table 4-15 (continued)
Projected ISP(E) or SSLR capsule fluence as a % of SLR 1/4T fluence for target plates

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Table 4-16
Projected ISP(E) or SSLR capsule fluence as a % of SLR 1/4T fluence for target welds [[

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Table 4-16 (continued)
Projected ISP(E) or SSLR capsule fluence as a % of SLR 1/4T fluence for target welds

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Figure 4-1
Projected 1/4T fluences vs. EFPY for target plate heats

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Figure 4-2
Projected 1/4T fluences vs. EFPY for target weld heats

5 RECONSTITUTION APPROACH

This section discusses the procedures that will be used in the specimen reconstitution process. As discussed in Chapter 3, the proposed approach to obtaining additional surveillance data to bound 80 years of plant operation is to further irradiate material from previously tested Charpy specimens and subsequently use that material to reconstitute Charpy specimens.

Broken Charpy halves will be retrieved from the ISP repository and machined to remove plastically deformed material or base metal from weld specimens. The resulting material comprises the central portion, or "insert," of the reconstituted Charpy specimen. Inserts from a total of 23 material heats will be placed in three newly fabricated SSLR capsules for further irradiation. The capsules will be installed in a host plant reactor vessel using a specially designed holder. After irradiation is complete, reconstituted Charpy specimens will be fabricated by welding end tabs to the irradiated inserts. The reconstituted specimens will then be subjected to impact testing.

The Charpy specimen reconstitution will be delayed until after irradiation of the inserts is complete. This approach has several advantages. First, the specimen packets and basket will be compact and thereby reduce uncertainties related to flux gradients. Second, delaying the fabrication of Charpy specimens until after the SSLR capsule irradiation enables the possibility of using new and improved material characterization techniques in the future. Further, since dose rates are low for BWR surveillance irradiations, there will be a minimal radiological impact.

5.1 Requirements for Reconstitution Inserts

ASTM E1253-13 [11] specifies procedures for reconstitution of irradiated Charpy specimens. Requirements on insert size and weld heat input are specified to ensure that reconstituted specimens produce test results equivalent to those of virgin material.

ASTM E1253-13 [11] specifies the use of an insert with a minimum length of 18 mm. The insert is to be welded between two end-tabs of the same, or similar, material. A primary objective of the weld reconstitution process is to ensure that the insert contains no plastically deformed material from the original specimen. The standard also states that smaller insert sizes can be used, provided certain conditions are met. One condition is that the plastic zone produced during testing will not interact with the reconstitution weld. A second condition is that the heat input during the welding procedure must be controlled so as not to overheat the material in the notch region. Further, the temperature during welding or testing in the central portion of the insert must not exceed the prior irradiation temperature. The intent of the temperature requirements is to avoid annealing of irradiation damage in the insert. Analytical or experimental methods can be used to demonstrate that these conditions are met.

ASTM E185-82 [5] specifies practices for conducting vessel surveillance testing and is the latest approved version referenced in 10CFR50 Appendix H [1]. Per ASTM E185-82, a minimum of 12 Charpy specimens shall be tested for each irradiation exposure set of capsule materials, recommending that a greater number of specimens be tested when possible.

5.2 Technical Basis for Relaxation of Insert Requirements

Due to the limited number of specimens of 18 mm length that can be used as inserts for reconstitution, the relaxation of requirements regarding insert size or number may be necessary for some materials. This section discusses the technical basis for the relaxation of insert requirements.

Regarding the use of inserts shorter than 18mm, ASTM E 1253-13 [11] states:

> "4.2.5.3 The dimensional requirement of 18 mm (0.71 in.) is based on Charpy impact specimens tested on the upper shelf (where the plastic zone is largest) and fabricated with the stud welding reconstitution technique (where heat input and HAZ sizes are largest). Reconstituted specimens tested in the lower transition range or on the lower shelf in accordance with Test Methods E23 and reconstituted precracked specimens tested in accordance with Test Methods E1820 or E1921 will have much smaller plastic zones. Other reconstitution techniques, such as electron beam welding, produce HAZs smaller than stud welding. Therefore, this dimensional requirement may be relaxed, if it can be experimentally or analytically shown that the plastic deformation zone in subsequent testing will not extend into the heat affected zones produced by reconstitution and the requirement of 4.4.1 is met....Test programs have shown acceptable Charpy results using shorter inserts."

In other words, the length requirement in ASTM E1253 [11] is based on conservative assumptions for heat input during weld reconstitution and maximum plastic zone size during Charpy testing on the upper shelf. Reconstituted specimens tested in the lower transition region or lower shelf have much smaller plastic zones, and alternative welding techniques such as electron beam welding produce smaller HAZs than stud welding. Therefore, ASTM E1253 [11] permits relaxation of this dimensional requirement if it can be experimentally or analytically shown that the plastic zone during testing will not extend into the HAZ produced by reconstitution and that specified heat input requirements are met.

5.2.1 Studies on Acceptable Insert Length for Reconstitution

A number of studies have examined the lengths of inserts that provide acceptable results for reconstituted Charpy specimens.

A large multi-lab effort in Europe, RESQUE, was a leading effort on this topic. Reference [18], which was reported in ASTM STP 1418, provided results for various insert lengths. Using a stud weld process optimized based on the methods found in References [19] and [20], 12 mm and 15 mm inserts were reconstituted and tested. The 12 mm inserts were found to lie within standard scatter for Charpy energy in the transition region, however they differ by 10-15% in upper shelf energy. The results for 15 mm inserts were found to be within normal scatter in both the transition region and upper shelf region. It was therefore concluded that so long as the insert is at least 12 mm in length it can be tested in the transition region, and if the insert is at least 15 mm in length it can be tested at any energy on the transition curve.

Results of a round robin study on reconstitution overseen by the ASTM and conducted by ten laboratories world-wide were reported in NUREG/CR-6777 [23] and ASTM STP 1329 [22]. The use of 10 mm inserts showed an effect of reconstitution on absorbed energy and lateral expansion, particularly for thicker reconstitution welds, though the effect was minimal for low upper shelf energy. It was concluded that 10 mm inserts could be used on the lower shelf or lower transition region of Charpy curves. The study found generally little effect of reconstitution on Charpy properties when a 14 mm insert is used for all reconstitution techniques tested (stud welding, electron beam welding, and upset butt welding) for all Charpy energy levels other than for high upper shelf energy using certain tup (load cell) geometry. Although the use of 14 mm inserts could not be recommended in all applications, the results of this program show acceptable Charpy results using reduced size inserts.

These conclusions on acceptable insert length are further substantiated by the findings within [21]. While this study deals primarily with laser welding, temperature dependent calculations for the size of plastic deformation in Charpy specimens were made. For dynamic unirradiated testing of reactor steels, the plastic zone normal to the crack plane was such that inserts larger than 15 mm could be recommended for upper shelf testing. Irradiated specimens will have a smaller plastic zone than unirradiated specimens due to the neutron embrittlement, and thus loss of ductility. For testing below 100°F, a plastic zone of less than 1 mm is predicted, thus allowing for the insert to be significantly smaller than the 18 mm required by ASTM E1253 [11].

An important parameter governing the minimum size of the insert that can be used is the temperature of the insert during the welding process. ASTM E1253 [11] states that the temperature during welding is not to exceed the irradiation temperature in the central 10 mm section of the insert. Specimen size requirements are illustrated in Figure 5-1. This requirement can be relaxed if it can be shown that the plastic zone will not enter into a region of the specimen where the irradiation temperature was exceeded. The purpose of this requirement is to ensure that the radiation damage is not annealed in the plastic zone of the reconstituted specimen that controls the fracture behavior. Temperature profile measurements are required by ASTM E1253 [11] for validation of the welding process. Results found by RESQUE [20] for arc-stud welding show that the region of high temperature during welding typically extends 3.5 ± 0.5 mm along the length of the insert as measured from the end-tab weld. A similar result for laser welding was reported in [21] with a thermally disturbed region extending about 4.0 mm from the end-tab weld.

The reconstitution temperature requirement dictates that approximately 8 mm of any insert (4 mm on each side of the central 10 mm portion) will potentially exceed the irradiation temperature. Due to this length being so large, a study was performed to determine the risk of annealing the radiation damage during specimen reconstitution [24]. The focus of the [24] work was on finding the optimum fluence at which to conduct radiation damage annealing studies. It was noted in this work that the literature shows that annealing is not likely to occur at temperatures of 450°C for a few minutes or 500°C for approximately 1 minute for irradiated RPV steels. Based on the welding method used in this reference (arc stud welding), the temperature 1.8 mm from the weld never exceeded 500°C, and after 5 seconds the specimen had been cooled by over 200°C. This study shows that there is little risk of annealing so long as the exposure time at high temperatures is kept to a minimum, as it is with arc stud welding.

5.2.2 Arc Stud Welding Procedures and Capability to Meet Insert Size Requirements

Arc stud welding is commonly used for reconstitution of Charpy specimens as a means of meeting the requirements of ASTM E1253 [11], which specifies that heat input during welding must be controlled so that the temperature in the central 10 mm (0.40-in) portion of the reconstituted specimen does not exceed the prior metal irradiation temperature (Figure 5-1).

Various arc stud welding methods have been perfected for pressure vessel surveillance application and are reported in the literature. In work done by Battelle [25], Argon gas was used with 10 mm square end-tabs. The 10 mm square end-tabs can eliminate the need for post-weld machining, and Argon shielding gas is a far cooler gas than helium due to its lower ionization potential. Work done in Mexico [26] used oversized end-tabs as well as helium gas as the shielding gas with good success. The larger end-tabs were used to conduct more of the heat away from the center of the specimen thereby reducing the HAZ. The helium was used due to its higher thermal conductivity despite having a higher ionization potential. By keeping the helium at a high flow rate, more heat was removed, thus warranting the higher heat input. While both of these methods worked, the Battelle method is much less complex and requires less control mechanisms. These methods are similar to those used by RESQUE, which allows for inserts smaller than 18 mm to be used.

The importance of the geometry of the end-tabs was examined in the RESQUE study as well [27]. Using 10 mm square end-tabs reduces the need for post weld machining, however these end-tabs are much more difficult to align precisely. The RESQUE study attempted to characterize the effects of misalignment forming a step of up to 0.41 mm, and angular misalignments of ± 5°. The results showed that slight misalignment of the end-tabs has no discernable effect on the impact energies, so long as the specimen is able to properly press against the anvils [27]. In addition to dimensional shifts, differences in yield strength of the end-tabs was also examined. Even with yield strength differences of up to 58 ksi (400 MPa) between the insert material and the end-tab material, no statistically significant differences were found in Charpy energy. It is recommended in ASTM E1253 [11], however, that the end-tab material match the insert material as closely as possible.

5.2.3 Number of Specimens per Material

Although it is desirable to comply with the requirements of ASTM E185-82 [5] by having at least 12 specimens available for testing, it is a common occurrence in BWR and PWR surveillance programs for capsules to contain fewer specimens. For instance, many capsules were designed to earlier versions of ASTM E185. Current BWR capsules often contain as few as 8 specimens, and the BWRVIP has had no issues developing high-quality Charpy curves with as few as 8 specimens.

5.3 Determination of Specimen Availability

The materials that will be included in the SSLR capsules are the same materials used in the existing ISP program. However, to include the existing weld materials, a feasibility study was conducted to determine whether the population of previously tested specimens has a sufficient number of specimens with adequate weld material to satisfy the ASTM E1253-13 [11] recommended insert length.

For weld materials, inserts can be fabricated from previously tested weld or HAZ specimens, provided the portion of the specimen consisting of weld material would yield an insert of adequate length. The volume of weld material available for reconstitution may be reduced by base metal or HAZ in the specimen.

For plate materials, all needed specimens are available in the ISP repository, and no issues were identified in obtaining inserts of 18 mm length.

5.3.1 Weld Specimen Etching Study

This section provides the results of measurements made on etched weld and HAZ specimens that are currently stored in the ISP repository. The etching work was performed to determine the length of weld material available for reconstitution of the previously tested specimens of the weld heats listed in Table 4-8. The weld heats examined in this study are specified in Table 5-1 and Table 5-2. A total of nine different weld heats were characterized, and the test specimens were available from a variety of ISP and SSP capsules. These tables list only nine welds because the Peach Bottom Unit 2 (PB2) ESW weld specimens will not be available for examination until the PB2 30° ISP capsule is withdrawn in late 2018. The weld and HAZ specimens from that capsule will be etched and characterized at that time to determine the number of inserts that can be used in the SSLR capsule irradiation.

The goal of the weld specimen etch study was to determine whether a sufficient number of weld inserts are available for Charpy specimen reconstitution for the nine weld heats of interest. The specific objective was to identify a total of 14 weld inserts containing at least 18 mm of weld metal for each heat. The target of 14 inserts is based on two spares in addition to the 12 specimens specified by ASTM E185-82. Each broken Charpy specimen half was examined starting with the lowest impact energy Charpy specimens. The initial approach was to examine the specimens with the least plastic deformation first. Ultimately, it was necessary to etch all available specimens for each heat to obtain the desired number of weld inserts of sufficient size for reconstitution.

The location along the broken specimen half where the plastic deformation starts was determined by cross section measurements. This, in addition to the etching of all four specimen faces, provided the usable weld reconstitution length data given in Table 5-1. In addition, each specimen half was examined for noteworthy blemishes which could have occurred due to tossing during testing or interaction with tools during capsule opening. A few of the capsules examined had engraved identification marks on the face of the specimen. The position of any such marks relative to the end of the specimen were measured and recorded. The specimens were also examined on the face that was in contact with the anvils during testing to characterize the Brinell marks. Once again, the longest distance to the anvil indentation was recorded along with the depth of the anvil indentation. The depth of the anvil indentation was measured using a calibrated digital plunger gage. The columns under "All Specimens" in Table 5-1 show the total number of inserts with at least 18 mm length available from both weld and HAZ specimen broken halves. The entries with parentheses indicate the range of numbers of available inserts that can be obtained depending on the results of the HAZ specimen identification. At present, it is not known which of the HAZ specimen halves is weld. Additional work is planned to identify the weld halves for these specimens.

5.3.2 Results of Weld Specimen Etching Study [[

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5.4 Proposed Approach

5.4.1 Insert Fabrication

To meet the condition in ASTM E1253 that plastic zone size does not extend into the reconstitution weld HAZ, the below approach is proposed.

First, the fracture surface and plastically-deformed material from the broken Charpy halves will be machined off to produce the weld reconstitution insert. For the weld and HAZ specimens, it will also be necessary to machine base metal from the end opposite the fracture surface for some specimens. The machining process will be electric discharge machining (EDM) because it is very precise and does not produce cold worked material as with conventional milling methods. Another important advantage of accurately machined inserts is that the packets can be packed very tight within the stainless steel enclosure for good heat transfer during irradiation.

Compliance with ASTM E1253-13 [11] will be ensured by a combination of analytical and experimental testing focused on ensuring that the plastic deformation zone for 12 mm and 15 mm inserts will not extend into the HAZ of the arc stud weld reconstituted specimens. Recent work discussed above strongly supports the use of 12 mm and 15 mm inserts for surveillance applications. Nevertheless, both finite element calculations and testing of arc stud welded specimens will be conducted on representative materials to qualify the methods.

Anvil indentations, engraving marks, and other blemishes will be oriented so that they are on the notch surface of the reconstituted specimen.

5.4.2 Arc Stud Welding Procedures

Arc stud welding will be used for reconstitution of the SSLR capsule inserts in accordance with the requirements of ASTM E1253 [11], which permit the use of any welding process provided that the specified heat input and dimensional requirements can be achieved. The standard specifies that heat input during welding must be controlled so that the temperature in the central 10-mm portion of the reconstituted specimen does not exceed the prior metal irradiation temperature. Specimen size requirements are illustrated in Figure 5-1.

As previously mentioned, a primary focus of ASTM E1253 [11] is to have 10 mm of weld in the center of the insert that never exceeded maximum irradiation temperatures during welding. Given the central 10 mm region, approximately 4 mm on both sides of the central 10 mm results in an 18 mm insert length. Thus, the standard allows for a total of 8 mm of length that will potentially be annealed. Therefore, up to 4 mm of base metal or plastically deformed material can be left on either side of the insert. Using this understanding, up to 4 mm of base metal or HAZ will be used for the weld interface material. This will likely increase the usable inserts to slightly above the current lengths given in Table 5-2. This provision will be employed where possible in the reconstitution of the SSLR capsule inserts. Therefore, the lengths given in Table 5-2 are a conservative indication of insert size, since the measurements consist only of weld metal.

The end-tabs will be oversized so that they can be EDM machined in plane with the irradiated insert. This avoids issues related to end-tab orientation and non-planar contact of the reconstituted specimens with the anvils and striker.

ASTM E1253 [11] requires measurements to demonstrate that the reactor irradiation temperature is not exceeded for a given selection of welding parameters. In accordance with the standard, temperature records shall be made daily, using thermocouples, during welding of a set of Charpy-sized reconstitution specimens. As discussed, the goal of the welding procedure is to minimize both the HAZ and the length over which the temperature exceeds the vessel irradiation temperature.

The specific materials to be reconstituted and tested will be determined at a later date based on the needs of plants pursuing SLR, as discussed in Section 8.

5.4.3 Charpy Test Procedures

Charpy impact tests will be conducted in accordance with ASTM Standards E185-82 [5] and E23-02 [17]. The 1982 version of ASTM E185 has been reviewed and approved by NRC for surveillance capsule testing applications. This standard references ASTM E23. The ASTM E23 [17] procedures for specimen temperature control will be followed. Absorbed energy, lateral expansion (LE), and the percentage of shear fracture area will be determined using the methods given in ASTM E23 [17].

The number of Charpy specimens for measurement of the transition region and upper shelf is limited. Therefore, the choice of test temperatures is very important. Prior to testing, the Charpy energy-temperature curve will be predicted using embrittlement models and previous data. The first test will then be conducted near the middle of the transition region using an 18 mm or 15 mm insert specimen, and test temperature decisions will then made based on the test results. Overall, the goal will be to perform two or three tests on the upper shelf, and to use the remaining specimens to characterize the 30 ft-lb (41 J) index temperature. It is typical to test two or three

specimens on the upper shelf, and, with the exception of weld 5P6756, all of the welds have enough specimens for three 18 mm insert specimens to be tested in the upper shelf region. For the remaining test temperature selections, the 15 mm insert specimens will be tested in the mid and upper transition region, and the 12 mm insert specimens will be tested only in the lower shelf region. Optimized testing procedures will be employed for the available number of specimens.

5.4.4 Number of Specimens

The target number of specimens per weld heat is 14, including the 12 specimens prescribed by E185-82 [5] and two spare. As shown in Table 5-2, six of nine weld heats will have at least 14 specimens available. Two of nine heats will have at least 12 but fewer than 14 specimens. One heat will have 10 specimens available.

For all materials tested under the ISP for SLR program, at least 2 capsules will have been previously tested. The embrittlement behavior of these materials has therefore been characterized, and previous test results can be used to inform selection of appropriate test temperatures.

5.4.5 Charpy Curve-Fitting Procedures

A study by ORNL on the irradiation effects of welds chose the hyperbolic tangent (TANH) curve-fitting method described in Section 9.3 as the best fit to CVN data using a mean square error method [38]. However, regardless of the curve fitting technique, additional considerations can be easily employed to optimize the TANH curve-fitting method [37]:

- A fixed lower shelf (L.S.) at either zero or some slightly higher than zero value (typically 2.5 ft-lb) which reduces the fit to actually three parameters since (A-B) is fixed. This typical L.S. value of 2.5 ft-lb is based on prior knowledge from a large number of Charpy data fits for RPV steels. Furthermore, a fixed lower shelf eliminates the need for testing of Charpy data at very low temperatures, thereby conserving the number of specimens needed for testing of the transition region. For lateral expansion, the L.S. can be fixed at 1.0 mil.
- Whenever possible, the upper shelf energy (USE) may be determined (and fixed) using fewer than three specimens if the fracture surface appearance is greater than 95% percent shear. For example, if there are at least two tests that exhibit greater than 95% shear, there is a fairly clear indication that the data is fully on the upper shelf. Using this definition, fewer tests need to be performed on the upper shelf portion of the curve.
- Using both a fixed L.S. and a fixed USE as defined by prior engineering knowledge and experience reduces the TANH fit to only two-parameters and optimizes testing of specimens in the transition region.

This combination of optimized testing and good engineering curve-fitting procedures can assure that illogical fits are avoided (e.g., L.S. < 0 ft-lbs) and it provides the best fit to the data with a minimal number of Charpy specimens.

5.5 Summary

The evaluations presented in this section confirm that the objectives of the ISP for SLR program can be accomplished with the materials available in the ISP repository.

The proposed approach for reconstitution and testing of SSLR capsule materials can be shown to meet the requirements of ASTM E1253 [11] and ASTM E185-82 [5]. Specimens will be reconstituted using arc welding procedures such that specimens will meet the size requirements of ASTM E1253 [11].

While ASTM E1253 [11] recommends the use of 18 mm inserts, extensive work has been done to show that smaller length inserts are acceptable. Studies performed independently, and years apart, have reached the conclusion that 15 mm inserts produce acceptable results at any Charpy impact energy level. The results of the multi-lab effort in Europe under the RESQUE program, as well as the plastic zone calculations done for irradiated dynamic Charpy testing [21], show that 12 mm inserts produce acceptable results when tested on the lower shelf through mid-transition region. Even though ASTM E1253 [11] has been shown to be overly conservative, all sources reviewed recommend using the longest possible inserts when available. It is also worth noting that if comparable data between the original and reconstituted specimens is required, then the orientation of both specimens must be identical [11]. For the SSLR capsule testing of weld materials, specimens made using 18 mm inserts will be tested on the upper shelf and in the upper transition region, 15 mm insert specimens will be tested in the mid-transition region, and 12 mm insert specimens will be tested on the lower shelf and in the lower transition region. One weld heat will have 10 inserts available for reconstitution, while all other weld and plate heats will have at least 12 inserts available. The provision in ASTM E1253 [11] to allow up to 4 mm of base metal or HAZ for the weld interface material on either side of the insert will be used when possible. Therefore, the measurements shown in Table 5-2 are a conservative indication of insert size, and it is likely that usable insert sizes will be larger.

Table 5-1
Summary of weld etch study results [[

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Table 5-2
Number of usable weld specimens as a function of insert length [[

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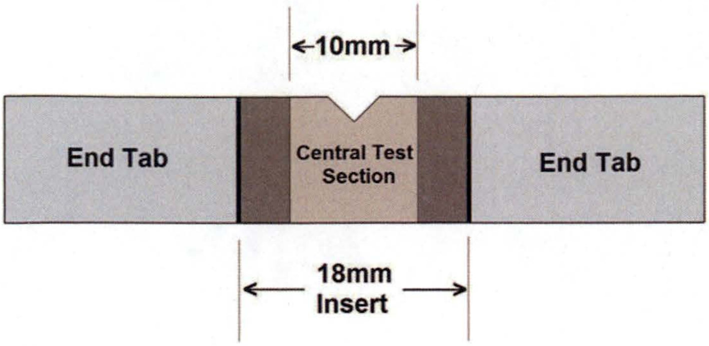

Figure 5-1
Illustration of ASTM E1253 requirements regarding insert length of 18 mm and control of heat input during welding to limit temperature such that the prior metal irradiation temperature is not exceeded in the central 10 mm of insert.

6
FLUENCE AND FLUX CONSIDERATIONS

The primary objective for obtaining additional surveillance data is to achieve a fluence exposure for representative heats that meets or exceeds target reactor vessel fluence for 80 years of plant operation. Needed catch up fluences cannot be attained prior to the end of 80 years of operation using typical BWR surveillance capsule flux rates. Further, it is desirable for catch up fluences to be reached within a reasonable timeframe, approximately 10 years. Therefore, an accelerated flux rate is needed.

This section discusses the target flux range for SSLR capsules and the identification of candidate host plant locations for attaining the range of target flux values.

6.1 Target Flux Range for SSLR Capsules

The target flux range for the proposed SSLR capsules has a minimum of 2.4×10^{10} n/cm^2-s and maximum of 4.39×10^{10} n/cm^2-s. The minimum flux is determined based on the need to attain the maximum catch up fluence of [[ ]] in a reasonable time, approximately 10 years. The maximum flux is based on a "breakpoint value" for flux of 4.39×10^{10} n/cm^2-s for the ETC in 10CFR50.61a [15].

The proposed SSLR capsule flux range is higher than typical BWR capsule flux, which are on the order of 10^8 to 10^9 n/cm^2-s, and a similar order of magnitude to the flux for some SSP capsules. Six SSP capsules irradiated in Oyster Creek had flux in the range 8.3×10^9 to 1.9×10^{10} n/cm^2-s [32, 33], and that high of a flux was attainable due to the absence of jet pumps, which provide a flux shielding effect for most BWR surveillance capsules.

ASTM E185 lead factor recommendations and concerns regarding flux embrittlement effects have been considered in planning the SSLR capsule irradiation, and it is concluded that a balanced perspective is needed concerning fluence, flux, and lead factor. ASTM E185-82 [5] recommends that surveillance capsule lead factors be in the range of 1 to 3. Lead factor is defined as the ratio of the neutron flux density at the location of the surveillance capsule to the neutron flux density at the vessel inside surface at the peak fluence location. However, ASTM E185 was prepared in the context of the development of a plant-specific surveillance program. This is evidenced by the fact that ASTM committee E10.02, which is responsible for maintaining ASTM E185, is currently considering an annex to this standard for integrated surveillance programs. Lead factor is not a meaningful consideration for an ISP, because the data for one capsule is representative of materials in multiple vessels, and a different lead factor exists for each. For planning the ISP for SLR, lead factor is not considered, and target flux and fluence are the primary considerations.

6.2 Selection of Candidate SSLR Capsule Host Plants

To identify suitable SSLR capsule locations to attain the target flux range, candidate host plants were first identified. The intent of this process was to identify multiple plants as candidate host plants to address the contingency planning requirements of 10CFR50 Appendix H [1] for cases of plant shutdown and provide flexibility for changes that may occur between the time of program plan development and capsule insertion, approximately 3-4 years from now.

Several plants have been selected as candidate host plants based on the following considerations:

1. *Similarity to Other Plant Designs*

   This would increase the potential for capsule transferability if needed. Parameters evaluated for similarity include shroud inside diameter and thickness, annulus width, and core size. A summary of parameters reviewed for the U.S. BWR fleet is in Table 6-1.

2. *End of 60-year License Dates*

   Selecting a host plant with a later end of 60-year license date provides enough time for SSLR capsules to be installed and obtain needed fluence levels, regardless of whether or not the host plant pursues SLR. The proposed schedule for capsule insertion and withdrawal in relation to plant license dates is discussed in Chapter 8.

3. *Existing Quality Fluence Model*

   An existing high-quality and up-to-date fluence model facilitates the evaluation of flux values at potential SSLR capsule installation locations.

4. *Existing ISP Host Plant*

   Host plants under the current ISP are already familiar with the existing ISP host plant responsibilities.

Based on consideration of the above factors, four BWR units were selected for further evaluation.

6.3 Investigation of Flux Values for SSLR Capsule Candidate Locations

In the process of determining a suitable host reactor and installation location for the SSLR capsules, four reactor vessels were selected for further investigation. Neutron flux values were determined for various azimuthal, axial, and radial positions within the annulus region. Four criteria were evaluated:

- Locations in a reactor vessel, and specifically the annulus region, that would be free of obstructions, such as jet pump hardware, to facilitate the installation and removal of an SSLR capsule in a currently operating BWR.
- Radial and azimuthal positions in the annulus region where the SSLR capsule would receive a neutron irradiation rate (flux) of about 4.39×10^{10} n/cm^2-s.
- Axial elevations where the entire capsule surface would be irradiated as equally as possible over the height of the SSLR capsule.
- Locations in the reactor vessel where the neutron spectrum experienced by the SSLR capsule is comparable to that which is experienced on the inner surface of the vessel wall.

6.3.1 Plant Descriptions

The four plants investigated are General Electric BWR/4 class plants, which is the dominant BWR design licensed to operate in the United States. Among these four designs, there are three different configurations. Plant A and Plant D each have a core loading of 764 fuel assemblies contained within a core shroud with a nominal diameter 526.1 cm (207.13 in). Plant B and Plant C are based on a 560-fuel assembly loading pattern with a nominal shroud diameter of 450.85 cm (177.5 in). However, Plant B and Plant C differ in that Plant C utilizes all 560 fuel assembly locations while Plant B replaces 12 fuel assembly locations with dummy (inert) assemblies yielding a core loading of 548 fuel assemblies. Additionally, Plant C has installed shroud tie rods which are not present in any of the other three plants.

Each reactor, independent of core configuration, is licensed to operate at different power levels. The different combinations of core configurations, shroud diameters, and power densities offer different potential locations for mounting the SSLR capsule to achieve the desired neutron flux irradiation.

One recent cycle was selected for each plant to evaluate the average flux that could be seen by the SSLR capsule. It is important to evaluate the flux over an entire cycle, because the neutron spectrum will shift as plutonium becomes a major contributor to the neutron source. Each cycle evaluated was the most recent cycle of data available for each plant, which included both true operating data as well as projection data. Table 6-2 summarizes the cycle data that was used for each plant. It is known that Plant A and Plant D were recently approved for power uprates; Plant D achieved a MUR that increased its rated power by 1.66%, and Plant A was approved for an extended power uprate of 14.3%. The Plant D MUR is reflected in the rated power presented in Table 6-2 and is not expected to perturb the power shape in the core. However, the Plant A extended power uprate is much more significant and took place several cycles after the most recently available cycle of data. This change in power is expected to increase the neutron flux at the SSLR capsule location, however, data was unavailable to appropriately model those effects.

6.3.2 Methodology for Flux Investigations

This section details the processes by which the flux values and flux spectra were calculated. Both calculations were based on transport models built for the four plants using the RAMA fluence methodology.

6.3.2.1 Tool Descriptions

The calculations were performed using the RAMA [13], RAFTER [34], and RAFFLE [35] software packages.

RAMA is a transport module that couples Monte Carlo modeling techniques with ray-tracing to render arbitrary geometry in a form solvable by deterministic transport methods. RAMA employs a three-dimensional deterministic transport method based on an arbitrary geometry formulation of the Method of Characteristics with anisotropic scattering.

The RAFTER and RAFFLE codes are post-processing tools that calculate the region-wise flux for specified components within the transport model. RAFTER reads the group-dependent fluxes from the RAMA data files and outputs flux for each region of the problem. RAFTER also integrates the solutions from discrete time steps (state points) over the power history to determine fluence values from the regions of the problem. RAFFLE performs three-dimensional interpolations on the data output by RAFTER to produce axial, azimuthal, and radial profiles in fine grid format for subsequent use in plots.

The RAMA and RAFTER modules access a nuclear data file to obtain the atomic weights, cross-sections, and energy production terms for each material nuclide used in the model. The production library contains nuclear data for 199 nuclides. Cross-section data is tabulated in energy group form and is provided in 47-neutron and 20-gamma energy groups for each nuclide. Scatter cross-sections are represented in P5 and P7 scattering moments. RAMA uses the highest tabulated moment for a nuclide in the transport calculation. The 47-neutron/20-gamma cross-section library is derived from the 199-neutron/42-gamma fine-group VITAMIN-B6 nuclear data file [36].

6.3.2.2 Analytical Methodology [[

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6.3.3 Results of Flux Investigations

The objective of the flux evaluation is to determine potential locations for the SSLR capsule by providing fast flux values for a span of locations in each of the candidate host plants. As discussed in Section 6.1, the target maximum flux for the capsule is 4.39 x 10^{10} n/cm^2-s. Rather than utilize the existing BWR capsule brackets at the vessel inside surface, accelerated flux values will be attained by mounting the SSLR capsules to the outside surface of the core shroud. Another criterion for determining the positioning of the SSLR capsule is to achieve a relatively uniform axial flux profile over the entire surface of the SSLR capsule. Through preliminary studies, the elevations of the core shrouds with the lowest axial gradients were determined. However, at these elevations, no position directly on the shroud wall, in any plant, would see a fast flux below 4.39 x 10^{10} n/cm^2-s. Therefore, it was determined that it would be necessary to

offset the SSLR capsule from the shroud wall (towards the reactor vessel) in order to obtain a flux below the maximum target flux. To meet these criteria and to limit the offset distance between the shroud wall and the SSLR capsule, several combinations of azimuthal and axial locations are evaluated that would provide a relatively flat flux profile over the height and width of the SSLR capsule container while still meeting the target flux criterion. This range of elevations and azimuths were then evaluated at multiple radial offsets to determine the offset needed in each plant to achieve a fast flux that approached 4.39×10^{10} n/cm^2-s.

For ease of installation, the best locations for mounting the SSLR capsule on the outer surface of the core shroud wall presumably correspond to Vessel North (0°) or Vessel South (180°). These locations are absent of any jet pump hardware that could impede placement of the capsule, plus allow adequate space for lowering installation equipment into the annulus region for mounting the capsule to the shroud. However, it is noted that some optimum locations for mounting the SSLR capsule on the shroud wall may encroach on shroud welds for certain host plants. This will also be taken into account in selecting a mounting location for the SLR capsule.

Figure 6-2 and Figure 6-3 show the azimuthal and axial flux profiles, respectively, for the four host plants. The profiles are characteristic of the neutron flux on the outer surface of the shroud wall (i.e., zero offset from the shroud). Even at the minimum flux locations shown in the figures, it is observed that the neutron flux exceeds the target maximum flux of 4.39×10^{10} n/cm^2-s. Synthesizing the azimuthal and axial flux profiles in Figure 6-2 and Figure 6-3, it can be readily discerned that the optimum locations for installing the SLR capsule in the reactors lie at the minimum flux locations around the 0° azimuth, as shown in Figure 6-2, and preferentially near the bottom of the core beltline, as shown in Figure 6-3.

Using the azimuthal and axial flux profiles provided in Figure 6-2 and Figure 6-3, respectively, and the determinations that the optimum locations for installing the SSLR capsule in the reactors will be at the minimum flux locations around the 0° azimuth and near the bottom of the core beltline, a range of acceptable azimuths and elevations were determined for each plant. Additional investigations were performed within these ranges to determine an offset distance for mounting the SSLR capsule from the shroud wall. These evaluations determined bounded areas relative to the shroud wall that would achieve the target maximum flux of 4.39×10^{10} n/cm^2-s and provide a relatively flat flux profile across the SLR capsule.

The flux maps generated for each plant were inspected to determine optimum azimuthal, axial and radial offsets for mounting the SSLR capsules for each plant. All plants are evaluated at 1° azimuthal increments and 5 cm axial increments. Numerous radial locations were evaluated for each plant; however, only selected radial locations meet the target maximum neutron flux of 4.39×10^{10} n/cm^2-s. As an example for Plant D, Figure 6-4 shows the flux profile in the annulus region at the 0° azimuth for various radial offset distances from the shroud outer surface.

Table 6-3 summarizes optimum mounting locations for SSLR capsules based on the flux maps generated for each plant. It is determined that optimum azimuthal position for mounting the SSLR capsules is around the 0° azimuth with an acceptable range of ± 5°. [[

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As a final consideration in selecting a mounting point on the core shroud for the plants, it is noted that both Plant B and Plant D have shroud welds that could potentially interfere with capsule placement. Plant D has a vertical weld along the 0° azimuth, and Plant B has a horizontal weld at an elevation of 266.23 cm (104.82 in) above the bottom of active fuel.

6.3.4 Results of Flux Spectrum Evaluation

In addition to the target flux criterion, an additional criterion identified in the determination of a suitable location for installation of SSLR capsules in candidate host plants is the assessment of the neutron spectrum in which the SSLR specimens and flux wire dosimetry will be irradiated. Because the neutron spectrum varies throughout the reactor vessel due to various neutron interactions with reactor material and water compositions, it is desirable that the SSLR capsule be irradiated in a neutron spectrum that is comparable to that which is experienced on the inner surface of the vessel wall where surveillance capsules are normally located. This section presents results of investigations of this criterion.

Four operating BWRs with different design and operating characteristics that can affect the irradiation of the proposed SSLR capsules are being evaluated.

In Section 6.3.3, ranges of acceptable SSLR capsule locations were provided for each plant to allow for flexibility in determining a precise final mounting location. In this section, the objective is instead to consider the shift in neutron spectra between the OEM capsule location and the potential SSLR capsule mounting locations. To provide an accurate spectral analysis, the capsule was modeled in a discrete location within the acceptable regions of each plant. For each plant, the SSLR capsule was placed along the 0° azimuth in the elevation range with the flattest flux profile at a radial offset where the flux was approaching 4.39×10^{10} n/cm^2-s. The results at this location should be representative of the flux spectrum within the full range of previously determined locations.

Figure 6-5 through Figure 6-8 compare the neutron spectra incident upon the OEM capsule location and the proposed SSLR capsule location for each of the plants. The fluxes in each location differ by orders of magnitude, so for comparison purposes, each flux spectrum is normalized to the total fast neutron flux (E > 1 MeV) for that region. For material damage and activation analyses of carbon steels that comprise RPV materials, the important activation measurement is ^{54}Fe (n,p) ^{54}Mn. For the purposes of activation, the important spectrum shift between the OEM and evaluated SSLR capsule locations lie in the energy range of approximately 2 MeV to 16 MeV. Figure 6-5 through Figure 6-8 show the flux spectra for the two locations for energies greater than 1 MeV, which includes the entire relevant range of the iron activation spectrum.

Table 6-4 shows the differences in the neutron spectrum by energy group for the OEM capsule locations and SSLR capsule locations for each reactor. **[[**

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The minimum and maximum differences important to ^{54}Fe activation are shown in **bold** type in Table 6-4. The values shown in **<u>bold underline</u>** type are the overall maximum values. It is noted that the maximum values in the lower energy groups are not important to the activation energy range for ^{54}Fe.

In summary, there is a small difference in neutron flux spectrum between typical BWR capsules and the proposed SSLR capsules. The maximum difference in flux between the SSLR capsules and a typical BWR capsule for all energy groupings is less than 2.5%.

6.4 Summary

The evaluations performed demonstrate that the target flux can be attained for the proposed SSLR capsules in four candidate host plants, and several possible installation locations are summarized that yield the target flux.

Target flux values for SSLR capsules can be attained through a combination of the following:

- Locating the capsules at a core flat position (0°, 90°, 180°, and 270°), illustrated in Figure 6-9.
- Offsetting the capsules from shroud by several inches.
- Positioning capsules lower in the core (though flux profile is less uniform across the capsule in this region).

Optimal installation locations are found to be:

- Several inches radially from the core shroud toward the RPV inside surface.
- Within ±5° of the 0° and 180° positions, which are low flux locations free from jet pump obstructions.
- Between 60-100" from the bottom of active fuel (BOAF), where the flux profile will be relatively uniform over the height of the capsule.

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Figure 6-1
Illustration of flux rate needed as a function of irradiation time to attain maximum catch up fluence for SSLR capsules of [[ ]]

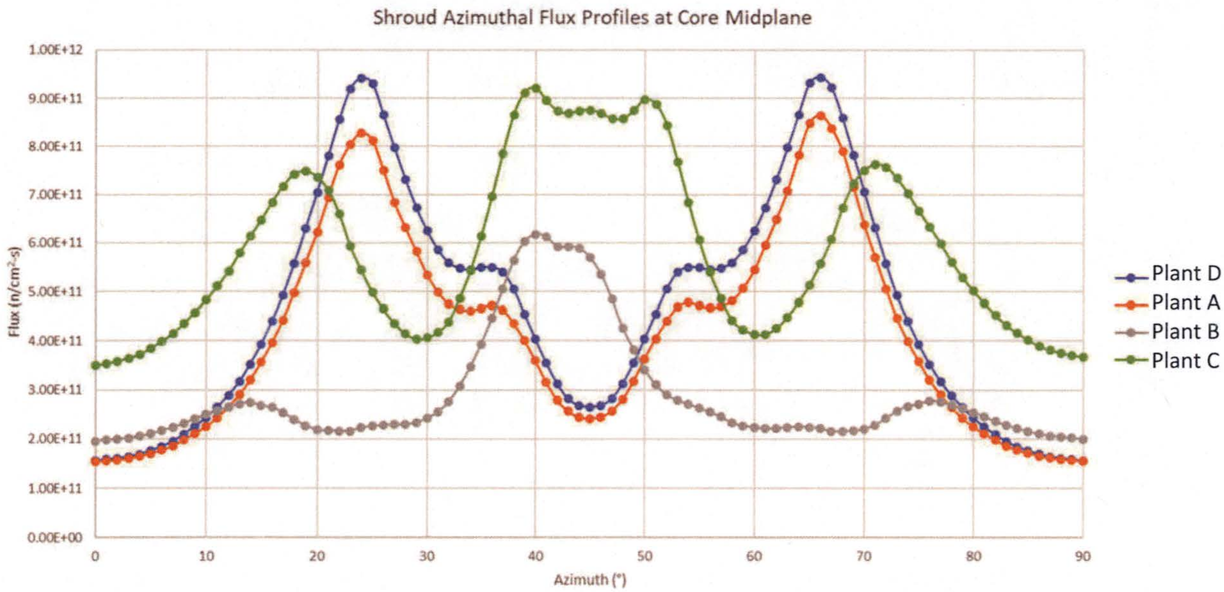

Figure 6-2
Shroud wall azimuthal flux profiles at core midplane elevation for four candidate host plants

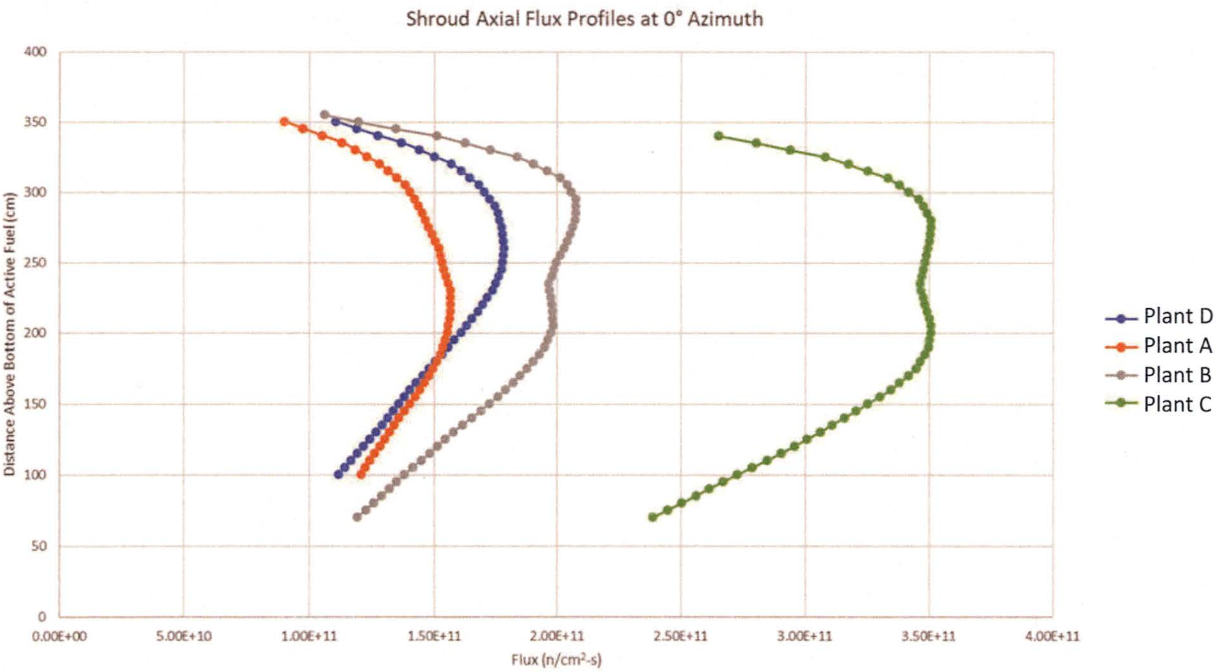

Figure 6-3
Shroud wall axial flux profiles at 0° azimuthal location for four candidate host plants

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Figure 6-4
Flux profile in the annulus region at 0° azimuth for various radial offset distances from shroud OD for Plant D

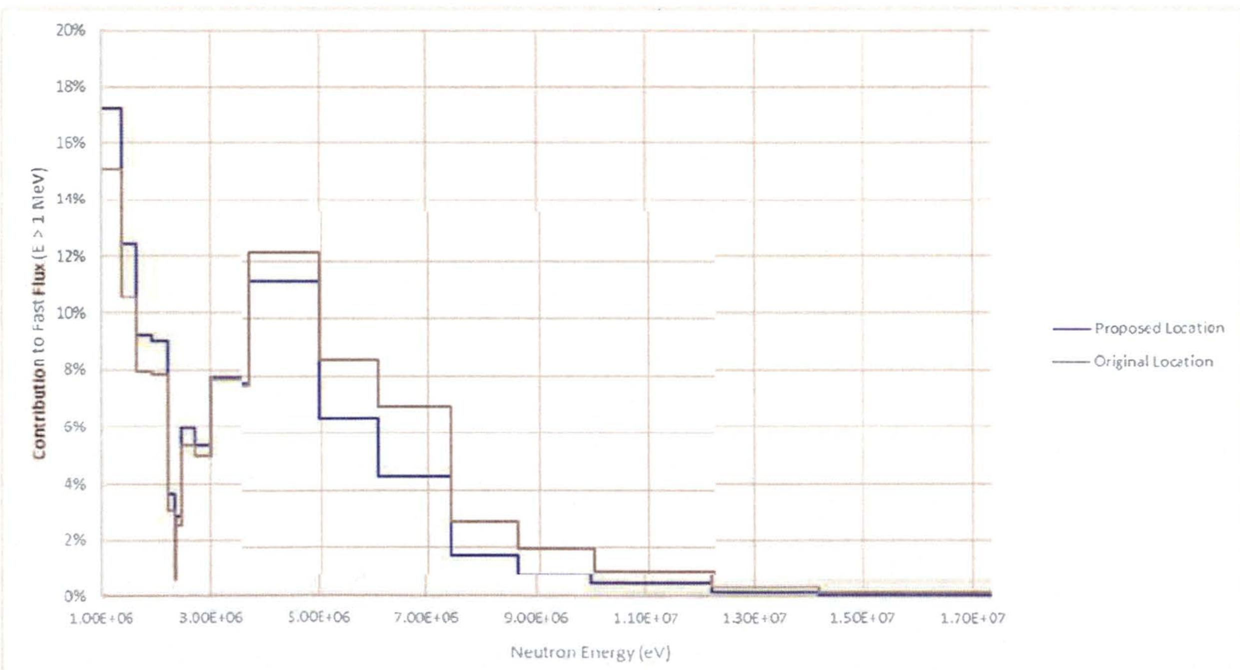

Figure 6-5
Comparison of relative fast flux spectra for Plant A capsule locations

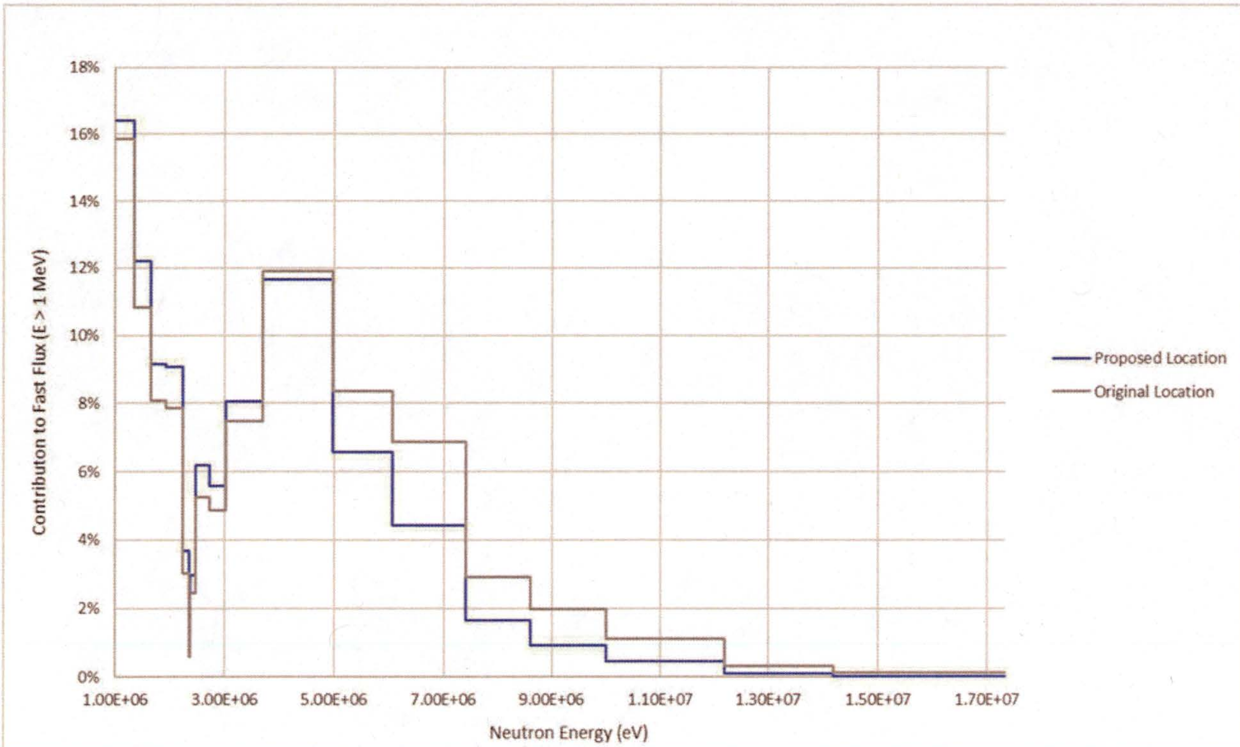

Figure 6-6
Comparison of relative fast flux spectra for Plant B capsule locations

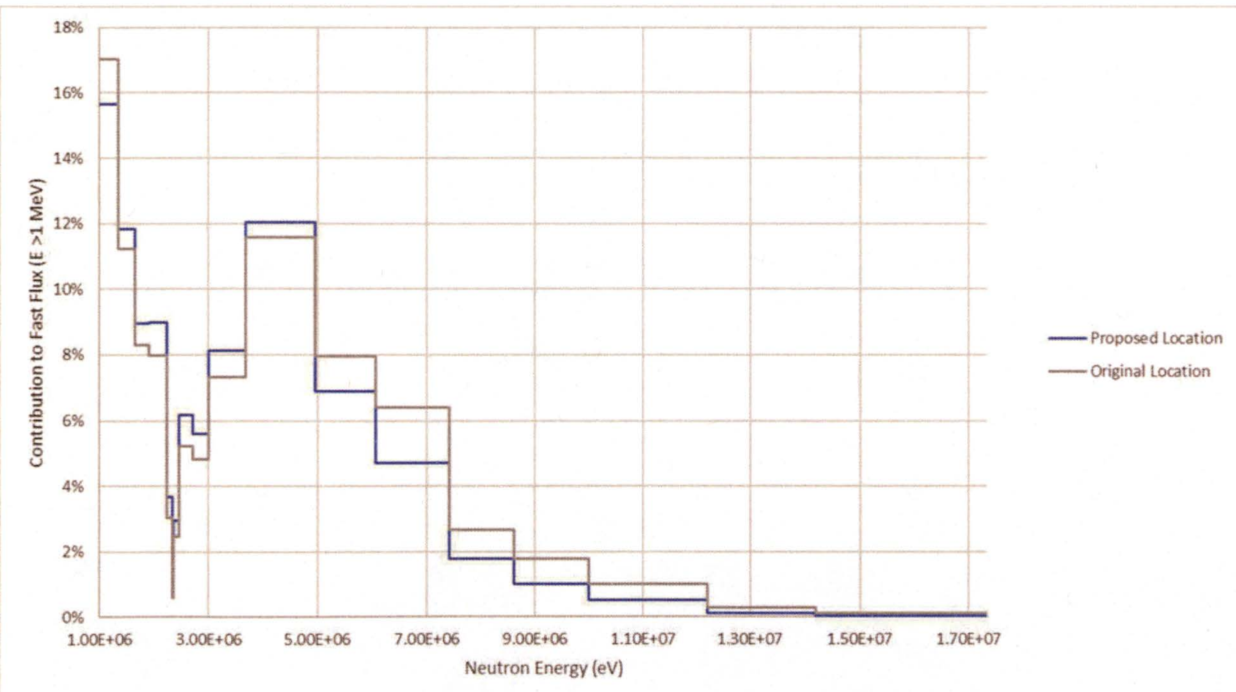

Figure 6-7
Comparison of relative fast flux spectra for Plant C capsule locations

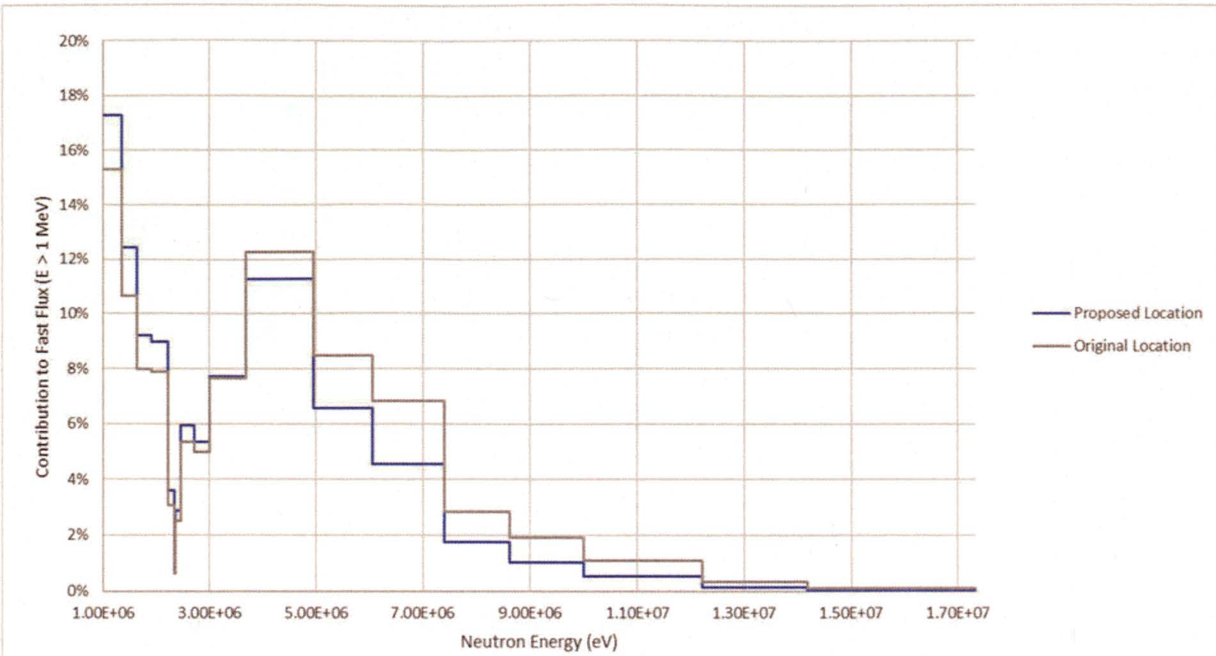

Figure 6-8
Comparison of relative fast flux spectra for Plant D capsule locations

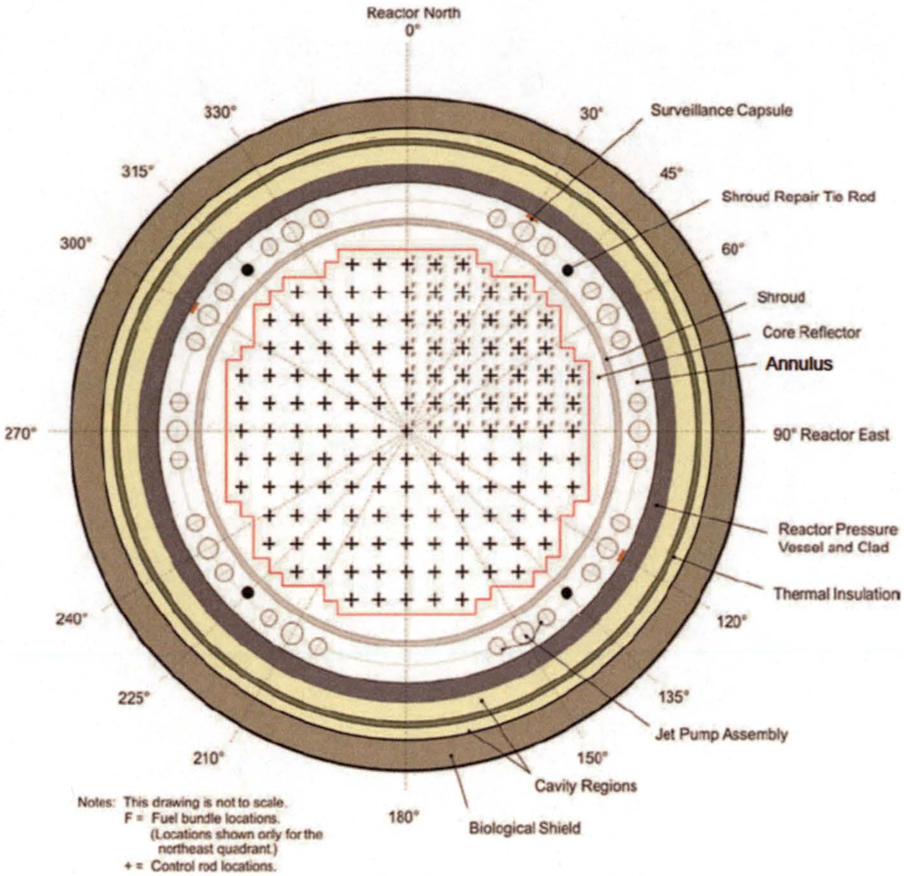

Figure 6-9
Schematic illustration of reactor azimuthal locations relative to core and internals for Plant C. The other candidate host plants may have slightly different core configurations and lack tie rods.

Table 6-1
Plant data considered for selection of SSLR capsule candidate host plants [[

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Table 6-2
Cycle data used as input for four candidate host plants

Plant	Cycle	Operation/Projection Data	Rated Power (MWt)
Plant A	16	Operation	3458
Plant B	33	Projection	2419
Plant C	27	Operation	2804
Plant D	22	Projection	4018

Table 6-3
Summary of proposed SSLR capsule mounting locations for four candidate host plants

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Table 6-4
Comparison of capsule fast flux contribution from each energy group

Energy Group (MeV)	Plant A	Plant C	Plant B	Plant D
1.000 – 1.353	**<u>2.14%</u>**	-1.37%	0.54%	**<u>1.96%</u>**
1.353 – 1.653	1.88%	0.62%	**<u>1.37%</u>**	1.78%
1.653 – 1.921	1.26%	0.68%	1.08%	1.21%
1.921 – 2.231	**1.16%**	**<u>0.99%</u>**	**1.21%**	**1.10%**
2.231 – 2.346	0.53%	0.62%	0.65%	0.52%
2.346 – 2.365	0.12%	0.15%	0.15%	0.12%
2.365 – 2.466	0.36%	0.50%	0.51%	0.35%
2.466 – 2.725	0.62%	0.95%	0.93%	0.58%
2.725 – 3.012	0.39%	0.78%	0.71%	0.37%
3.012 – 3.679	0.07%	0.80%	0.58%	0.04%
3.679 – 4.966	-1.02%	0.45%	-0.23%	-0.98%
4.966 – 6.065	-2.04%	-1.05%	-1.78%	-1.92%
6.065 – 7.508	**-2.46%**	**-1.69%**	**-2.45%**	**-2.29%**
7.408 – 8.607	-1.19%	-0.88%	-1.24%	-1.11%
8.607 – 10.000	-0.96%	-0.77%	-1.04%	-0.90%
10.000 – 12.214	-0.60%	-0.50%	-0.66%	-0.57%
12.214 – 14.191	-0.20%	-0.18%	-0.23%	-0.19%
14.191 – 17.332	-0.08%	-0.07%	-0.09%	-0.08%

Note: The minimum and maximum differences important to ^{54}Fe activation are shown in **bold** type. The values shown in **<u>bold underline</u>** type are the overall maximum values.

7 CONCEPTUAL DESIGN FOR SSLR CAPSULES

The SSLR capsules will consist of several components, described in the following sections. The Charpy inserts for each surveillance material will be contained in a packet, with one packet per material. Sets of packets will be contained in three capsules, with the groupings as defined in Table 4-11, Table 4-12, and Table 4-13. The three capsules will be contained in a capsule holder. The following sections describe the conceptual design for these components.

7.1 Surveillance Packet Design

7.1.1 Positive Identification of Material

Positive identification of the materials must be maintained throughout the insert preparation, encapsulation, irradiation, weld reconstitution, and post-irradiation testing. All previously tested ISP and SSP Charpy specimens are currently in the BWRVIP specimen repository in individual containers that are marked with the plant and capsule identification. The inventory list is carefully maintained and reviewed annually so that every broken Charpy specimen is known and easily retrievable.

Positive identification of the reconstitution inserts will be maintained during the irradiation period by only including one material in each packet. While it is possible to mark each insert, any marks on the outer surfaces of the inserts are undesirable since they would adversely affect the post-irradiation reconstitution and testing. Therefore, positive identification during packet fabrication will be ensured by only having one material worked on at a time during the machining, packet loading, and packet weld closure operation. Each packet will be marked on the end-tab with both lettering and with a binary code. An example of a Charpy packet end-tab identification is shown in Figure 7-1 for plate heat C4114-2. The binary code is a redundant material identifier in case the engraved letters and numbers are not easily readable. As discussed in Section 5, some of the packets will have 12 mm and 15 mm inserts. These shorter inserts will require a carbon steel spacer blank. Each of the blanks will be engraved with the word "BLANK" on it. This will avoid any possible confusion with the unmarked weld inserts after irradiation. As shown in Figure 7-1 and Figure 7-2, the corner of the packet end-tabs is chamfered to indicate the position of the dosimetry during irradiation. The packets will be loaded in the capsule basket with the chamfered corner up for every packet. In this case, up is defined as the highest elevation in the reactor for each packet.

The irradiated inserts will remain unmarked until the packets are opened. Positive identification will be maintained by only opening one Charpy packet at a time after irradiation. Immediately after weld reconstitution, the specimen ends will be engraved with the specimen ID. The specimens will be kept in individual marked containers until they are tested. The final reconstituted specimen dimensions, notch orientation, arc stud welding thermal profiles, and any noteworthy marks will be recorded and the records will be maintained.

7.1.2 Surveillance Packet Construction [[

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7.1.3 Dosimetry

Each packet will contain a dosimeter wire assembly for measurement of specific activities. The dosimeter wire assembly consists of a dosimeter wire holder, four dosimeter wires, and a cover plate.

Figure 7-6 shows an exploded view of the dosimeter wire assembly components. The dosimeter wire holder and cover plate are made of carbon steel. Dosimeter wires are made of high-purity iron, nickel, copper, and niobium. ASTM E844 [30] provides guidance on neutron dosimetry for reactor surveillance and provides the basis for selection of these materials.

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After each SSLR capsule has been irradiated and withdrawn, all capsule packets will be opened and dosimetry measurements will be collected before specimens are put into storage. This will be performed for all SSLR capsule materials regardless of whether it has been determined that specimens of a given material will be reconstituted. It is important to measure dosimetry soon after capsule withdrawal, since some capsules may be withdrawn several years before plants make the decision to pursue SLR.

7.2 Capsule Holder Design

For the SSLR capsules, a specialized holder will be used that has the following characteristics:

- A single holder capable of containing three capsules corresponding to the three catch-up fluence groupings (refer to Table 4-11, Table 4-12, and Table 4-13).
- Allows for the removal of each capsule from the holder independently.
- Attaches to the outside surface of the core shroud to enable capsules to attain neutron flux in the target range of 2.4×10^{10} to 4.39×10^{10} n/cm^2-s.
- Allows for the possibility of removal and transfer of the capsules to an alternate host plant if needed.
- Does not restrict access to welds or components that are subject to in-vessel visual inspections (IVVI), or if so, is able to easily be relocated and reinstalled to allow for these activities.
- Requires minimal modification to the host plant.
- Withstands host plant seismic conditions (and for the alternate host plant, should the capsule need to be moved).
- Is not susceptible to flow-induced vibration (FIV).

Conceptual capsule holder designs have been developed and evaluated for the candidate host plants. The SSLR capsule holder will be mounted to the shroud outside surface using mechanical methods, and therefore, issues regarding weldability of irradiated materials do not need to be addressed. Based on the conceptual design efforts, it is concluded that the SSLR capsule plan can be implemented, and the capsule holder can be designed to withstand applicable loads, including seismic and FIV loads. A detailed capsule holder design effort will be conducted after NRC approval of the ISP for SLR program plan. Appropriate design and licensing requirements for implementing the installation of the holder will be met.

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Figure 7-1
Example of a packet end-tab showing the identification markings. [[
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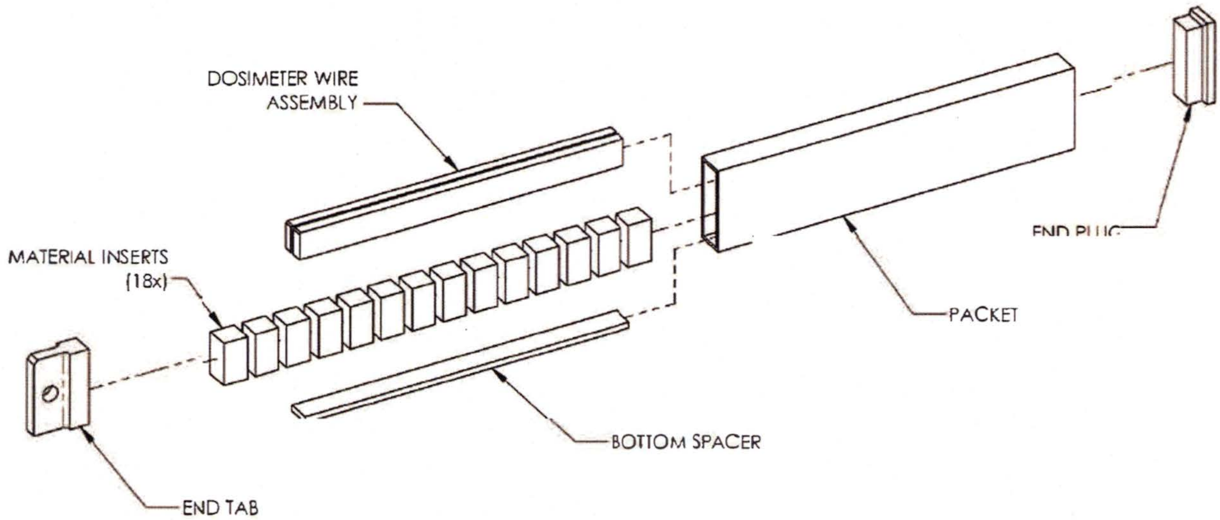

Figure 7-2
Exploded view of surveillance packet components and assembly sequence

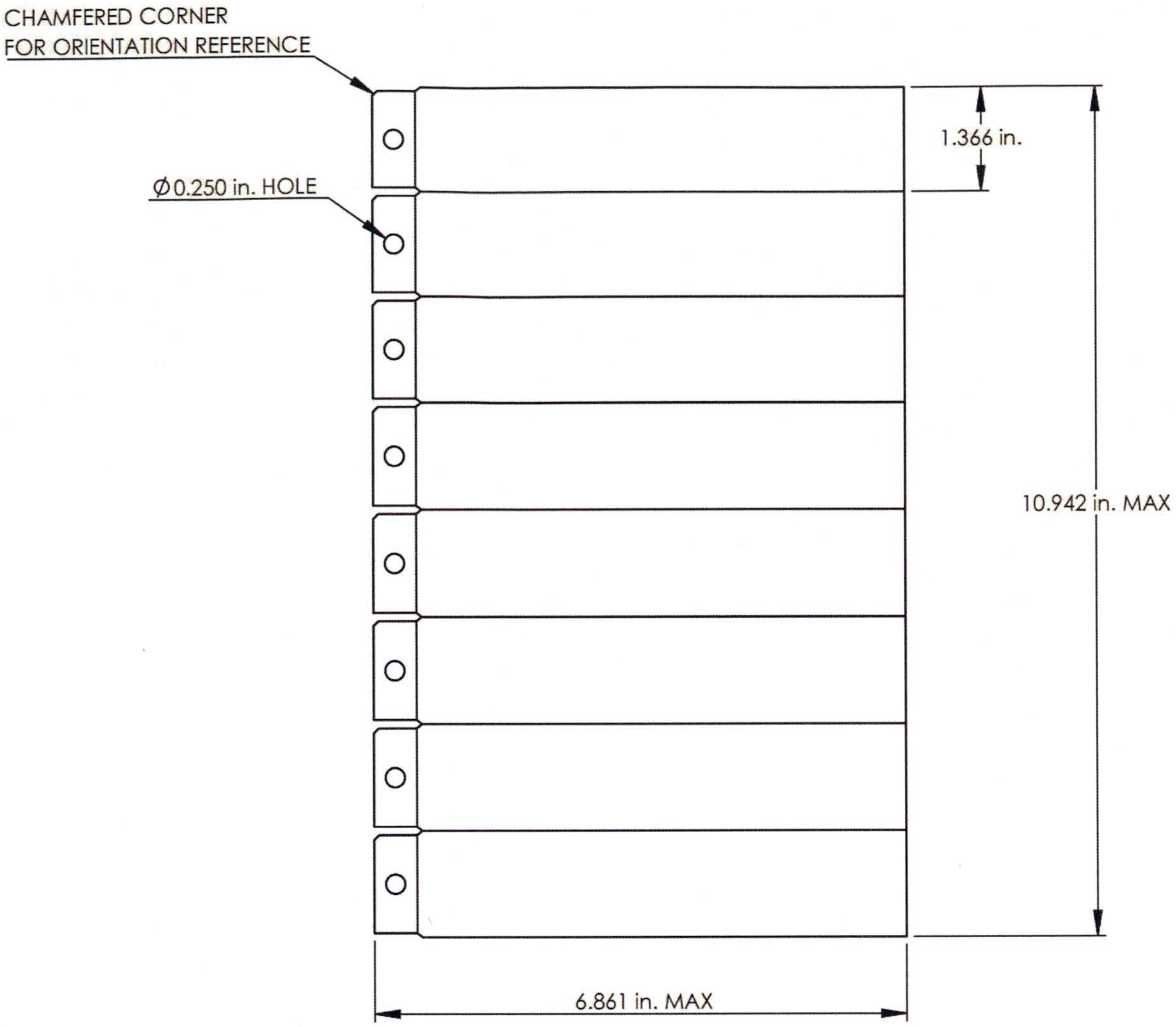

Figure 7-3
Layout drawing of eight packets within each surveillance capsule

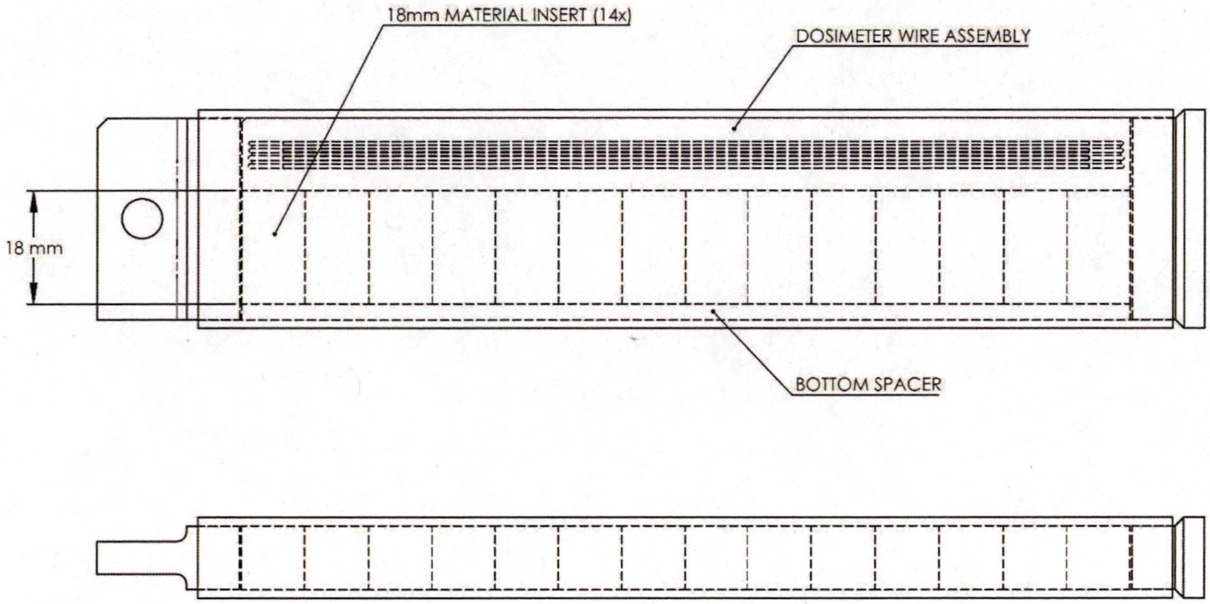

Figure 7-4
Transparent view of example packet with 14 material inserts of desired 18mm length

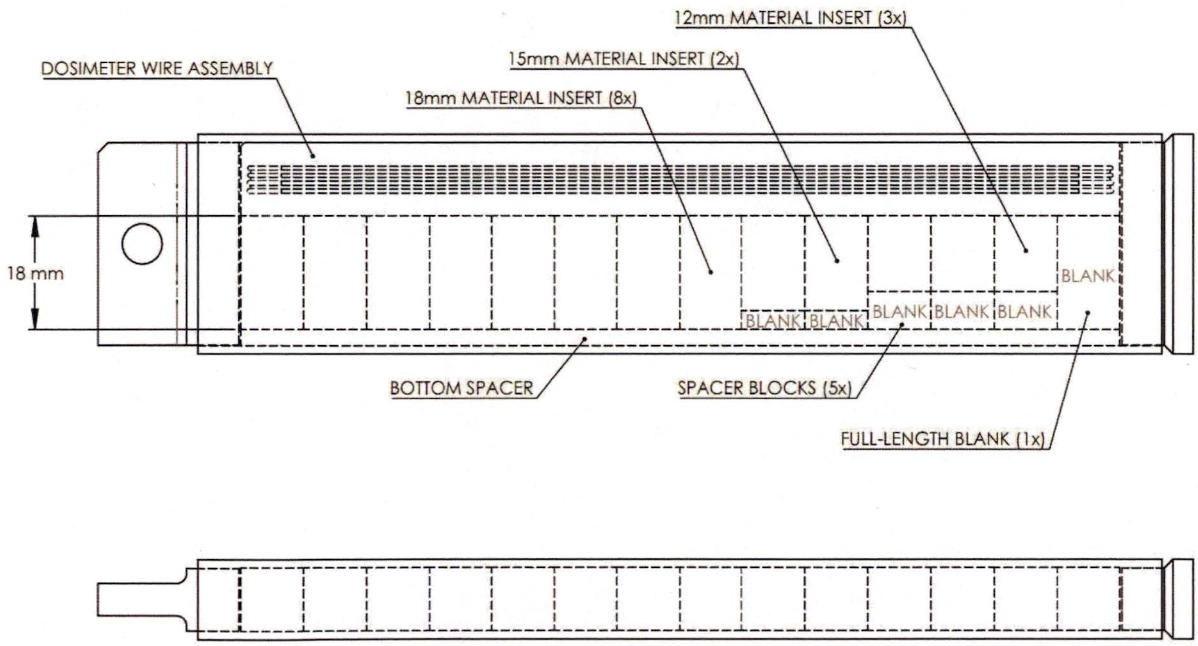

Figure 7-5
Transparent view of example Packet for weld heat [[ ]], with 8 weld material inserts of desired 18mm length, 2 inserts of 15mm length, 3 inserts of 12mm length, and spacer blocks/blanks

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Figure 7-6
Exploded view of dosimeter wire assembly

8
SCHEDULE FOR SSLR CAPSULE INSERTION, WITHDRAWAL, AND TESTING

The potential schedule for capsule insertion, withdrawal, and testing is discussed below. Chapter 5 discussed the selection of candidate host plants and potential capsule insertion locations based on the feasibility of attaining the needed catch up fluence and neutron flux. Four candidate host plants have been identified. Evaluation of flux maps for the four vessels indicates that flux in the target range of 2.4×10^{10} to 4.39×10^{10} n/cm^2-s can be attained if the capsule is located in the annulus region in selected ranges of azimuthal, axial, and radial locations.

In Chapter 4, Table 4-11, Table 4-12, and Table 4-13 summarize the three proposed SSLR capsule groupings and the needed catch up fluences for all representative materials. [[

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]] Table 4-11, Table 4-12, and Table 4-13 also summarize the final fluence exposure for all representative materials for the minimum and maximum flux in the target range for the projected durations of irradiation.

The anticipated timeframe for SSLR capsule insertion and withdrawal is compared with license periods for BWRs impacted by the capsule data in Figure 8-1, Figure 8-2, and Figure 8-3 for the three SSLR capsule groupings. It is assumed in the construction of these figures that capsules will be installed in the host vessel in 2022. These plots have been constructed for scoping and planning purposes, and the irradiation schedule will depend on the outage schedule of the selected host plant. The plots show that irradiation of all three SSLR capsules will be completed well before the end of the second PEO for all BWRs, and for nearly all BWRs before the end of the first PEO. Additionally, Tables 8-1, 8-2 and 8-3 provide a range of possible insertion and withdrawal dates (2022, 2023 and 2024) for three flux values (minimum, intermediate and maximum). The final scenario chosen will depend on the host plant that is selected for the irradiation campaign. The actual irradiation schedule (selected from Table 8-1, 8-2, or 8-3) will be provided to the NRC upon program approval and host plant selection. NRC acceptance of these scenarios as part of the ISP SLR program plan are expected to comply with the requirements of 10 CFR50, Appendix H, paragraph III.B.3.

The specific materials to be reconstituted and tested will be determined at a later date based on the needs of plants pursuing SLR, as discussed in Section 9. The sequence of events that will trigger testing of SSLR capsule materials is described as follows. A licensee will submit an application for SLR indicating the plant intends to take credit for the ISP for SLR program and providing the projected SLR end-of-license fluence. Based on the projected SLR fluence of the target materials at that plant, the BWRVIP will evaluate whether the existing or projected ISP(E) fluence bounds the SLR fluence or whether the representative materials from the SSLR capsules need to be tested. If existing ISP or ISP(E) capsules are bounding, then the representative

material would not be tested at that time. When an SLR application is submitted by a target plant whose SLR fluence is not bounded by existing ISP or ISP(E) capsules (those in bold text in Table 4-3, Table 4-4, Table 4-6, and Table 4-7), the BWRVIP will develop a schedule for testing and reporting of results for the representative materials for those plants (see Section 10.3.2).

Table 8-1
Scenario 1: Insertion and Withdrawal Dates for Minimum Flux of 2.4E10 n/cm^2-s

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Table 8-2
Scenario 2: Insertion and Withdrawal Dates for Intermediate Flux of 3.4E10 n/cm^2-s

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Table 8-3
Scenario 3: Insertion and Withdrawal Dates for Maximum Flux of 4.39E10 n/cm²-s

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Figure 8-1
Schedule for Group 1 SSLR capsule irradiation compared with license dates for BWRs represented by the Group 1 capsule materials

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Figure 8-2
Schedule for Group 2 SSLR capsule irradiation compared with license dates for BWRs represented by the Group 2 capsule materials

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Figure 8-3
Schedule for Group 3 SSLR capsule irradiation compared with license dates for BWRs represented by the Group 3 capsule materials

9 ADMINISTRATION AND IMPLEMENTATION

The ISP for SLR program plan will maintain all elements of the currently approved ISP as provided in BWRVIP-86, Revision 1-A [4], with exceptions as noted below.

9.1 Project Management Responsibilities

Consistent with BWRVIP-86, Revision 1-A [4], ISP for SLR project management responsibilities will be assigned to the BWRVIP. The BWRVIP will manage capsule withdrawal and testing in accordance with the approximate schedule contained in this plan. Project management activities will include:

- Working with utilities to identify the SSLR capsule host plant and backup plant, determine the actual insertion and withdrawal schedule depending on plant outage schedule, and notify the NRC.
- Working with utilities to identify those materials which will be needed to support SLR and to coordinate and support the testing of those materials and publication of test reports.
- Shipping, reconstitution, and testing of materials and associated dosimetry per applicable standards.
- Distributing capsule test reports to all plants impacted by the representative materials tested in the capsule.
- Planning for changes and contingencies in the SSLR capsule insertion and withdrawal schedule.

9.2 Licensee Responsibilities

At the time that a licensee submits an application for SLR, the licensee must validate the conclusions in this report regarding whether additional surveillance data from the SSLR capsule materials is needed to bound the plant's SLR fluence needs for 80 years.

Section 4 in this report presents the evaluations performed to determine whether the data credited under the current ISP program will bound a given plant's fluence needs for 80 years of operation, or whether additional surveillance data is needed. This is determined by examining the capsule fluence as a percentage of 72-EFPY 1/4T target material fluence. A value of at least 100% indicates that the previously tested or near-term capsule data bounds the target plate or weld for 80 years. A value less than 100% indicates that additional surveillance data is needed. Table 4-3 and Table 4-4 present the capsule fluence as a percentage of target fluence for previously tested and near-term capsules, while Table 4-6 and Table 4-7 present capsule fluence as a percentage of target fluence for ISP(E) capsules.

The target RPV fluence values used in the evaluations in Section 4 are estimated based on extrapolations from currently available fluence values. These fluence values and the percentages

shown in Table 4-3, Table 4-4, Table 4-6, and Table 4-7 must be updated with the latest fluence projections for a given plant at the time that the SLR application is submitted.

The process to be followed by plants represented by the 23 materials in the SSLR capsules is detailed below and illustrated in Figure 9-1.

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9.3 Capsule Data Evaluation

Data evaluation will be consistent with BWRVIP-86, Revision 1-A [4]. The SSLR capsules will be withdrawn according to the approximate schedule contained in this plan. Testing will be performed as needed based on the needs of plants pursuing SLR, as described above. The data from the testing of individual materials will be summarized in a test report containing Charpy impact test results, dosimetry data from various locations within the capsule, and chemistries of irradiated test specimens. An evaluation of the test data will be performed to determine the applicability to the BWR target vessels. In particular, fitted curves will be developed for the irradiated transition temperature Charpy impact energy vs. temperature, lateral expansion vs. temperature, and percent shear vs. temperature data.

The method of Charpy curve-fitting to be employed will be the symmetric hyperbolic tangent (TANH) function [37]:

$$Y = A + B \times TANH\left[\frac{T-T_0}{C}\right] \quad \textbf{Eq. 9-1}$$

where

Y	=	the toughness response measurement (i.e. energy, lateral expansion, or percent shear) at a given temperature, T
A	=	the mid transition energy at a temperature T_0
B	=	the difference between the mid transition and the upper shelf energy levels
(A-B)	=	the asymptotic lower shelf energy level
(A+B)	=	the asymptotic upper shelf energy level
T_0	=	the mid transition temperature corresponding to the value A
C	=	a measure of the slope of the transition region (B/C is the actual slope)

These fitted Charpy curves will be evaluated together with the unirradiated data for the corresponding surveillance weld and plate materials. For both the unirradiated and irradiated transition temperature curves, the 30 ft-lb, 50 ft-lb, and 35 mils lateral expansion values and upper shelf energies will be determined. The 30 ft-lb shift values (ΔT_{30}) will be calculated from the results of the fitted Charpy impact energy curves. The Charpy data from each capsule will be evaluated along with the unirradiated baseline data and any prior capsule test results for the same heats of weld or plate material. Data from both ISP and SSP capsules will be combined for the purpose of evaluation when the same heat of material is contained in multiple surveillance capsules. In particular, the surveillance data will be fitted as follows to obtain the best-fit chemistry factor (CF) per Reg. Guide 1.99, Rev. 2 [6]:

(a) Calculate the fluence factors for each data point from the measured fluence values

$$fluence\ factor_1 = f_1^{(0.28-0.10 log f_1)} \quad \textbf{Eq. 9-2}$$

$$fluence\ factor_2 = f_2^{(0.28-0.10 log f_2)} \quad \textbf{Eq. 9-3}$$

where f = fluence in units of 10^{19} n/cm^2.

(b) Calculate the best fit CF from the least-squares fit equation

$$best\ fit\ CF = \frac{(\Delta T30_1 \times fluence\ factor_1 + \Delta T30_2 \times fluence\ factor_2 + \ )}{(fluence\ factor_1^2 + fluence\ factor_2^2 + \ )} \qquad \textbf{Eq. 9-4}$$

The best fit CF is used to determine the measured RT_{NDT} shift in surveillance materials from the below equation

$$\Delta RT_{NDT} = CF \times f^{(0.28-0.10 log f)} \qquad \textbf{Eq. 9-5}$$

The evaluated test results will be compared to the predicted behavior from Reg. Guide 1.99, Rev. 2, for the CF values from the known chemistries of the surveillance materials. The measured vs. predicted embrittlement response will be documented in the SSLR surveillance material test report.

9.4 Fluence and Dosimetry

Consistent with BWRVIP-86, Revision 1-A [4], an evaluation of capsule fluences will be performed for each of the SSLR capsules as part of the testing and reporting of the capsule. The flux wires will be removed from each capsule and analyzed for radioactivity content by gamma spectroscopy. Dosimetry measurements will be performed soon after withdrawal, since specimen testing will be conducted on an as-needed basis. The analysis of dosimeters will be performed using standard, benchmarked methods. Procedures will be in place for handling and management of capsules. SSLR capsule fluence evaluations will be performed in a consistent manner using a RPV neutron fluence calculational methodology that will meet current NRC Staff guidance in U.S. NRC Regulatory Guide 1.190 [14].

BWR facilities other than the SSLR capsule host plant will continue to determine vessel fluences as needed, utilizing an NRC-approved neutron fluence determination methodology.

If a BWR facility proposes to change its neutron determination methodology, the methodology must be consistent with the guidance of Regulatory Guide 1.190 and approved by the NRC.

9.5 Plan for Ongoing Vessel Dosimetry

Under the ISP for SLR program, ongoing vessel dosimetry will be performed consistent with BWRVIP-86, Revision 1-A [4]. For the SSLR capsule host plant, dosimetry will be available from the capsule as an updated basis for the projected vessel fluence. Capsules from plants other than the SSLR capsule host plant will not be tested. The provisions for dosimetry for those plants not withdrawing and testing surveillance capsules will remain the same as in BWRVIP-86, Revision 1-A [4]. Three options are currently provided for dosimetry for those plants not withdrawing and testing capsules:

1. If a plant has previously tested a capsule, the dosimetry from that capsule is generally the basis for its current fluence projection. This plant's fluence projection will continue to be based on its capsule dosimetry unless a major change to the core design or management is undertaken in the future.

2. If a plant has not previously tested a capsule, but has tested a first cycle dosimeter, the first cycle dosimetry is generally the basis for its current fluence projection. Comparisons of first cycle and first capsule dosimetry results have consistently shown that first cycle dosimetry results are conservative. Therefore, this plant's fluence projection will continue to be based on its first cycle dosimetry unless a major change to the core design or management is undertaken in the future.

3. Alternatively, if a plant has not had a previous capsule tested, a selective neutron transport recalculation could be performed for this vessel using a benchmarked fluence methodology, dosimetry data from plants with similar design and any related information (e.g., ex-vessel dosimetry) that could improve the calculation of fluence in the vessel beltline region.

It should be noted that a number of untested surveillance capsules remain installed in reactor vessels. The capsules held in reserve at the ISP host plants are intended to be used for fluence monitoring beyond the original licensed period of plant operation. [[Content Deleted - *EPRI Proprietary Information*]]

9.6 Data Sharing

Consistent with BWRVIP-86, Revision 1-A [4], the exchange and sharing of surveillance data will be coordinated with all participants under the ISP for SLR program. Evaluation of surveillance data will continue be managed in the same manner as for the current ISP program. The program plan to manage data sharing will be updated to reflect the results of SSLR capsule testing.

9.7 Data Utilization

Consistent with BWRVIP-86, Revision 1-A [4], there are two options for applying the measured surveillance data:

1. Under Option 1, if the heat of material does not specifically match the limiting heat of beltline material for that vessel, the chemistry factor for the limiting beltline material will be determined by the tables in Reg. Guide 1.99, Rev. 2. The corresponding margin term as stated in Position C.1 will apply. The same method (i.e., Position C.1) will be applied to calculate adjusted reference temperature (ART) for all weld and plate materials in the vessel beltline.

2. If two or more surveillance data sets with matching heat numbers are available for the limiting beltline material, Option 2 may be used to calculate adjusted reference temperature when the data has been determined to be credible. The chemistry factor and margin term are calculated using Reg. Guide 1.99, Rev. 2, Position C.2. This data will only be used for evaluating the ART for the limiting beltline materials in the vessel that is being represented. The ART for all other materials in the beltline will be evaluated according to the requirements of Reg. Guide 1.99, Rev. 2, Position C.1.

Credibility of the surveillance data will be judged by the following criteria:

a) Materials in the capsules should be those most likely to be controlling with regard to radiation embrittlement.

b) Scatter in the plots of Charpy energy vs. temperature for the irradiated and unirradiated conditions should be small enough to permit the determination of the 30 ft-lb temperatures and upper shelf energies unambiguously.

c) When there are two or more sets of surveillance data from one reactor, the scatter of ΔRT_{NDT} values about a best-fit line (given by Eq. 9-5) normally should be less than 28°F for welds and 17°F for base metal. Even if the fluence range is large (two or more orders of magnitude), the scatter should not exceed twice those values.

d) The irradiation temperature of the Charpy specimens in the capsule(s) should match the vessel wall temperature at the cladding/base metal interface within ±25°F.

e) If correlation monitor material is available in the capsules, the surveillance data for the correlation monitor material should fall within the scatter band of the data base for that material.

Data points falling outside the normal 2-sigma scatter band for welds or plates will be evaluated in detail and compared to similar material test results to understand the embrittlement behavior. Applicability to individual BWR vessels will be considered on a plant-specific basis.

9.8 Planning for ISP Changes

Consistent with BWRVIP-86, Revision 1-A [4], the BWRVIP will monitor the progress of the ISP for SLR program, coordinate future actions such as withdrawal and testing of the SSLR capsules and reporting of surveillance material test results, and identify additional program needs. The BWRVIP will identify and implement minor changes to the program as the need arises, such as changes to the insertion, withdrawal, and testing schedule.

Contingency planning for the ISP for SLR program will need to address any major interruptions in host plant operation, such as an extended outage or early, permanent plant shutdown. In the event of SSLR host plant shutdown, depending on when shutdown occurs relative to the planned capsule withdrawal date, the capsules would be withdrawn and the fluence needs reassessed. The capsules could be tested early and data collected, or, if needed, the capsules could be reinstalled in the backup host plant. Reinstalling capsules in the backup host plant would require designing and fabricating a new plant-specific holder for the capsules.

The contingency plans under the ISP for SLR program are the same as under the ISP, should an ISP host plant prematurely shut down. Early shutdown of one of the existing ISP host plants would not impact the capability of this program to provide 80-year surveillance data for all BWRs pursuing SLR. [[

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In the event of loss or damage to an SSLR capsule, a backup capsule could be fabricated and irradiated. Each material to be included in the SSLR capsules has other previously tested capsules that could be used as a source of specimens. This eventuality would extend the time needed to obtain the surveillance data.

If necessary, it would be possible to utilize the contingency capsules from the existing ISP program, as described in the Individual Vessel Evaluations in Appendix A of BWRVIP-86, Revision 1-A [4]. The work performed by the BWRVIP to select the best representative materials for inclusion in the ISP also identified other surveillance materials in other BWR vessels that could be used as backup surveillance materials to support the ISP. These capsules remain available to support the ISP for SLR program if needed. To assure that these backup materials are available for possible future testing, these backup materials must be kept in a condition which allows for testing. The BWRVIP and all plants that possess capsule specimens for which unirradiated Charpy baseline data exist will not dispose of the specimens without NRC approval. Capsules not identified as test capsules under the ISP or ISP for SLR programs will continue to be irradiated in their reactors. Should it become necessary to remove a non-ISP capsule for any reason without the intent to perform testing, the site must reinstall the capsule before restart unless it can be determined that there is adequate technical basis to defer reinstalling the capsule or maintain the capsule indefinitely in the refueling pool. The objective of these actions is to maintain the capsules in a condition to allow for possible future testing under the contingency plan.

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Figure 9-1
Flowchart illustrating procedure for determining need for additional surveillance data for a given target plant based on updated 80-year RPV fluence projections

10
LICENSING ASPECTS OF IMPLEMENTATION

The intent of the ISP for SLR program approach is to utilize the existing ISP program to the greatest extent possible and to collect additional surveillance data needed to bound the U.S. BWR fleet for 80 years of operation. From a licensing perspective, each utility will continue to demonstrate compliance with 10CFR50 Appendix H [1] by reference to the ISP and ISP for SLR programs in Plant Technical Specifications (Tech Specs) or Updated Final Safety Analysis Reports (UFSAR). In the implementation phase, the ISP for SLR program documents and material test reports will be submitted to the NRC through the BWRVIP. Throughout the program, the BWRVIP will continue to review the ISP for SLR program and, if necessary, will implement revisions to meet the licensing needs of utilities.

10.1 Implementation in Plant Technical Specifications or UFSAR

Implementation of the ISP for SLR program will be performed consistent with BWRVIP-86, Revision 1-A [4]. All U.S. BWRs have already amended their operating licenses to maintain their 10CFR50 Appendix H surveillance programs by implementing the ISP. Licensees currently reference the ISP program and implementation plans in the individual plant Tech Specs or UFSARs as appropriate. Details of the ISP test matrix included in plant Tech Specs or UFSARs include identification of the specific representative weld and plate materials, which will remain the same under the ISP for SLR program.

BWRs intending to pursue SLR will update their licenses to indicate that for SLR, the data to support compliance with 10CFR50 Appendix H will be provided by the ISP for SLR program. Plants intending to implement the ISP for SLR program will do so through the SLR license renewal application and license amendment process. Upon NRC approval of the ISP for SLR program, individual BWR plant owners will submit requests to the NRC to implement the program as part of the SLR application or license amendment process.

A second step in the implementation process is the plant-specific review of existing plant operating P-T limit curves. An initial review of the SSLR surveillance data will confirm that the projections of ART used in developing the present curves are still valid, or are conservative, for each BWR vessel. The period of validity (EFPY) for the existing curves will be evaluated based on the available information for each reactor vessel, and a reassessment of the date for revision will be determined if changes to the P-T curves are deemed to be necessary.

A reassessment of the validity of P-T limit curves will continue on an ongoing basis as new data becomes available from the ISP for SLR program and as the data is evaluated for embrittlement behavior of the limiting weld and plate materials for specific BWR reactor vessels.

Because the ISP for SLR is a continuation of the ISP program, in the event that one of the materials tested from SSLR capsules is representative for a plant still within its 60-year license period, it is expected that such plants will evaluate P-T limits for the impact of the SSLR capsule data.

10.2 Compliance with 10CFR50 Appendix H and GALL-SLR

The ISP for SLR program is an extension of the current ISP providing additional surveillance data for the SLR period and uses the same methodology in determining compliance with 10CFR50 Appendix H [1]. The continuation of the ISP under the ISP for SLR program represents the minimum possible change to the existing program. In the process, some alternatives to 10CFR50 Appendix H [1] and GALL-SLR [10] must be implemented while still representing minimal change to the existing program

10.2.1 Areas of Compliance with 10CFR50 Appendix H and GALL-SLR

The BWRVIP has addressed the following requirements of 10CFR50 Appendix H [1] in establishing the ISP, as evaluated by the NRC in the SERs to BWRVIP-86, Revision 1-A [4], and BWRVIP-116 [31]. Compliance of the ISP for SLR program with these requirements is described below.

- *Similarity of Plant Operating Environments*

  The BWRVIP and NRC concluded in [4, 31] that overall operating environments (normal operating temperatures in annulus region, neutron energy spectra) for all U.S. BWRs are sufficiently similar to support data sharing and implementation of an ISP. BWRs other than the SSLR capsule host plant will determine vessel fluence during the SLR period utilizing an NRC approved neutron fluence calculational methodology.

- *RPV Neutron Dosimetry Program*

  The BWRVIP and NRC concluded in [4, 31] that existing available sources of dosimetry data and acceptable fluence calculational methodologies would continue to provide accurate estimates of RPV neutron fluence through the PEO. All BWRs that have implemented the ISP use neutron fluence calculational methodologies that have been benchmarked against existing dosimetry databases. Therefore, this requirement would continue to be met through implementation of the ISP for SLR.

- *Data Sharing Arrangements*

  BWRVIP has demonstrated the ability to successfully integrate and distribute data to all BWR licensees through the ISP and many other programs. This commitment continues to apply for the ISP for SLR program. Individual BWR licensees intending to pursue SLR will continue to demonstrate compliance with the regulatory requirements of 10CFR50 Appendices G and H by referencing the ISP for SLR program in facility Technical Specifications or Updated Final Safety Analysis Reports, as all U.S. BWRs have previously done for the ISP program.

- *Contingency Plan Development*

  The NRC concluded in in [4, 31] that the BWRVIP ISP has established an adequate contingency plan. The BWRVIP identified several options that may be undertaken to ensure that adequate surveillance data continues to be obtained in the event of capsule damage or loss or the indefinite shutdown of a host plant, such as early withdrawal and testing of capsules prior to shutdown or the use of non-ISP surveillance capsules maintained as backup capsules. Contingency plans for the ISP remain as described in BWRVIP-86, Revision 1-A, and additional contingency plans for the ISP for SLR program are discussed in Section 9.8.

- *Identification of Substantial Advantages to be Gained as a Direct Result of Implementation of an ISP*

  The BWRVIP and NRC concluded in [4, 31] that there are substantial advantages to be gained by implementation of the ISP. The establishment of the ISP addressed shortcomings of the original plant-specific surveillance programs, such as lack of adequate unirradiated baseline Charpy data and surveillance materials which were not representative of a plant's limiting RPV materials. Implementation of the ISP reduces the cost of surveillance testing and analysis for the BWR fleet and improves the overall quality of data and evaluation of BWR RPV embrittlement by identifying and evaluating materials which may better represent plant limiting materials. The ISP for SLR program maintains these advantages in providing data to bound 80 years of plant operation.

GALL-SLR [10] includes the following provisions for aging management programs for reactor vessel material surveillance in the SLR period. The applicability of these provisions to the ISP for SLR program is described below.

- *Use of an ISP*

  GALL-SLR allows for the use of an ISP that meets the requirements of 10CFR50 Appendix H [1].

- *Use of Reconstituted Specimens*

  GALL-SLR recognizes that additional surveillance capsules may be needed to address the subsequent PEO, whether for an ISP or for an individual plant program, and allows for the surveillance program to fabricate and irradiate additional capsules using reconstituted specimens from previously tested capsules.

- *ISP Implementation for SLR Period*

  GALL-SLR calls for the plant-specific implementation of the ISP during the SLR period to be maintained consistent with the latest approved version of the ISP plan for the subsequent PEO. This requirement will be met by plants incorporating the approved ISP for SLR program plan in their licensing basis, in addition to BWRVIP-86, Revision 1-A, which plants have already incorporated.

  GALL-SLR also requires reactors in the ISP for SLR program to maintain an adequate dosimetry plan. This requirement will continue to be met during the SLR period, consistent with the plan described in the SERs to BWRVIP-86, Revision 1-A [4], and BWRVIP-116 [31].

- *Neutron Fluence Criterion for Capsules Addressing the Subsequent PEO*

  SSLR capsules will be irradiated such that they attain a fluence that meets or exceeds the reactor vessel 1/4T fluence.

  GALL-SLR requires the withdrawal and testing of at least one capsule addressing the subsequent PEO with a neutron fluence of one to two times the peak neutron fluence of interest at the end of the subsequent PEO.

  GALL-SLR allows a previously tested surveillance capsule that meets this fluence criterion to be credited as addressing the subsequent PEO. This is the case for a number of BWRs, for which existing ISP data or projected ISP(E) data will bound the target 72-EFPY fluence.

Plants bounded by ISP and ISP(E) data are identified in Table 4-3, Table 4-4, Table 4-6, Table 4-7.

Under GALL-SLR, surveillance capsules previously identified for withdrawal and testing to address the initial period of extended operation shall not be postponed to increase the neutron fluence to meet the GALL-SLR fluence criterion. For the ISP for SLR program, reconstitution will be used to fabricate new SSLR capsules to supplement the capsules in the existing ISP test matrix. All capsules that are credited under the current ISP will be withdrawn and tested according to the existing ISP test schedule. No ISP capsules will be deferred to the SLR period.

10.2.2 Alternatives to 10CFR50 Appendix H and GALL-SLR

Alternatives to 10CFR50 Appendix H [1] and GALL-SLR [10] in the ISP for SLR program are identified below.

- *10CFR50 Appendix H, Paragraph IV.A: Capsule Test Reporting*

  10CFR50 Appendix H requires that capsule material test results be submitted to the NRC within one year of the date of capsule withdrawal. Under the ISP for SLR program, upon SSLR capsule withdrawal, all specimens will be placed into storage until it is determined that data for a given material is needed. However, all packets will be opened and dosimetry tested at the earliest opportunity following capsule withdrawal and shipment to the testing facility. Materials will be tested only for plants applying for SLR that need the surveillance data provided by those materials.

- *10CFR50 Appendix H, Paragraph III.C.2: Reduction in Number of Specimens*

  The BWRVIP and NRC concluded that establishment of the ISP does not result in a reduction in the number of materials being irradiated, number of specimen types, or number of specimens per reactor being tested. For the SLR period, reconstitution will be used to fabricate new SSLR capsules to supplement the capsules in the existing ISP test matrix. All capsules that are credited under the current ISP will be withdrawn and tested according to the schedule established in BWRVIP-86, Revision 1-A. No ISP capsules will be deferred to the SLR period.

  At this time, it is not known if there will be a reduction in the number of specimens tested in the ISP for SLR program, since it is unknown at this time which plants will pursue SLR and which specimens will need to be tested. However, the number of materials in the ISP test matrix is unchanged from the existing ISP.

  The ISP for SLR program will not include tensile specimens as prescribed in ASTM E185-82, as tensile data is not used by the ISP or ISP for SLR programs. The SSP capsules included in the current approved ISP program also did not include tensile specimens.

- *GALL-SLR: Capsule Fluence Criterion*

  GALL-SLR requires the withdrawal and testing of at least one capsule addressing the subsequent PEO with a neutron fluence of one and two times the peak neutron fluence of interest at the end of the subsequent PEO. This criterion is met for the target plant that is the host plant for the SSLR capsule. This criterion is also generally met for the target plant that has the highest 72-EFPY fluence needs for a given representative material. However, for other target plants, the SSLR capsule will generally exceed this fluence criterion, which is an inherent part of data sharing in an ISP and is relevant to some materials in the approved ISP. For BWRs, the fluence location of interest is the 1/4T wall thickness location. The ISP for SLR program will continue the practice in the ISP of obtaining surveillance data which bounds the 1/4T fluence at the end of the subsequent PEO.

10.3 Reporting to NRC

10.3.1 Host Plant Selection and Withdrawal Schedule

The BWRVIP will notify the NRC when the following program plan details have been confirmed:

- Notification of final host plant selection.
- Notification of the planned SSLR capsule insertion and withdrawal schedule.
- Notification of any changes to the SSLR capsule withdrawal schedule.
- Notification of capsule withdrawal.
- Selection of materials to be reconstituted and tested, and timeline for reporting of test results (see Section 10.3.2).

10.3.2 Test Plan and Reporting on Test Results

Because the selection of materials to be reconstituted and tested will depend on which BWRs pursue SLR and need additional surveillance data, the BWRVIP will notify the NRC of test plans and timeline for reporting test results at a later date. The proposed process is described below.

Upon NRC approval of an application for SLR which credits the ISP for SLR program and identifies the need for additional surveillance data from the program, the BWRVIP will submit a test report for the applicable representative materials to the NRC in accordance with Section IV for Appendix H. There are two scenarios that apply; 1) Appendix H reporting requirements commence at the time of SLR application approval for capsules withdrawn prior to the approval and 2) Appendix H reporting requirements commence immediately following withdrawal of the capsule when the SLR application has already been approved.

The report will include the results of all fracture toughness tests conducted on the surveillance material in the irradiated and unirradiated conditions and all data required by ASTM E185-82. In general, this includes mechanical test results, analyses of the test data (e.g., index temperature determinations), and evaluation of dosimetry.

11
REFERENCES

1. 10CFR50 Appendix H, "Reactor Vessel Material Surveillance Program Requirements," Appendix H to Part 50 of Title 10 of the Code of Federal Regulations, U.S. Nuclear Regulatory Commission, January 31, 2008.
2. 10CFR50 Appendix G, "Fracture Toughness Requirements," Appendix G to Part 50 of Title 10 of the Code of Federal Regulations, U.S. Nuclear Regulatory Commission, December 12, 2013.
3. *BWRVIP-86-A: BWR Vessel and Internals Project, Updated BWR Integrated Surveillance Program (ISP) Implementation Plan*. EPRI, Palo Alto, CA: 2002. 1003346.
4. *BWRVIP-86, Revision 1-A, BWR Vessel and Internals Project, Updated BWR Integrated Surveillance Program (ISP) Implementation Plan*. EPRI, Palo Alto, CA: 2012. 1025144.
5. ASTM E185-82, "Standard Practice for Conducting Surveillance Tests for Light-Water Cooled Nuclear Power Reactor Vessels," American Society for Testing and Materials, July 1982.
6. U.S. Nuclear Regulatory Commission, Regulatory Guide 1.99, "Radiation Embrittlement of Reactor Vessel Materials," Revision 2, May 1988.
7. Letter from William H. Bateman (NRC) to Carl Terry (BWRVIP Chairman), "Proprietary Request for Additional Information (BWRVIP-78) (TAC NO. MA91111)," dated June 19, 2000.
8. *BWRVIP-239: BWR Vessel and Internals Project, Updated Evaluation of the Integrated Surveillance Program (ISP) Capsule Withdrawal Schedule*. EPRI, Palo Alto, CA: 2010. 1021009.
9. U.S. Nuclear Regulatory Commission, NUREG-1801, "Generic Aging Lessons Learned (GALL) Report," Revision 2, December 2010.
10. U.S. Nuclear Regulatory Commission, NUREG-2191, Volumes 1 and 2, "Generic Aging Lessons Learned for Subsequent License Renewal (GALL-SLR) Report," Final Report, July 2017.
11. ASTM E1253-13, "Standard Guide for Reconstitution of Irradiated Charpy-Sized Specimens," ASTM International, West Conshohocken, PA, 2013, www.astm.org.
12. *Reconstituted Charpy Impact Specimens*. EPRI, Palo Alto, CA: 1982. NP-2759.
13. *BWRVIP-126, Revision 2: BWR Vessel and Internals Project: RAMA Fluence Methodology, Version 1.20 User's Manual*. EPRI, Palo Alto CA: 2010. 1020240.

14. U.S. Nuclear Regulatory Commission, Regulatory Guide 1.190, "Calculational and Dosimetry Methods for Determining Pressure Vessel Neutron Fluence," March 2001.

15. 10CFR50.61a, "Alternate Fracture Toughness Requirements for Protection against Pressurized Thermal Shock Events," Part 50 of Title 10 of the Code of Federal Regulations, U.S. Nuclear Regulatory Commission, August 29, 2017.

16. Manahan, M. P., "Nine Mile Point Unit 1 Surveillance Capsule Program," Report NMEL-90001, January 4, 1991.

17. ASTM E23-02, "Standard Test Method for Notched Bar Impact Testing of Metallic Materials," ASTM International, West Conshohocken, PA, 2002.

18. E. Keim, R. Langer, E. van Walle, M. Scibetta, M.J. Valo, H-W. Viehrig, H. Richter, T. Atkins, M.R. Wootton, L. Debarberis and M. Horsten, "RESQUE: Determination of the Lowest Acceptable Insert Length for Reconstituted Cv-impact and Pre-cracked Cv Specimen," Small Specimen Test Techniques: Fourth Volume, ASTM STP 1418, M. A. Sokolov, G. D. Landes, and G. E. Lucas, Eds., ASTM International, West Conshohocken, PA, 2002.

19. van Walle, E., Scibetta, M., Valo, M.J., Viehrig, H.-W., Richter, H., Atkins, T., Wootton, M.R., Keim, E., Debarberis, L., Horsten, M., "RESQUE: Reconstitution Techniques Qualification & Evaluation to Study Ageing Phenomena of Nuclear Pressure Vessel Materials," Small Specimen Test Techniques: Fourth Volume, ASTM STP 1418, M.A. Sokolov, J.D. Landes and G.E. Lucas, Eds., ASTM International, West Conshohocken, PA, 2002.

20. Valo, M., Keim, E., van Walle, E., Scibetta, M., Atkins, T., Wootton, M., Viehrig, H-W., Richter, H., Debarberis, L. and Horsten, M., "RESQUE: Validation of Specimen Reconstitution Techniques with Temperature Measurements and Comparative Testing of Irradiated Materials," Small Specimen Test Techniques: Fourth Volume. ASTM STP 1418, M. A. Sokolov, J. D. Landes, and G. E. Lucas, Eds., ASTM International, West Conshohocken, PA, 2002.

21. Manahan, M. P., Williams, J., and Martukanitz, R. P., "Laser Weld Reconstitution of Conventional Charpy and Miniaturized Notch Test (MNT) Specimens," Small Specimen Test Techniques Applied to Nuclear Reactor Vessel Thermal Annealing and Plant Life Extension, ASTM STP 1204, W. R. Corwin, F. M. Haggag, and W. L. Server, Eds., American Society for Testing and Materials, Philadelphia, 1993, pp 62-76.

22. Onizawa, K., van Walle, E., Nanstad, R.K., Sokolov, M., and Pavinich, W., "Critical Analysis of the ASTM Round Robin on Reconstitution," ASTM STP 1329, W.R. Corwin, S.T. Rosinski, and E. van Walle, Eds., ASTM, 1997.

23. Onizawa, K., van Walle, E., Pavinich, W.A., and Nanstad, R.K., "Results and Analysis of the ASTM Round Robin on Reconstitution," ORNL/TN-2001/34, Oak Ridge National Laboratory, NUREG/CR-6777, U.S. Nuclear Regulatory Commission, Washington, DC, August 2002.

24. Otsuka, E., Hatano, S., and Atago, Y., "Selection of the Optimum Irradiation Fluence to Assess Annealing during the Reconstitution of Charpy Impact Specimens," Small Specimen Test Techniques: Fourth Volume, ASTM STP 1418, M. A. Sokolov, J. D. Landes, and G. E. Lucas, Eds., ASTM International, West Conshohocken, PA, 2002.

25. Perrin, J.S., Fromm, E.O., Server, W.L., and McConnell, P.E., "Preparation of Reconstituted Charpy V-Notch Impact Specimens for Generating Pressure Vessel Steel Fracture Toughness Data", Effects of Radiation on Materials: Eleventh Conference, ASTM STP 782, H.R. Brager and J.S. Perrin, Eds., American Society for Testing and Materials, 1982.

26. Romero, J., Hernandez, R., Fernandez, F., Mercado, F., and van Walle, E. "Reconstitution Process by Stud Welding for the Surveillance Program in Mexico." Journal of Testing and Evaluation, Vol. 35, no. 5, 2007, pp. 514-521.

27. Viehrig, H.-W., Richter, H., Atkins, T., van Walle, E., Scibetta, M., Valo, M. J., Wootton, M. R., Keim, E., Debaberis, L., and Horsten, M., "RESQUE: Dependence of Test Results on Reconstituted Specimens with Tolerance Deviations and Variation of End Block Materials," Small Specimen Test Techniques: Fourth Volume, ASTM STP 1418, M. A. Sokolov, J. D. Landes, and G. E. Lucas, Eds., ASTM International, West Conshohocken, PA, 2002.

28. Andresen, P. et al., "Expanded Materials Degradation Assessment (EMDA), Volume 2: Aging of Core Internals and Piping Systems," NUREG/CR-7153, Vol. 2 (ORNL/TM-2013/532), USNRC, October 2014.

29. ASTM E165M-12, "Standard Practice for Liquid Penetrant Examination for General Industry," ASTM International, West Conshohocken, PA, 2012.

30. ASTM E844-09 (2014), "Standard Guide for Sensor Set Design and Irradiation for Reactor Surveillance," ASTM International, West Conshohocken, PA, 2014.

31. Letter from Matthew A. Mitchell (USNRC) to Bill Eaton (BWRVIP Chairman), "Non-Proprietary Safety Evaluation of the 'BWRVIP Vessel and Internals Project, Integrated Surveillance Program (ISP) Implementation for License Renewal (BWRVIP-116),' EPRI Report TR-1007824, July 2003," dated March 1, 2006. (ADAMS Accession No. ML060800240).

32. *BWRVIP-87, Revision 1: BWR Vessel and Internals Project, Testing and Evaluation of BWR Supplemental Surveillance Program Capsules D, G, and H.* EPRI, Palo Alto, CA: 2007. 1015000.

33. *BWRVIP-111, Revision 1: BWR Vessel and Internals Project, Testing and Evaluation of BWR Supplemental Surveillance Program Capsules E, F and I.* EPRI, Palo Alto, CA: 2007. 1015001.

34. "RAFTER Computer Code User's Manual," Document number TWE-TFX-001-FM-004-001, TransWare Enterprises Inc.

35. "Design Review Report for the RAFFLE Software Program," Document number TWE-TFX-001-FR-005-001, TransWare Enterprises Inc.

36. "VITAMIN-B6: A Fine-Group Cross Section Library Based on ENDF/B-VI Release 3 for Radiation Transport Applications," RSICC Data Library Collection, DLC-184, December 1996.

37. Long, E., "Palisades Nuclear Power Plant Extended Beltline Reactor Vessel Integrity Evaluation," WCAP-17403-NP, Westinghouse Electric Corp., January 2013. (ADAMS Accession No. ML14316A199).

38. Nanstad, R. K., et. al., "Irradiation Effects on Fracture Toughness of Two High-Copper Submerged-Arc Welds," *HSSI Series 5*, NUREG/CR-5913, August 1992.

39. Letter from Tim Hanley (BWRVIP Chairman) to Scott Wall (NRC), "Duane Arnold 288° Surveillance Capsule Test Results Report," dated December 1, 2020 (BWRVIP Letter 2020-100).

A
PLANT-SPECIFIC EVALUATIONS

Browns Ferry 1

Representative Surveillance Materials

The ISP Representative Surveillance Materials for the Browns Ferry 1 vessel target weld and plates are shown in the following table.

Table A-1
Target vessel materials and ISP representative materials for Browns Ferry 1

Target Vessel Materials		ISP Representative Materials
Weld	406L44	SSP 406L44
Plate	C2868-2	A0981-1

Summary of Availability of Tested Surveillance Specimens – Weld

Six capsules containing representative weld heat 406L44 have been tested, summarized in the below table. The projected 80-year 1/4T fluence for target weld heat 406L44 in the Browns Ferry 1 vessel is Content Deleted - *EPRI Proprietary Information*

Table A-2
ISP capsule fluence and availability for Browns Ferry 1 – Weld

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Summary of Availability of Tested Surveillance Specimens – Plate

Two capsules containing representative plate heat A0981-1 have been tested, summarized in the below table. The projected 80-year 1/4T fluence for target plate heat C2868-2 in the Browns Ferry 1 vessel is

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Table A-3
ISP capsule fluence and availability for Browns Ferry 1 – Plate

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Browns Ferry 2

Representative Surveillance Materials

The ISP Representative Surveillance Materials for the Browns Ferry 2 vessel target weld and plates are shown in the following table.

Table A-4
Target vessel materials and ISP representative materials for Browns Ferry 2

Target Vessel Materials		ISP Representative Materials
Weld	ESW	BF2 ESW
Plate	C2467-1	A0981-1

Summary of Availability of Tested Surveillance Specimens – Weld

Two capsules containing representative weld heat BF2 ESW have been tested, summarized in the below table. The projected 80-year 1/4T fluence for target weld heat ESW in the Browns Ferry 2 vessel is

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Table A-5
ISP capsule fluence and availability for Browns Ferry 2 – Weld

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Summary of Availability of Tested Surveillance Specimens – Plate

Two capsules containing representative plate heat A0981-1 have been tested, summarized in the below table. The projected 80-year 1/4T fluence for target plate heat C2467-1 in the Browns Ferry 2 vessel is Content Deleted - *EPRI Proprietary Information*

Table A-6
ISP capsule fluence and availability for Browns Ferry 2 – Plate

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Browns Ferry 3

Representative Surveillance Materials

The ISP Representative Surveillance Materials for the Browns Ferry 3 vessel target weld and plates are shown in the following table.

Table A-7
Target vessel materials and ISP representative materials for Browns Ferry 3

Target Vessel Materials		ISP Representative Materials
Weld	ESW	BF2 ESW
Plate	C3222-2	A0981-1

Summary of Availability of Tested Surveillance Specimens – Weld

Two capsules containing representative weld heat BF2 ESW have been tested, summarized in the below table. The projected 80-year 1/4T fluence for target weld heat ESW in the Browns Ferry 3 vessel is

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Table A-8
ISP capsule fluence and availability for Browns Ferry 3 – Weld

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Summary of Availability of Tested Surveillance Specimens – Plate

Two capsules containing representative plate heat A0981-1 have been tested, summarized in the below table. The projected 80-year 1/4T fluence for target plate heat C3222-2 in the Browns Ferry 3 vessel is Content Deleted - *EPRI Proprietary Information*

Table A-9
ISP capsule fluence and availability for Browns Ferry 3 – Plate

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EPRI Proprietary Information

Brunswick 1

Representative Surveillance Materials

The ISP Representative Surveillance Materials for the Brunswick 1 vessel target weld and plates are shown in the following table.

Table A-10
Target vessel materials and ISP representative materials for Brunswick 1

Target Vessel Materials		ISP Representative Materials
Weld	1P4218	5P6756
Plate	B8496-1	B0673-1

Summary of Availability of Tested Surveillance Specimens – Weld

Four capsules containing representative weld heat 5P6756 have been tested, summarized in the below table. The projected 80-year 1/4T fluence for target weld heat 1P4218 in the Brunswick 1 vessel is Content Deleted - *EPRI Proprietary Information*

Table A-11
ISP capsule fluence and availability for Brunswick 1 – Weld

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EPRI Proprietary Information

Summary of Availability of Tested Surveillance Specimens – Plate

Four capsules containing representative plate heat B0673-1 have been tested, summarized in the below table. The projected 80-year 1/4T fluence for target plate heat B8496-1 in the Brunswick 1 vessel is Content Deleted - *EPRI Proprietary Information*

Table A-12
ISP capsule fluence and availability for Brunswick 1 – Plate

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EPRI Proprietary Information

Brunswick 2

Representative Surveillance Materials

The ISP Representative Surveillance Materials for the Brunswick 2 vessel target weld and plates are shown in the following table.

Table A-13
Target vessel materials and ISP representative materials for Brunswick 2

Target Vessel Materials		ISP Representative Materials
Weld	S3986	5P6756
Plate	C4500-2	B0673-1

Summary of Availability of Tested Surveillance Specimens – Weld

Four capsules containing representative weld heat 5P6756 have been tested, summarized in the below table. The projected 80-year 1/4T fluence for target weld heat S3986 in the Brunswick 2 vessel is Content Deleted - *EPRI Proprietary Information*

Table A-14
ISP capsule fluence and availability for Brunswick 2 – Weld

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EPRI Proprietary Information

Summary of Availability of Tested Surveillance Specimens – Plate

Four capsules containing representative plate heat B0673-1 have been tested, summarized in the below table. The projected 80-year 1/4T fluence for target plate heat B8496-1 in the Brunswick 2 vessel is Content Deleted - *EPRI Proprietary Information*

Table A-15
ISP capsule fluence and availability for Brunswick 2 – Plate

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EPRI Proprietary Information

Clinton

Representative Surveillance Materials

The ISP Representative Surveillance Materials for the Clinton vessel target weld and plates are shown in the following table.

Table A-16
Target vessel materials and ISP representative materials for Clinton

Target Vessel Materials		ISP Representative Materials
Weld	76492	5P6756
Plate	C4380-2	C3054-2

Summary of Availability of Tested Surveillance Specimens – Weld

Four capsules containing representative weld heat 5P6756 have been tested, summarized in the below table. The projected 80-year 1/4T fluence for target weld heat 76492 in the Clinton vessel is Content Deleted - *EPRI Proprietary Information*

Table A-17
ISP capsule fluence and availability for Clinton – Weld

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EPRI Proprietary Information

Summary of Availability of Tested Surveillance Specimens – Plate

One capsule containing representative plate heat C3054-2 has been tested, summarized in the below table. The projected 80-year 1/4T fluence for target plate heat C4380-2 in the Clinton vessel is

Content Deleted - *EPRI Proprietary Information*

Table A-18
ISP capsule fluence and availability for Clinton – Plate

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EPRI Proprietary Information

Columbia

Representative Surveillance Materials

The ISP Representative Surveillance Materials for the Columbia vessel target weld and plates are shown in the following table.

Table A-19
Target vessel materials and ISP representative materials for Columbia

Target Vessel Materials		**ISP Representative Materials**
Weld	5P6756	5P6756
Plate	C1272-1	B0673-1

Summary of Availability of Tested Surveillance Specimens – Weld

Four capsules containing representative weld heat 5P6756 have been tested, summarized in the below table. The projected 80-year 1/4T fluence for target weld heat 5P6756 in the Columbia vessel is Content Deleted - *EPRI Proprietary Information*

Table A-20
ISP capsule fluence and availability for Columbia – Weld

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EPRI Proprietary Information

Summary of Availability of Tested Surveillance Specimens – Plate

Four capsules containing representative plate heat B0673-1 have been tested, summarized in the below table. The projected 80-year 1/4T fluence for target plate heat C1272-1 in the Columbia vessel is

Content Deleted - *EPRI Proprietary Information*

Table A-21
ISP capsule fluence and availability for Columbia – Plate

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EPRI Proprietary Information

Cooper

Representative Surveillance Materials

The ISP Representative Surveillance Materials for the Cooper vessel target weld and plates are shown in the following table.

Table A-22
Target vessel materials and ISP representative materials for Cooper

Target Vessel Materials		ISP Representative Materials
Weld	27204/12008	20291
Plate	C2307-2	C2307-2

Summary of Availability of Tested Surveillance Specimens – Weld

Four capsules containing representative weld heat 20291 have been tested, summarized in the below table. The projected 80-year 1/4T fluence for target weld heat 27204/12008 in the Cooper vessel is Content Deleted - *EPRI Proprietary Information*

Table A-23
ISP capsule fluence and availability for Cooper – Weld

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EPRI Proprietary Information

Summary of Availability of Tested Surveillance Specimens – Plate

Three capsules containing representative plate heat C2307-2 have been tested, summarized in the below table. The projected 80-year 1/4T fluence for target plate heat C2307-2 in the Cooper vessel is Content Deleted - *EPRI Proprietary Information*

Table A-24
ISP capsule fluence and availability for Cooper – Plate

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EPRI Proprietary Information

Dresden 2

Representative Surveillance Materials

The ISP Representative Surveillance Materials for the Dresden 2 vessel target weld and plates are shown in the following table.

Table A-25
Target vessel materials and ISP representative materials for Dresden 2

Target Vessel Materials		ISP Representative Materials
Weld	DR2 ESW	DR3 ESW
Plate	A9128-1	A0610-1

Summary of Availability of Tested Surveillance Specimens – Weld

Four capsules containing representative weld heat DR3 ESW have been tested, summarized in the below table. The projected 80-year 1/4T fluence for target weld heat DR2 ESW in the Dresden 2 vessel is Content Deleted - *EPRI Proprietary Information*

Table A-26
ISP capsule fluence and availability for Dresden 2 – Weld

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EPRI Proprietary Information

Summary of Availability of Tested Surveillance Specimens – Plate

Three capsules containing representative plate heat A0610-1 have been tested, summarized in the below table. The projected 80-year 1/4T fluence for target plate heat A9128-1 in the Dresden 2 vessel is Content Deleted - *EPRI Proprietary Information*

Table A-27
ISP capsule fluence and availability for Dresden 2 – Plate

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EPRI Proprietary Information

Dresden 3

Representative Surveillance Materials

The ISP Representative Surveillance Materials for the Dresden 3 vessel target weld and plates are shown in the following table.

Table A-28
Target vessel materials and ISP representative materials for Dresden 3

Target Vessel Materials		ISP Representative Materials
Weld	299L44	DR3 SAW
Plate	A2037-1	A0610-1

Summary of Availability of Tested Surveillance Specimens – Weld

Two capsules containing representative weld heat DR3 SAW have been tested, summarized in the below table. The projected 80-year 1/4T fluence for target weld heat 299L44 in the Dresden 3 vessel is Content Deleted - *EPRI Proprietary Information*

Table A-29
ISP capsule fluence and availability for Dresden 3 – Weld

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EPRI Proprietary Information

Summary of Availability of Tested Surveillance Specimens – Plate

Three capsules containing representative plate heat A0610-1 have been tested, summarized in the below table. The projected 80-year 1/4T fluence for target plate heat A0237-1 in the Dresden 3 vessel is

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Table A-30
ISP capsule fluence and availability for Dresden 3 – Plate

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EPRI Proprietary Information

Duane Arnold

Representative Surveillance Materials

The ISP Representative Surveillance Materials for the Duane Arnold vessel target weld and plates are shown in the following table.

Table A-31
Target vessel materials and ISP representative materials for Duane Arnold

Target Vessel Materials		ISP Representative Materials
Weld	432Z0471	DA1 SMAW
Plate	B0673-1	B0673-1

Summary of Availability of Tested Surveillance Specimens – Weld

Four capsules containing representative weld heat DA1 SMAW have been tested, summarized in the below table. The projected 80-year 1/4T fluence for target weld heat 432Z0471 in the Duane Arnold vessel is Content Deleted - *EPRI Proprietary Information*

Table A-32
ISP capsule fluence and availability for Duane Arnold – Weld

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EPRI Proprietary Information

Summary of Availability of Tested Surveillance Specimens – Plate

Four capsules containing representative plate heat B0673-1 have been tested, summarized in the below table. The projected 80-year 1/4T fluence for target plate heat B0673-1 in the Duane Arnold vessel is Content Deleted - *EPRI Proprietary Information*

Table A-33
ISP capsule fluence and availability for Duane Arnold – Plate

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EPRI Proprietary Information

Enrico Fermi 2

Representative Surveillance Materials

The ISP Representative Surveillance Materials for the Fermi 2 vessel target weld and plates are shown in the following table.

Table A-34
Target vessel materials and ISP representative materials for Fermi 2

Target Vessel Materials		ISP Representative Materials
Weld	13253/12008	CE-2(WM) [Heat 13253/12008]
Plate	C4554-1, C4568-2	C4114-2

Summary of Availability of Tested Surveillance Specimens – Weld

Two capsules containing representative weld heat CE-2(WM), which has been identified as heat 13253 and 12008, have been tested and are summarized in the below table. The projected 80-year 1/4T fluence for target weld heat 13253/12008 in the Fermi 2 vessel is

Content Deleted - *EPRI Proprietary*

Table A-35
ISP capsule fluence and availability for Fermi 2 – Weld

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EPRI Proprietary Information

Summary of Availability of Tested Surveillance Specimens – Plate

Three capsules containing representative plate heat C4114-2 have been tested, summarized in the below table. The projected 80-year 1/4T fluence for target plate heat C4554-1, C4568-2 in the Fermi 2 vessel is Content Deleted - *EPRI Proprietary Information*

Table A-36
ISP capsule fluence and availability for Fermi 2 – Plate

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EPRI Proprietary Information

FitzPatrick

Representative Surveillance Materials

The ISP Representative Surveillance Materials for the FitzPatrick vessel target weld and plates are shown in the following table.

Table A-37
Target vessel materials and ISP representative materials for FitzPatrick

Target Vessel Materials		ISP Representative Materials
Weld	27204/12008	CE-1(WM) [27204]
Plate	C3376-2	C6345-1

Summary of Availability of Tested Surveillance Specimens – Weld

Two capsules containing representative weld heat CE-1(WM), which has been identified as heat 27204, have been tested and are summarized in the below table. The projected 80-year 1/4T fluence for target weld heat 27204/12008 in the FitzPatrick vessel is

Content Deleted - *EPRI Proprietary*

Table A-38
ISP capsule fluence and availability for FitzPatrick – Weld

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EPRI Proprietary Information

Summary of Availability of Tested Surveillance Specimens – Plate

Two capsules containing representative plate heat C6345-1 have been tested, summarized in the below table. The projected 80-year 1/4T fluence for target plate heat C3376-2 in the FitzPatrick vessel is Content Deleted - *EPRI Proprietary Information*

Table A-39
ISP capsule fluence and availability for FitzPatrick – Plate

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EPRI Proprietary Information

Grand Gulf

Representative Surveillance Materials

The ISP Representative Surveillance Materials for the Grand Gulf vessel target weld and plates are shown in the following table.

Table A-40
Target vessel materials and ISP representative materials for Grand Gulf

Target Vessel Materials		ISP Representative Materials
Weld	5P6214B	5P6214B
Plate	A1224-1, C2594-2	A1224-1

Summary of Availability of Tested Surveillance Specimens – Weld

Eight capsules containing representative weld heat 5P6214B have been tested, summarized in the below table. The projected 80-year 1/4T fluence for target weld heat 5P6214B in the Grand Gulf vessel is Content Deleted - *EPRI Proprietary Information*

Table A-41
ISP capsule fluence and availability for Grand Gulf – Weld

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EPRI Proprietary Information

Summary of Availability of Tested Surveillance Specimens – Plate

Six capsules containing representative plate heat A1224-1 have been tested, summarized in the below table. The projected 80-year 1/4T fluence for target plate heats A1224-1 and C2594-2 in the Grand Gulf vessel is Content Deleted - *EPRI Proprietary Information*

Table A-42
ISP capsule fluence and availability for Grand Gulf – Plate

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EPRI Proprietary Information

Hatch 1

Representative Surveillance Materials

The ISP Representative Surveillance Materials for the Hatch 1 vessel target weld and plates are shown in the following table.

Table A-43
Target vessel materials and ISP representative materials for Hatch 1

Target Vessel Materials		ISP Representative Materials
Weld	1P2815	20291
Plate	C4114-2	C4114-2

Summary of Availability of Tested Surveillance Specimens – Weld

Four capsules containing representative weld heat 20291 have been tested, summarized in the below table. The projected 80-year 1/4T fluence for target weld heat 1P2815 in the Hatch 1 vessel is Content Deleted - *EPRI Proprietary Information*

Table A-44
ISP capsule fluence and availability for Hatch 1 – Weld

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EPRI Proprietary Information

Summary of Availability of Tested Surveillance Specimens – Plate

Three capsules containing representative plate heat C4114-2 have been tested, summarized in the below table. The projected 80-year 1/4T fluence for target plate heat C4114-2 in the Hatch 1 vessel is Content Deleted - *EPRI Proprietary Information*

Table A-45
ISP capsule fluence and availability for Hatch 1 – Plate

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EPRI Proprietary Information

Hatch 2

Representative Surveillance Materials

The ISP Representative Surveillance Materials for the Hatch 2 vessel target weld and plates are shown in the following table.

Table A-46
Target vessel materials and ISP representative materials for Hatch 2

Target Vessel Materials		ISP Representative Materials
Weld	10137	51912
Plate	C8579-2	C8554

Summary of Availability of Tested Surveillance Specimens – Weld

Two capsules containing representative weld heat 51912 have been tested, summarized in the below table. The projected 80-year 1/4T fluence for target weld heat 10137 in the Hatch 2 vessel is Content Deleted - *EPRI Proprietary Information*

Table A-47
ISP capsule fluence and availability for Hatch 2 – Weld

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EPRI Proprietary Information

Summary of Availability of Tested Surveillance Specimens – Plate

Two capsules containing representative plate heat C8554 have been tested, summarized in the below table. The projected 80-year 1/4T fluence for target plate heat C8579-2 in the Hatch 2 vessel is Content Deleted - *EPRI Proprietary Information*

Table A-48
ISP Capsule Fluence and Availability for Hatch 2 – Plate

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EPRI Proprietary Information

Hope Creek

Representative Surveillance Materials

The ISP Representative Surveillance Materials for the Hope Creek vessel target weld and plates are shown in the following table.

Table A-49
Target vessel materials and ISP representative materials for Hope Creek

Target Vessel Materials		ISP Representative Materials
Weld	D53040	D53040
Plate	5K3025/1	5K3238/1

Summary of Availability of Tested Surveillance Specimens – Weld

Two capsules containing representative weld heat D53040 has been tested, summarized in the below table. The projected 80-year 1/4T fluence for target weld heat D53040 in the Hope Creek vessel is Content Deleted - *EPRI Proprietary Information*

Table A-50
ISP capsule fluence and availability for Hope Creek – Weld

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EPRI Proprietary Information

Summary of Availability of Tested Surveillance Specimens – Plate

Two capsules containing representative plate heat 5K3238/1has been tested, summarized in the below table. The projected 80-year 1/4T fluence for target plate heat 5K3025/1 in the Hope Creek vessel is Content Deleted - *EPRI Proprietary Information*

Table A-51
ISP capsule fluence and availability for Hope Creek – Plate

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EPRI Proprietary Information

LaSalle 1

Representative Surveillance Materials

The ISP Representative Surveillance Materials for the LaSalle 1 vessel target weld and plates are shown in the following table.

Table A-52
Target vessel materials and ISP representative materials for LaSalle 1

Target Vessel Materials		ISP Representative Materials
Weld	1P3571	1P3571
Plate	C5978-2	C6345-1

Summary of Availability of Tested Surveillance Specimens – Weld

Two capsules containing representative weld heat 1P3571 have been tested, summarized in the below table. The projected 80-year 1/4T fluence for target weld heat 1P3571 in the LaSalle 1 vessel is Content Deleted - *EPRI Proprietary Information*

Table A-53
ISP capsule fluence and availability for LaSalle 1– Weld

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EPRI Proprietary Information

Summary of Availability of Tested Surveillance Specimens – Plate

Two capsules containing representative plate heat C6345-1 have been tested, summarized in the below table. The projected 80-year 1/4T fluence for target plate heat C5978-2 in the LaSalle 1 vessel is Content Deleted - *EPRI Proprietary Information*

Table A-54
ISP capsule fluence and availability for LaSalle 1 – Plate

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EPRI Proprietary Information

LaSalle 2

Representative Surveillance Materials

The ISP Representative Surveillance Materials for the LaSalle 2 vessel target weld and plates are shown in the following table.

Table A-55
Target vessel materials and ISP representative materials for LaSalle 2

Target Vessel Materials		ISP Representative Materials
Weld	3P4966	402K9171, 411L3071
Plate	C9404-2	C3054-2

Summary of Availability of Tested Surveillance Specimens – Weld

Two capsules containing representative weld heat 402K9171, 411L3071 have been tested, summarized in the below table. The projected 80-year 1/4T fluence for target weld heat 3P4966 in the LaSalle 2 vessel is Content Deleted - *EPRI Proprietary Information*

Table A-56
ISP capsule fluence and availability for LaSalle 2 – Weld

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EPRI Proprietary Information

Summary of Availability of Tested Surveillance Specimens – Plate

One capsule containing representative plate heat C3054-2 has been tested, summarized in the below table. The projected 80-year 1/4T fluence for target plate heat C9404-2 in the LaSalle 2 vessel is Content Deleted - *EPRI Proprietary Information*

Table A-57
ISP capsule fluence and availability for LaSalle 2 – Plate

Content Deleted –
EPRI Proprietary Information

Limerick 1

Representative Surveillance Materials

The ISP Representative Surveillance Materials for the Limerick 1 vessel target weld and plates are shown in the following table.

Table A-58
Target vessel materials and ISP representative materials for Limerick 1

Target Vessel Materials		ISP Representative Materials
Weld	640892	5P6756
Plate	C7677-1	C2761-2

Summary of Availability of Tested Surveillance Specimens – Weld

Four capsules containing representative weld heat 5P6756 have been tested, summarized in the below table. The projected 80-year 1/4T fluence for target weld heat 640892 in the Limerick 1 vessel is Content Deleted - *EPRI Proprietary Information*

Table A-59
ISP capsule fluence and availability for Limerick 1 – Weld

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EPRI Proprietary Information

Summary of Availability of Tested Surveillance Specimens – Plate

One capsule containing representative plate heat C2761-2 has been tested, summarized in the below table. The projected 80-year 1/4T fluence for target plate heat C7677-1 in the Limerick 1 vessel is Content Deleted - *EPRI Proprietary Information*

Table A-60
ISP capsule fluence and availability for Limerick 1 – Plate

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EPRI Proprietary Information

Limerick 2

Representative Surveillance Materials

The ISP Representative Surveillance Materials for the Limerick 2 vessel target weld and plates are shown in the following table.

Table A-61
Target vessel materials and ISP representative materials for Limerick 2

Target Vessel Materials		ISP Representative Materials
Weld	640892	5P6756
Plate	B3416-1	B0673-1

Summary of Availability of Tested Surveillance Specimens – Weld

Four capsules containing representative weld heat 5P6756 have been tested, summarized in the below table. The projected 80-year 1/4T fluence for target weld heat 640892 in the Limerick 2 vessel is Content Deleted - *EPRI Proprietary Information*

Table A-62
ISP capsule fluence and availability for Limerick 2 – Weld

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EPRI Proprietary Information

Summary of Availability of Tested Surveillance Specimens – Plate

Four capsules containing representative plate heat B0673-1 have been tested, summarized in the below table. The projected 80-year 1/4T fluence for target plate heat B3416-1 in the Limerick 2 vessel is Content Deleted - *EPRI Proprietary Information*

Table A-63
ISP capsule fluence and availability for Limerick 2 – Plate

Content Deleted –
EPRI Proprietary Information

Monticello

Representative Surveillance Materials

The ISP Representative Surveillance Materials for the Monticello vessel target weld and plates are shown in the following table.

Table A-64
Target vessel materials and ISP representative materials for Monticello

Target Vessel Materials		ISP Representative Materials
Weld	Unknown heat	5P6756
Plate	C2220	C2220

Summary of Availability of Tested Surveillance Specimens – Weld

Four capsules containing representative weld heat 5P6756 have been tested, summarized in the below table. The projected 80-year 1/4T fluence for the target weld heat in the Monticello vessel is Content Deleted - *EPRI Proprietary Information*

Table A-65
ISP capsule fluence and availability for Monticello – Weld

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EPRI Proprietary Information

Summary of Availability of Tested Surveillance Specimens – Plate

Two capsules containing representative plate heat C2220 have been tested, summarized in the below table. The projected 80-year 1/4T fluence for target plate heat C2220 in the Monticello vessel is Content Deleted - *EPRI Proprietary Information*

Table A-66
ISP capsule fluence and availability for Monticello – Plate

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EPRI Proprietary Information

Nine Mile Point 1

Representative Surveillance Materials

The ISP Representative Surveillance Materials for the Nine Mile Point 1 vessel target weld and plates are shown in the following table.

Table A-67
Target vessel materials and ISP representative materials for Nine Mile Point 1

Target Vessel Materials		ISP Representative Materials
Weld	1248	51912
Plate	P2076	C1079-1

Summary of Availability of Tested Surveillance Specimens – Weld

Two capsules containing representative weld heat 51912 have been tested, summarized in the below table. The projected 80-year 1/4T fluence for target weld heat 1248 in the Nine Mile Point 1 vessel is Content Deleted - *EPRI Proprietary Information*

Table A-68
ISP capsule fluence and availability for Nine Mile Point 1 – Weld

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EPRI Proprietary Information

Summary of Availability of Tested Surveillance Specimens – Plate

Three capsules containing representative plate heat C1079-1 have been tested, summarized in the below table. The projected 80-year 1/4T fluence for target plate heat P2076 in the Nine Mile Point 1 vessel is Content Deleted - *EPRI Proprietary Information*

Table A-69
ISP capsule fluence and availability for Nine Mile Point 1 – Plate

Content Deleted –
EPRI Proprietary Information

Nine Mile Point 2

Representative Surveillance Materials

The ISP Representative Surveillance Materials for the Nine Mile Point 2 vessel target weld and plates are shown in the following table.

Table A-70
Target vessel materials and ISP representative materials for Nine Mile Point 2

Target Vessel Materials		ISP Representative Materials
Weld	5P5657	5P6214B
Plate	C3147-1	C2761-2

Summary of Availability of Tested Surveillance Specimens – Weld

Eight capsules containing representative weld heat 5P6214B have been tested, summarized below. The projected 80-year 1/4T fluence for target weld heat 5P5657 in the Nine Mile Point 2 vessel is Content Deleted - *EPRI Proprietary Information*

Table A-71

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EPRI Proprietary Information

Summary of Availability of Tested Surveillance Specimens – Plate

One capsule containing representative plate heat C2761-2 has been tested, summarized in the below table. The projected 80-year 1/4T fluence for target plate heat C3147-1 in the Nine Mile Point 2 vessel is Content Deleted - *EPRI Proprietary Information*

Table A-72
ISP capsule fluence and availability for Nine Mile Point 2 – Plate

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EPRI Proprietary Information

Peach Bottom 2

Representative Surveillance Materials

The ISP Representative Surveillance Materials for the Peach Bottom 2 vessel target weld and plates are shown in the following table.

Table A-73
Target vessel materials and ISP representative materials for Peach Bottom 2

Target Vessel Materials		ISP Representative Materials
Weld	37C065	PB2 ESW
Plate	C2873-1	C2761-2

Summary of Availability of Tested Surveillance Specimens – Weld

One capsule containing representative weld heat PB2 ESW has been tested, summarized in the below table. The projected 80-year 1/4T fluence for target weld heat 37C065 in the Peach Bottom 2 vessel is Content Deleted - *EPRI Proprietary Information*

Table A-74
ISP capsule fluence and availability for Peach Bottom 2 – Weld

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EPRI Proprietary Information

Summary of Availability of Tested Surveillance Specimens – Plate

One capsule containing representative plate heat C2761-2 has been tested, summarized in the below table. The projected 80-year 1/4T fluence for target plate heat C2783-1 in the Peach Bottom 2 vessel is Content Deleted - *EPRI Proprietary Information*

Table A-75
ISP capsule fluence and availability for Peach Bottom 2 – Plate

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EPRI Proprietary Information

Peach Bottom 3

Representative Surveillance Materials

The ISP Representative Surveillance Materials for the Peach Bottom 3 vessel target weld and plates are shown in the following table.

Table A-76
Target vessel materials and ISP representative materials for Peach Bottom 3

Target Vessel Materials		ISP Representative Materials
Weld	1P4217	5P6756
Plate	C2773-2	B0673-1

Summary of Availability of Tested Surveillance Specimens – Weld

Four capsules containing representative weld heat 5P6756 have been tested, summarized in the below table. The projected 80-year 1/4T fluence for target weld heat 1P4217 in the Peach Bottom 3 vessel is Content Deleted - *EPRI Proprietary Information*

Table A-77
ISP capsule fluence and availability for Peach Bottom 3 – Weld

Content Deleted –
EPRI Proprietary Information

Summary of Availability of Tested Surveillance Specimens – Plate

Four capsules containing representative plate heat B0673-1 have been tested, summarized in the below table. The projected 80-year 1/4T fluence for target plate heat C2773-2 in the Peach Bottom 3 vessel is

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Table A-78
ISP capsule fluence and availability for Peach Bottom 3 – Plate

Content Deleted –
EPRI Proprietary Information

Perry

Representative Surveillance Materials

The ISP Representative Surveillance Materials for the Perry vessel target weld and plates are shown in the following table.

Table A-79
Target vessel materials and ISP representative materials for Perry

Target Vessel Materials		ISP Representative Materials
Weld	5P6214B	5P6214B
Plate	C2557-1	C2557-1

Summary of Availability of Tested Surveillance Specimens – Weld

Eight capsules containing representative weld heat 5P6214B have been tested, summarized in the below table. The projected 80-year 1/4T fluence for target weld heat 5P6214B in the Perry vessel is

Content Deleted - *EPRI Proprietary Information*

Table A-80
ISP capsule fluence and availability for Perry – Weld

Content Deleted –
EPRI Proprietary Information

Summary of Availability of Tested Surveillance Specimens – Plate

Two capsules containing representative plate heat C2557-1 have been tested, summarized in the below table. The projected 80-year 1/4T fluence for target plate heat C2557-1 in the Perry vessel is Content Deleted - *EPRI Proprietary Information*

Table A-81
ISP capsule fluence and availability for Perry – Plate

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EPRI Proprietary Information

Pilgrim

Representative Surveillance Materials

The ISP Representative Surveillance Materials for the Pilgrim vessel target weld and plates are shown in the following table.

Table A-82
Target vessel materials and ISP representative materials for Pilgrim

Target Vessel Materials		ISP Representative Materials
Weld	27204/12008	CE-1(WM) [27204]
Plate	C2921-2	C6345-1

Summary of Availability of Tested Surveillance Specimens – Weld

Two capsules containing representative weld heat CE-1(WM), which has been identified as heat 27204, have been tested and are summarized in the below table. The projected 80-year 1/4T fluence for target weld heat 27204/12008 in the Pilgrim vessel is

Content Deleted - *EPRI Proprietary Information*

Table A-83
ISP capsule fluence and availability for Pilgrim – Weld

Content Deleted –
EPRI Proprietary Information

Summary of Availability of Tested Surveillance Specimens – Plate

Two capsules containing representative plate heat C6345-1 have been tested, summarized in the below table. The projected 80-year 1/4T fluence for target plate heat C2921-2 in the Pilgrim vessel is Content Deleted - *EPRI Proprietary Information*

Table A-84
ISP capsule fluence and availability for Pilgrim – Plate

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EPRI Proprietary Information

Quad Cities 1

Representative Surveillance Materials

The ISP Representative Surveillance Materials for the Quad Cities 1 vessel target weld and plates are shown in the following table.

Table A-85
Target vessel materials and ISP representative materials for Quad Cities 1

Target Vessel Materials		ISP Representative Materials
Weld	Unknown ESW	DR3 ESW
Plate	B5524-1	A0610-1

Summary of Availability of Tested Surveillance Specimens – Weld

Four capsules containing representative weld heat DR3 ESW have been tested, summarized in the below table. The projected 80-year 1/4T fluence for target weld heat unknown ESW in the Quad Cities 1 vessel is Content Deleted - *EPRI Proprietary Information*

Table A-86
ISP capsule fluence and availability for Quad Cities 1 – Weld

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EPRI Proprietary Information

Summary of Availability of Tested Surveillance Specimens – Plate

Three capsules containing representative plate heat A0610-1 have been tested, summarized in the below table. The projected 80-year 1/4T fluence for target plate heat B5524-1 in the Quad Cities 1 vessel is Content Deleted - *EPRI Proprietary Information*

Table A-87
ISP capsule fluence and availability for Quad Cities 1 – Plate

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EPRI Proprietary Information

Quad Cities 2

Representative Surveillance Materials

The ISP Representative Surveillance Materials for the Quad Cities 2 vessel target weld and plates are shown in the following table.

Table A-88
Target vessel materials and ISP representative materials for Quad Cities 2

Target Vessel Materials		ISP Representative Materials
Weld	Unknown ESW	DR3 ESW
Plate	C1516-2	A0610-1

Summary of Availability of Tested Surveillance Specimens – Weld

Four capsules containing representative weld heat DR3 ESW have been tested, summarized in the below table. The projected 80-year 1/4T fluence for target weld heat unknown ESW in the Quad Cities 2 vessel is Content Deleted - *EPRI Proprietary Information*

Table A-89
ISP capsule fluence and availability for Quad Cities 2 – Weld

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EPRI Proprietary Information

Summary of Availability of Tested Surveillance Specimens – Plate

Three capsules containing representative plate heat A0610-1 have been tested, summarized in the below table. The projected 80-year 1/4T fluence for target plate heat C1516-2 in the Quad Cities 2 vessel is Content Deleted - *EPRI Proprietary Information*

Table A-90
ISP capsule fluence and availability for Quad Cities 2 – Plate

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EPRI Proprietary Information

River Bend

Representative Surveillance Materials

The ISP Representative Surveillance Materials for the River Bend vessel target weld and plates are shown in the following table.

Table A-91
Target vessel materials and ISP representative materials for River Bend

Target Vessel Materials		ISP Representative Materials
Weld	5P6756	5P6756
Plate	C3138-2	C3054-2

Summary of Availability of Tested Surveillance Specimens – Weld

Four capsules containing representative weld heat 5P6756 have been tested, summarized in the below table. The projected 80-year 1/4T fluence for target weld heat 5P6756 in the River Bend vessel is Content Deleted - *EPRI Proprietary Information*

Table A-92
ISP capsule fluence and availability for River Bend – Weld

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EPRI Proprietary Information

Summary of Availability of Tested Surveillance Specimens – Plate

One capsule containing representative plate heat C3054-2 has been tested, summarized in the below table. The projected 80-year 1/4T fluence for target plate heat C3138-2 in the River Bend vessel is Content Deleted - *EPRI Proprietary Information*

Table A-93
ISP capsule fluence and availability for River Bend – Plate

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EPRI Proprietary Information

Susquehanna 1

Representative Surveillance Materials

The ISP Representative Surveillance Materials for the Susquehanna 1 vessel target weld and plates are shown in the following table.

Table A-94
Target vessel materials and ISP representative materials for Susquehanna 1

Target Vessel Materials		ISP Representative Materials
Weld	494K2351	402K9171, 411L3071
Plate	C2433-1	C2433-1

Summary of Availability of Tested Surveillance Specimens – Weld

Two capsules containing representative weld heat 402K9171, 411L3071 have been tested, summarized in the below table. The projected 80-year 1/4T fluence for target weld heat 494K2351 in the Susquehanna 1 vessel is

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Table A-95
ISP capsule fluence and availability for Susquehanna 1 – Weld

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EPRI Proprietary Information

Summary of Availability of Tested Surveillance Specimens – Plate

Two capsules containing representative plate heat C2433-1 have been tested, summarized in the below table. The projected 80-year 1/4T fluence for target plate heat C2433-1 in the Susquehanna 1 vessel is Content Deleted - *EPRI Proprietary Information*

Table A-96
ISP capsule fluence and availability for Susquehanna 1 – Plate

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EPRI Proprietary Information

Susquehanna 2

Representative Surveillance Materials

The ISP Representative Surveillance Materials for the Susquehanna 2 vessel target weld and plates are shown in the following table.

Table A-97
Target vessel materials and ISP representative materials for Susquehanna 2

Target Vessel Materials		ISP Representative Materials
Weld	624263	5P6756
Plate	C2421-3	B0673-1

Summary of Availability of Tested Surveillance Specimens – Weld

Four capsules containing representative weld heat 5P6756 have been tested, summarized in the below table. The projected 80-year 1/4T fluence for target weld heat 624263 in the Susquehanna 2 vessel is Content Deleted - *EPRI Proprietary Information*

Table A-98
ISP capsule fluence and availability for Susquehanna 2 – Weld

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EPRI Proprietary Information

Summary of Availability of Tested Surveillance Specimens – Plate

Four capsules containing representative plate heat B0673-1 have been tested, summarized in the below table. The projected 80-year 1/4T fluence for target plate heat C2421-3 in the Susquehanna 2 vessel is Content Deleted - *EPRI Proprietary Information*

Table A-99
ISP capsule fluence and availability for Susquehanna 2 – Plate

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EPRI Proprietary Information

B
NRC REQUEST FOR ADDITIONAL INFORMATION ON BWRVIP-321

From: Holonich, Joseph [mailto:Joseph.Holonich@nrc.gov]
Sent: Wednesday, October 23, 2019 5:33 AM
To: McGruder, Wynter <WMcGruder@epri.com>; Palm, Nathan <npalm@epri.com>
Cc: Gonzalez, Hipolito <Hipolito.Gonzalez@nrc.gov>; Yee, On <On.Yee@nrc.gov>; Medoff, James <James.Medoff@nrc.gov>; Morey, Dennis <Dennis.Morey@nrc.gov>
Subject: [EXTERNAL] BWRVIP-321 Requests for Additional Information

*** Exercise caution. This is an EXTERNAL email. DO NOT open attachments or click links from unknown senders or unexpected email. ***.

*** Email is from prvs=192c706ea=Joseph.Holonich@nrc.gov ***.
Wynter,

I have placed an electronic version of the Requests for Additional Information (RAIs) for BWRVIP-321, ""Boiling Water Reactor Vessel And Internals Project: Plan For Extension of The BWR [Boiling Water Reactor] Integrated Surveillance Program (ISP) Through The Second License Renewal," in the box.com folder and have given you access to it. This email serves as the formal transmittal of those RAIs.

Staff has not redacted any proprietary information from the RAIs so the file in the Agencywide Document Access and Management System (ADAMS) and box.com are marked as proprietary. The RAIs have also been placed the RAIs in ADAMS as nonpublic so they can be declared an Official Agency Record. When responding to the RAIs, please provide a proprietary and nonproprietary version of both the RAIs and the responses. Your formal response, provided via letter under authorized signature, will generate the public version of the RAIs as well as the responses.

In order to support the staff's review schedule, please provide your responses no later than June 30, 2020. This date was provided by you based on the need to obtain ISP capsule testing before the RAIs can be answered.

If you have any questions or would like to discuss the RAIs with staff to ensure you understand them, please let me know.

This email will also go in ADAMS and will be declared public.

Joe Holonich, Senior Project Manager
U.S. Nuclear Regulatory Commission
Office of Nuclear Reactor Regulation
301-415-7297
jjh1@nrc.gov

BWRVIP 2019-100A, Attachment 1

U.S. NUCLEAR REGULATORY COMMISSION
OFFICE OF NUCLEAR REACTOR REGULATION
REQUEST FOR ADDITIONAL INFORMATION
"BOILING WATER REACTOR VESSEL AND INTERNALS PROJECT:
PLAN FOR EXTENSION OF THE BWR INTEGRATED SURVEILLANCE PROGRAM (ISP)
THROUGH THE SECOND LICENSE RENEWAL (sic) (SLR) (BWRVIP-321)"

RAI #1 – Associated with Section 4

By letter dated May 15, 2019 (Agencywide Documents Access and Management System (ADAMS) Accession No. ML 19137A027), the Boiling Water Reactor (BWR) Vessels and Internals Project (BWRVIP) requested a change in the BWRVIP Integrated Surveillance Program (ISP) capsule test schedule for license renewal to accommodate early closure of the Duane Arnold Energy Center. This request to change the BWRVIP ISP capsule test schedule for license renewal to accommodate early closure of the Duane Arnold Energy Center was accepted for use by the Nuclear Regulatory Commission (NRC) staff in letter dated July 23, 2019 (ADAMS Accession No.: ML19198A010).

Table 4-8 of BWRVIP-321, "Summary of representative materials for which additional surveillance data is required," indicates that the "Duane Arnold Shielded Metal Arc Weld" (DA SMAW) material requires additional surveillance data. In addition, Table 4-7, "Projected ISP(E) capsule fluence as a% of SLR 1/4T fluence for target welds," indicates that Duane Arnold is the only target vessel for the "DA SMAW" material.

1. Discuss the impact of the early withdrawal of the Duane Arnold capsule with respect to BWRVIP-321.
2. Explain whether additional surveillance data is still required for the "DA SMAW" material?

RAI #2 – Associated with Section 4

There are several instances in the tables in Section 4 where the capsule fluence as a % of target fluence for 72-Effective Full Power Years (EFPY) are mathematically incorrect. In some cases, because of the errors, the Supplemental Subsequent License Renewal (SSLR) capsule groupings may change and in at least one instance in Table 4-4, "ISP capsule fluence as a % of SLR 1/4T fluence for target welds," a value over 100% should be less than 100%. These errors can impact whether a plant pursuing subsequent license renewal (SLR) (1) expects to need additional surveillance data, and (2) is relying on an ISP(E) capsule or if the material is in the incorrect SSLR capsule grouping. The following are only meant to be examples and not a complete list of errors:

-
-

Content Deleted – *EPRI Proprietary Information*

□

Content Deleted – *EPRI Proprietary Information*

□

Verify the accuracy of information in Section 4, "Data Investigations," of BWRVIP-321 and identify any additional discrepancies. Discuss and justify the impacts of all discrepancies to BWRVIP-321?

RAI #3 – Associated with Section 4

Section 4.3. "Results," states, in part, the following:

> When ISP(E) capsules are considered (Table 4-6 and Table 4-7), surveillance data are expected to bound the 72-EFPY 1/4T fluences of five additional target plates and ***eight additional target welds*** beyond those capsules that are bounded by the capsules that will be tested by the end of the original license period. *Emphasis added*

Based on Tables 4-4 and 4-7, there only appears to be seven additional target welds instead of eight that will be bounded when considering surveillance data from ISP(E) capsules.

Reconcile the information in Section 4.3 and Tables 4-4 – 4.7. Justify the impacts, if any, as a result of this reconciliation in BWRVIP-321?

RAI #4 – Associated with Section 5

Section 5.3.1, "Weld Specimen Etching Study," states

> "[t]he weld heats examined in this study are specified in Table 5-1 and Table 5-2. A total of nine different weld heats were characterized, and the test specimens were available from a variety of ISP and SSP capsules. These tables list only nine welds because the Peach Bottom Unit 2 (PB2) ESW [electroslag welding] weld specimens will not be available for examination until the PB2 30° ISP capsule is withdrawn in late 2018. The weld and HAZ [Heat affected zone] specimens from that capsule will be etched and characterized at that time to determine the number of inserts that can be used in the SSLR capsule irradiation."

1. Discuss the impact, if any, to BWRVIP-321 when considering the actual neutron fluence received by the PB2 30° ISP capsule withdrawn in late 2018 compared to the projected

fluence in BWRVIP-86, Revision 1-A"BWR Vessel and Internals Project, Updated BWR Integrated Surveillance Program (ISP) Implementation Plan,"

2. Justify the number of available inserts for the materials in PB2 30° ISP capsule withdrawn in late 2018 are adequate to support the implementation of BWRVIP-321.

RAI #5 – Associated with Section 6

Section 6, "Fluence and Flux Considerations," of BWRVIP-321 provides evaluations performed to demonstrate that the target flux can be attained for the proposed SSLR capsules in four candidate host plants and identified several possible installation locations that yield the target flux.

The staff noted that the irradiation temperature is one of the parameters that is closely correlated with the effects of neutron embrittlement of reactor pressure vessel (RPV) steels, with lower embrittlement measured at higher irradiation temperatures within a range close to the standard operating temperature of 288 degrees C (550 degrees F). Therefore, knowledge of the irradiation temperature history of surveillance capsules is important to ensure that the surveillance data are properly interpreted and do not portray a non-conservative estimate of the RPV neutron embrittlement.

BWRVIP-321 indicates that rather than utilize the existing BWR capsule brackets at the vessel inside surface, accelerated flux values will be attained by mounting the SSLR capsules to the outside surface of the core shroud. However, BWRVIP-321 does not discuss that the proposed mounting locations on outside surface of the core shroud experience an irradiation temperature consistent with the inner diameter surface of the reactor vessel and how the SSLR capsule irradiation temperature history will be estimated/determined.

1. Justify that the proposed mounting locations on outside surface of the core shroud experiences an irradiation temperature consistent with the inner diameter surface of the reactor vessel of the BWR ISP participants.
2. Justify the method that the SSLR capsule irradiation temperature history will be estimated/determined to ensure that surveillance data is properly interpreted and does not portray a non-conservative estimate of the reactor vessel neutron embrittlement.

RAI #6 – Associated with Section 6

Section 6.3.1 states the following:

> It is known that Plant A and Plant D were recently approved for power uprates; Plant D achieved a MUR [measurement uncertainty recapture] that increased its rated power by 1.66%, and ***Plant A was approved for an extended power*** uprate of 14.3%. The ***Plant D MUR*** is reflected in the rated power presented in Table 6-2 and is not expected to perturb the power shape in the core. However, ***the Plant D extended power uprate*** is much more significant and took place several cycles after the most recently available cycle of data. This change in power is expected to increase the neutron flux at the SSLR capsule location, however, data was unavailable to appropriately model those effects. *Emphasis added*

Based on the information in Section 6.3.1, "Plant Description," of BWRVIP-321, it is not clear which plant underwent an extended power uprate (EPU) and whether this uprate was adequately considered when determining the optimal mounting location for the SSLR capsule.

1. Clarify discrepancy regarding the plant that was approved for an MUR and an extended power uprate.
2. Given that data was unavailable for the plant that underwent an EPU to appropriately model those effects with respect to the change in power and increased neutron flux and/or fleunce at the SSLR capsule location – Justify that the evaluation performed in Section 6 of BWRVIP-321 for identifying host plants and determining the optimal location for the SSLR capsule is still applicable for this plant that underwent an EPU.

RAI #7 – Associated with Section 9

Section 9.7, "Data Utilization," of BWRVIP-321 indicates that there are two options for applying the measured surveillance data (i.e. Regulatory Guide (RG) 1.99, Revision "Radiation Embrittlement of Reactor Vessel Materials Regulatory," (ADAMS Accession No.; ML003740284) Position C.1 and C.2). Option 1 is for situations when the heat of material does not specifically match the limiting heat of beltline material for that vessel, and Option 2 is when two or more surveillance data sets with matching heat numbers are available for the limiting beltline material. The Electric Power Research Institute (EPRI) indicated that these options are consistent with BWRVIP-86, Revision 1-A.

Section 2.1, "Historical Background of the BWRVIP ISP," of BWRVIP-321 states, in part, the following about the purpose and development of the ISP:

- Instead of using the plant-specific surveillance data from a given plant, the data from all BWR surveillance programs has been evaluated to select the ***"best" representative*** material to monitor radiation embrittlement for that plant. *Emphasis added*
- Development of the ISP consisted of the following general activities:
  - Identification of the limiting materials in each reactor vessel that the program would be designed to monitor, and
  - Selecting the best surveillance material from all available candidates to ***represent*** each limiting material. *Emphasis added*

The basis for the ISP was established in "BWR Vessel and Internals Project, BWR Integrated Surveillance Program Plan (BWRVIP-78)," which indicates that the ISP will "provide for data sharing, and an extensive high-quality database for improved monitoring of embrittlement trends," and that the BWR Supplemental Surveillance Program (SSP), which is integral to the ISP, "was designed to supplement the available vessel embrittlement database and to examine BWR specific irradiation trends." In addition, the staff noted an inconsistency between the options for applying the measured surveillance data identified in BWRVIP-86, Revision 1-A, and BWRVIP-321.

Given the proposal in BWRVIP-321 to extend the current ISP for SLR and the original purpose of the ISP, respond to the following so the NRC staff can assess the continued adequacy of the EPRI's approach for data utilization during the SLR period:

1. Discuss how the surveillance data from "representative materials" will be evaluated and used to inform the embrittlement trends for the plant(s) they represent for the SLR period?

2. Discuss the consistency of the surveillance data from "representative materials" that do not specifically match the heat or composition of beltline material [welds and base] for a particular RPV with the RG 1.99 Rev. 2 projections?
3. Justify that the statement below, which is in BWRVIP-86, Revision 1-A, is not part of "Option 1" in BWRVIP-321.
    - "Data from the representative material will be analyzed to confirm that the measured Charpy ΔT_{30} shift is within the normally expected scatter in the predicted shift."

RAI #8 – Associated with Section 9

Figure 9-1, "Flowchart illustrating procedure for determining need for additional surveillance data for a given target plant based on updated 80-year RPV fluence projections," guides an ISP participant to review Tables 4-6 and 4-7 of BWRVIP-321 to determine if the ratio of ISP and ISP(E) capsule fluence to 80-year 1 /4 T target fluence and determine if its greater than or less than 100%. The staff noted that the information in Tables 4-6 and 4-7 are based on the *projected* fluences for ISP and ISP(E) capsules and that at the time a licensee decides to pursue SLR it is possible that these ISP and ISP (E) capsules have already been pulled. In addition, based on the current environment of plants shutting down early, the staff noted it would be prudent to verify the as tested ISP and ISP(E) capsule fluence (i.e., Duane Arnold withdrawing ISP capsule ~7 years early) because the *projected* fluences for ISP and ISP(E) capsules may not be reached. Thus, it appears that a verification step is necessary for a licensee that implements BWRVIP-321 to ensure the actual tested capsule fluence has been accounted for in determining if additional surveillance data is needed for SLR.

> For Figure 9-1, "Flowchart illustrating procedure for determining need for additional surveillance data for a given target plant based on updated 80-year RPV fluence projections," and the licensee responsibilities in Section 9.2, "Licensee Responsibilities," justify the absence of a step for licensees to verify the actual neutron fluence of ISP and ISP(E) capsules that were withdrawn subsequent to the submission of BWRVIP-321 at the time of the Subsequent License Renewal Application is submitted and prior to entering the subsequent period of extended operation.

RAI #9 – Associated with Section 10

Section 10.3.1, "Host Plant Selection and Withdrawal Schedule," states, in part, the BWRVIP will notify the NRC of any changes to the SSLR capsule withdrawal schedule.

The staff's review of the withdrawal schedule in BWRVIP-321 is based on the assumptions made by EPRI in Section 8, "Schedule for SSLR Capsule Insertion, Withdrawal, and Testing," that SSLR capsules will be installed in the host vessel in 2022, and the needed catch-up fluence and the target flux range for the SSLR capsules, as discussed in Section 4 and 6, respectively. Therefore, changes to the withdrawal schedule of SSLR capsules beyond what is identified during the NRC staff's review of BWRVIP-321 must be approved prior to implementation consistent with III.B.3 of Appendix H.

Justify that changes to the SSLR capsule withdrawal schedule do not require approval prior to implementation in accordance with III.B.3 of Appendix H.

RAI #10 – Associated with Section 10

Section 10.3.2, "Test Plan and Reporting on Test Results," states, in part, "[e]ach material test report will be distributed to the NRC before the affected plant(s) enter the SLR period, or within two years of capsule withdrawal in the event the plant enters SLR before capsule withdrawal."

The staff noted that once a SLR application that references BWRVIP-321 is accepted, the surveillance data obtained from materials in the SSLR capsules are credited for demonstrating adequate aging management. It is the staff's understanding that EPRI's proposed timeline for submitting the material test reports may be inconsistent with the reporting requirements in Section IV of Appendix H to 10 CFR Part 50. Specifically, in certain circumstances the timeline for submitting the material test reports can exceed the amount of time permitted by Appendix H and would require a licensee to request a plant-specific extension or exemption.

If the staff's understanding of EPRI's proposal is accurate, a condition on the use of BWRVIP-321 will be necessary. Based on plant-specific circumstance, this condition may cause a licensee to request an extension for submitting material test reports in accordance with Section IV of Appendix H to 10 CFR Part 50 during the licensing action that proposes the use of BWRVIP-321.

If the staff's understanding is not accurate – justify that the proposal in BWRVIP-321 for submitting material test reports aligns with the timeframe established in Section IV of Appendix H to 10 CFR Part 50.

C
BWRVIP RESPONSE TO NRC REQUEST FOR ADDITIONAL INFORMATION ON BWRVIP-321

ELECTRIC POWER RESEARCH INSTITUTE

2020-046 BWR Vessel & Internals Project (BWRVIP)

(via e-mail)

June 8, 2020

Document Control Desk
U.S. Nuclear Regulatory Commission
11555 Rockville Pike
Rockville, MD 20852

Attention: Joseph Holonich

Subject: BWRVIP Docket No. 99902016 – BWRVIP Response to BWRVIP-321 Request for Additional Information (RAIs)

Reference: Email from Joseph J. Holonich (NRC) to Wynter McGruder (EPRI BWRVIP), "BWRVIP-321 Requests for Additional Information" dated October 23, 2019 (NRC ADAMS Accession No. ML19288A052)

Enclosed is one (1) copy of the BWRVIP proprietary response to the NRC Request for Additional Information (RAI) on the BWRVIP report entitled "BWRVIP-321, Plan for Extension of the BWR Integrated Surveillance Program (ISP) Through the Second License Renewal"

Please note that the enclosed response contains proprietary information. A letter requesting that the response be withheld from public disclosure and an affidavit describing the basis for withholding this information are provided as Attachment 1. The response includes yellow shading and double brackets to indicate the proprietary information. The pages that contain proprietary information are also marked with the letters "TS" indicating the information is considered trade secrets in accordance with 10CFR2.390.

One copy of a non-proprietary version of the BWRVIP response to the RAIs is also enclosed. This non-proprietary response is identical to the enclosed proprietary response except that the proprietary information has been deleted.

If you have any questions regarding this subject, please contact Wynter McGruder at EPRI by telephone at 704-595-2205 or by e-mail at wmcgruder@epri.com.

Sincerely,

Nathan Palm, EPRI, BWRVIP Program Manager

Together . . . Shaping the Future of Electricity

CHARLOTTE OFFICE
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BWRVIP 2020-046, Attachment 1

EPRI | ELECTRIC POWER RESEARCH INSTITUTE

NEIL WILMSHURST
Vice President and
Chief Nuclear Officer

Ref. EPRI BWRVIP Docket No. 99902016

June 8, 2020

Document Control Desk
Office of Nuclear Reactor Regulation
U.S. Nuclear Regulatory Commission
Washington, DC 20555-0001

Subject: Request for Withholding of the following Proprietary Information Included in:

BWRVIP Responses to NRC Request for Additional Information on "BWRVIP-321, Plan for Extension of the BWR Integrated Surveillance Program (ISP) Through the Second License Renewal"

To Whom It May Concern:

This is a request under 10 C.F.R. §2.390(a)(4) that the U.S. Nuclear Regulatory Commission ("NRC") withhold from public disclosure the information identified in the enclosed Affidavit consisting of the proprietary information owned by Electric Power Research Institute, Inc. ("EPRI") identified in the subject report. Proprietary and non-proprietary versions of the Responses and the Affidavit in support of this request are enclosed.

EPRI desires to disclose the Proprietary Information in confidence as a means of exchanging technical information with the NRC. The Proprietary Information is not to be divulged to anyone outside of the NRC or to any of its contractors, nor shall any copies be made of the Proprietary Infomation provided herein. EPRI welcomes any discussions and/or questions relating to the information enclosed.

If you have any questions about the legal aspects of this request for withholding, please do not hesitate to contact me at (704) 595-2732. Questions on the content of the Report should be directed to Nathn Palm of EPRI at (724) 288-4043.

Sincerely,

Attachment(s)

Together . . . Shaping the Future of Electricity

1300 West W.T. Harris Boulevard, Charlotte, NC 28262-8550 USA • 704.595.2732 • Mobile 704.490.2653 • nwilmshurst@epri.com

EPRI | ELECTRIC POWER RESEARCH INSTITUTE

AFFIDAVIT

RE: Request for Withholding of the Following Proprietary Information Included In:

BWRVIP Responses to NRC Request for Additional Information on "BWRVIP-321, Plan for Extension of the BWR Integrated Surveillance Program (ISP) Through the Second License Renewal"

I, Neil Wilmshurst, being duly sworn, depose and state as follows:

I am the Vice President and Chief Nuclear Officer at Electric Power Research Institute, Inc. whose principal office is located at 3420 Hillview Avenue, Palo Alto, California ("EPRI") and I have been specifically delegated responsibility for the above-listed response that contains EPRI Proprietary Information that is sought under this Affidavit to be withheld "Proprietary Information". I am authorized to apply to the U.S. Nuclear Regulatory Commission ("NRC") for the withholding of the Proprietary Information on behalf of EPRI.

EPRI Proprietary Information is identified in the above referenced response with highlighted text and double brackets. The pages with the proprietary information are also marked with the letters "TS" in the page footer indicating that information is considered trade secrets in accordance with 10 CFR 2.390. Example of such identification is as follows:

[[This sentence is an example]]

Tables, figures, or graphics containing EPRI Proprietary Information are identified with double brackets before and after the object. In each case this affidavit is the basis for the proprietary determination.

EPRI requests that the Proprietary Information be withheld from the public on the following bases:

Withholding Based Upon Privileged And Confidential Trade Secrets Or Commercial Or Financial Information (see e.g. 10 C.F.R. §2.390(a)(4))::

a. The Proprietary Information is owned by EPRI and has been held in confidence by EPRI. All entities accepting copies of the Proprietary Information do so subject to written agreements imposing an obligation upon the recipient to maintain the confidentiality of the Proprietary Information. The Proprietary Information is disclosed only to parties who agree, in writing, to preserve the confidentiality thereof.

b. EPRI considers the Proprietary information contained therein to constitute trade secrets of EPRI. As such, EPRI holds the Information in confidence and disclosure thereof is strictly limited to individuals and entities who have agreed, in writing, to maintain the confidentiality of the Information.

c. The information sought to be withheld is considered to be proprietary for the following reasons. EPRI made a substantial economic investment to develop the Proprietary Information, and, by prohibiting public disclosure, EPRI derives an economic benefit in the form of licensing royalties and other

additional fees from the confidential nature of the Proprietary Information. If the Proprietary Information were publicly available to consultants and/or other businesses providing services in the electric and/or nuclear power industry, they would be able to use the Proprietary Information for their own commercial benefit and profit and without expending the substantial economic resources required of EPRI to develop the Proprietary Information.

d. EPRI's classification of the Proprietary Information as trade secrets is justified by the Uniform Trade Secrets Act which California adopted in 1984 and a version of which has been adopted by over forty states. The California Uniform Trade Secrets Act, California Civil Code §§3426 – 3426.11, defines a "trade secret" as follows:

> "Trade secret' means information, including a formula, pattern, compilation, program device, method, technique, or process, that:
>
> (1) Derives independent economic value, actual or potential, from not being generally known to the public or to other persons who can obtain economic value from its disclosure or use; and
>
> (2) Is the subject of efforts that are reasonable under the circumstances to maintain its secrecy."

e. The Proprietary Information contained therein are not generally known or available to the public. EPRI developed the Information only after making a determination that the Proprietary Information was not available from public sources. EPRI made a substantial investment of both money and employee hours in the development of the Proprietary Information. EPRI was required to devote these resources and effort to derive the Proprietary Information. As a result of such effort and cost, both in terms of dollars spent and dedicated employee time, the Proprietary Information is highly valuable to EPRI.

f. A public disclosure of the Proprietary Information would be highly likely to cause substantial harm to EPRI's competitive position and the ability of EPRI to license the Proprietary Information both domestically and internationally. The Proprietary Information can only be acquired and/or duplicated by others using an equivalent investment of time and effort.

I have read the foregoing and the matters stated herein are true and correct to the best of my knowledge, information and belief. I make this affidavit under penalty of perjury under the laws of the United States of America and under the laws of the State of California.

Executed at 1300 W WT Harris Blvd, Charlotte, NC being the premises and place of business of Electric Power Research Institute, Inc.

Date: 6-8-2020

[signature]

Neil Wilmshurst

(State of North Carolina)
(County of Mecklenburg)

Subscribed and sworn to (or affirmed) before me on this 8 day of June, 2020 by Neil Wilmshurst, proved to me on the basis of satisfactory evidence to be the person(s) who appeared before me.

Signature Candra B Sheriff (Seal)

CANDRA B SHERIFF
Notary Public
Cabarrus
County
NORTH CAROLINA

My Commission Expires 12 day of August, 2023

BWRVIP 2020-046, Attachment 2

Request for Additional Information on "Boiling Water Reactor Vessel and Internals Project: Plan for Extension of the BWR Integrated Surveillance Program (ISP) Through the Second License Renewal (BWRVIP-321)"

Each item from the NRC Request for Additional Information (RAI) from the NRC is repeated below verbatim followed by the BWRVIP response to that item. All EPRI proprietary text is marked in **[[yellow and double brackets]]**

RAI #1 – Associated with Section 4

By letter dated May 15, 2019 (Agencywide Documents Access and Management System (ADAMS) Accession No. ML 19137A027), the Boiling Water Reactor (BWR) Vessels and Internals Project (BWRVIP) requested a change in the BWRVIP Integrated Surveillance Program (ISP) capsule test schedule for license renewal to accommodate early closure of the Duane Arnold Energy Center. This request to change the BWRVIP ISP capsule test schedule for license renewal to accommodate early closure of the Duane Arnold Energy Center was accepted for use by the Nuclear Regulatory Commission (NRC) staff in letter dated July 23, 2019 (ADAMS Accession No.: ML19198A010).

Table 4-8 of BWRVIP-321, "Summary of representative materials for which additional surveillance data is required," indicates that the "Duane Arnold Shielded Metal Arc Weld" (DA SMAW) material requires additional surveillance data. In addition, Table 4-7, "Projected ISP(E) capsule fluence as a% of SLR 1/4T fluence for target welds," indicates that Duane Arnold is the only target vessel for the "DA SMAW" material.

1. Discuss the impact of the early withdrawal of the Duane Arnold capsule with respect to BWRVIP-321.
2. Explain whether additional surveillance data is still required for the "DA SMAW" material?

BWRVIP Response to RAI #1, item #1

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The Duane Arnold weld heat DA SMAW has only one target plant, Duane Arnold, and is not a heat match to the Duane Arnold target weld heat.

For these reasons, there is no impact of early withdrawal of the Duane Arnold capsule with respect to BWRVIP-321.

BWRVIP Response to RAI #1, item #2

No additional surveillance data is required for the Duane Arnold weld heat "DA SMAW". As stated above, the Duane Arnold weld heat "DA SMAW" has only one target plant which is Duane Arnold. Since Duane Arnold will be shutting down in late 2020, there is no further need for data for the "DA SMAW" material.

RAI #2 – Associated with Section 4

There are several instances in the tables in Section 4 where the capsule fluence as a % of target fluence for 72-Effective Full Power Years (EFPY) are mathematically incorrect. In some cases, because of the errors, the Supplemental Subsequent License Renewal (SSLR) capsule groupings may change and in at least one instance in Table 4-4, "ISP capsule fluence as a % of SLR 1/4T fluence for target welds," a value over 100% should be less than 100%. These errors can impact whether a plant pursuing subsequent license renewal (SLR) (1) expects to need additional surveillance data, and (2) is relying on an ISP(E) capsule or if the material is in the incorrect SSLR capsule grouping. The following are only meant to be examples and not a complete list of errors:

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Verify the accuracy of information in Section 4, "Data Investigations," of BWRVIP-321 and identify any additional discrepancies. Discuss and justify the impacts of all discrepancies to BWRVIP-321?

BWRVIP Response to RAI #2

The tables in Section 4 have been reviewed and discrepancies were identified in Tables 4-3, 4-4, 4-6, and 4-7, as shown in the attached marked-up pages from BWRVIP-321. The fluence and percentage values in the other Section 4 tables are correct. The discrepancies noted in the mark-up were due to errors in transcr bing values from calculation worksheets into the report tables. However, the discrepancies in these report tables did not propagate into subsequent

calculations. Consequently, there is no impact to the SSLR capsule projections. Therefore, the overall impact of these discrepancies in BWRVIP-321 is minimal. A revision to BWRVIP-321 will be issued to correct the affected tables.

RAI #3 – Associated with Section 4

Section 4.3. "Results," states, in part, the following:

> When ISP(E) capsules are considered (Table 4-6 and Table 4-7), surveillance data are expected to bound the 72-EFPY 1/4T fluences of five additional target plates and ***eight additional target welds*** beyond those capsules that are bounded by the capsules that will be tested by the end of the original license period. *Emphasis added*

Based on Tables 4-4 and 4-7, there only appears to be seven additional target welds instead of eight that will be bounded when considering surveillance data from ISP(E) capsules.

Reconcile the information in Section 4.3 and Tables 4-4 – 4.7. Justify the impacts, if any, as a result of this reconciliation in BWRVIP-321?

BWRVIP Response to RAI #3

Per the response to RAI #2, some percentage values were incorrect in Tables 4-3, 4-4, 4-6, and 4-7. Attached are the corrected table values shown in red. Additionally, the percentages in all tables in Section 4 were rounded to the nearest whole number since accuracy to one significant digit is not deemed necessary.

When the percentages are corrected, the results are as follows: When only the existing ISP capsules are considered, 8 target welds are bounded by existing surveillance data. If the ISP(E) data are considered, 16 target welds are bounded by surveillance data. The following statement is correct as written: The ISP(E) data bounds 8 additional target welds. Therefore, there is no impact to the SSLR capsules and no need to reconcile any differences.

RAI #4 – Associated with Section 5

Section 5.3.1, "Weld Specimen Etching Study," states

> "[t]he weld heats examined in this study are specified in Table 5-1 and Table 5-2. A total of nine different weld heats were characterized, and the test specimens were available from a variety of ISP and SSP capsules. These tables list only nine welds because the Peach Bottom Unit 2 (PB2) ESW [electroslag welding] weld specimens will not be available for examination until the PB2 30° ISP capsule is withdrawn in late 2018. The weld and HAZ [Heat affected zone] specimens from that capsule will be etched and characterized at that time to determine the number of inserts that can be used in the SSLR capsule irradiation."

1. Discuss the impact, if any, to BWRVIP-321 when considering the actual neutron fluence received by the PB2 30° ISP capsule withdrawn in late 2018 compared to the projected fluence in BWRVIP-86, Revision 1-A"BWR Vessel and Internals Project, Updated BWR Integrated Surveillance Program (ISP) Implementation Plan,"

2. Justify the number of available inserts for the materials in PB2 30° ISP capsule withdrawn in late 2018 are adequate to support the implementation of BWRVIP-321.

BWRVIP Response to RAI #4, item #1

The calculated neutron fluence of the Peach Bottom Unit 2 30° capsule is 9.13×10^{17} n/cm^2 (E>1.0 MeV) [1]. The projected fluence of the capsule given in Table 4-7 of BWRVIP-86, Revision 1-A is [[ ]]. Since the Peach Bottom Unit 2 capsule received a higher fluence than originally predicted, there is no impact to any of the calculations performed to determine the materials selected for the SSLR capsules, as well as their corresponding catch-up fluences. Therefore, the actual fluence of the Peach Bottom Unit 2 capsule does not result in any changes to BWRVIP-321.

BWRVIP Response to RAI #4, item #2

Following completion of the Peach Bottom Unit 2 capsule testing, the broken Charpy specimens of the weld metal and HAZ were etched to determine the number of available inserts. Based on the etching it has been determined that there are a sufficient number of 18 mm inserts for the weld material. Revisions to Tables 5-1 and 5-2 of BWRVIP-321 containing the Peach Bottom Unit 2 weld are shown below.

RAI #5 – Associated with Section 6

Section 6, "Fluence and Flux Considerations," of BWRVIP-321 provides evaluations performed to demonstrate that the target flux can be attained for the proposed SSLR capsules in four candidate host plants and identified several possible installation locations that yield the target flux.

The staff noted that the irradiation temperature is one of the parameters that is closely correlated with the effects of neutron embrittlement of reactor pressure vessel (RPV) steels, with lower embrittlement measured at higher irradiation temperatures within a range close to the standard operating temperature of 288 degrees C (550 degrees F). Therefore, knowledge of the irradiation temperature history of surveillance capsules is important to ensure that the surveillance data are properly interpreted and do not portray a non-conservative estimate of the RPV neutron embrittlement.

BWRVIP-321 indicates that rather than utilize the existing BWR capsule brackets at the vessel inside surface, accelerated flux values will be attained by mounting the SSLR capsules to the outside surface of the core shroud. However, BWRVIP-321 does not discuss that the proposed mounting locations on outside surface of the core shroud experience an irradiation temperature consistent with the inner diameter surface of the reactor vessel and how the SSLR capsule irradiation temperature history will be estimated/determined.

1. Justify that the proposed mounting locations on outside surface of the core shroud experiences an irradiation temperature consistent with the inner diameter surface of the reactor vessel of the BWR ISP participants.
2. Justify the method that the SSLR capsule irradiation temperature history will be estimated/determined to ensure that surveillance data is properly interpreted and does not portray a non-conservative estimate of the reactor vessel neutron embrittlement.

BWRVIP Response to RAI #5, item #1

The proposed mounting location of the SSLR capsules will be several inches (radially) away from the outside diameter (OD) core shroud surface. The exact dimensions will be determined for the selected host plant to achieve the desired flux and fluence for the three capsule groupings. Irrespective of the exact radial location relative to the shroud OD, the capsules will be exposed to the fluid temperature in the reactor annulus which is typically 525°F to 535°F, depending on the feedwater temperature. The reactor coolant in the annulus is well mixed and any radial temperature variation is expected to be negligible. As such, the SSLR capsules will be exposed to an irradiation temperature that is consistent with normal BWR surveillance capsules at the inner diameter surface of the reactor vessel.

BWRVIP Response to RAI #5, item #2

As discussed in the response to RAI #5, item #1, the SSLR capsules are located in the annulus between the shroud and the RPV and will experience the same environment/temperatures as the original BWR surveillance capsules. Additionally, the fast flux spectra between the original and proposed locations compare well. Consequently, any differences/variations in fast flux and the effect on irradiation temperature are judged to be minor. The design of the SSLR capsules will be similar to those of the original design in terms of overall dimensions, materials of construction, flux wires, etc. Therefore, the BWRVIP will use the same methods as currently used to determine surveillance capsule irradiation temperature history. Furthermore, based on the design and environmental similarities between standard surveillance capsules and the SSLR capsules, there is no reason to expect that the SSLR capsules will produce non-conservative estimates of embrittlement for the materials to be irradiated.

RAI #6 – Associated with Section 6

Section 6.3.1 states the following:

It is known that Plant A and Plant D were recently approved for power uprates; Plant D achieved a MUR [measurement uncertainty recapture] that increased its rated power by 1.66%, and ***Plant A was approved for an extended power*** uprate of 14.3%. The ***Plant D MUR*** is reflected in the rated power presented in Table 6-2 and is not expected to perturb the power shape in the core. However, ***the Plant D extended power uprate*** is much more significant and took place several cycles after the most recently available cycle of data. This change in power is expected to increase the neutron flux at the SSLR capsule location, however, data was unavailable to appropriately model those effects. *Emphasis added*

Based on the information in Section 6.3.1, "Plant Description," of BWRVIP-321, it is not clear which plant underwent an extended power uprate (EPU) and whether this uprate was adequately considered when determining the optimal mounting location for the SSLR capsule.

1. Clarify discrepancy regarding the plant that was approved for an MUR and an extended power uprate.

2. Given that data was unavailable for the plant that underwent an EPU to appropriately model those effects with respect to the change in power and increased neutron flux and/or fluence at the SSLR capsule location – Justify that the evaluation performed in Section 6 of BWRVIP-321 for identifying host plants and determining the optimal location for the SSLR capsule is still applicable for this plant that underwent an EPU.

BWRVIP Response to RAI #6, item #1

The statements in Section 6.3.1 that "Plant A was approved for an extended power uprate" and "Plant D achieved a MUR" are correct as written. The statement "However, the Plant D extended power uprate…" should instead state "However, the **Plant A** extended power uprate…" This statement will be corrected in the revised report.

BWRVIP Response to RAI #6, item #2

The intent of the evaluation in Section 6 was to demonstrate that multiple plants could serve as host plants for the SSLR capsules. Regardless of which plant is ultimately selected, several actions would still be required including, but not limited to, 1) designing a capsule that has the proper flux and fluence, i.e., determining the radial offset from the core shroud and azimuthal position, 2) verifying projected fluence values and 3) developing the withdrawal schedule. The selected plant and results of supporting actions will be communicated to the NRC as discussed in Section 10.3 of BWRVIP-321.

RAI #7 – Associated with Section 9

Section 9.7, "Data Utilization," of BWRVIP-321 indicates that there are two options for applying the measured surveillance data (i.e. Regulatory Guide (RG) 1.99, Revision "Radiation Embrittlement of Reactor Vessel Materials Regulatory," (ADAMS Accession No.; ML003740284) Position C.1 and C.2). Option 1 is for situations when the heat of material does not specifically match the limiting heat of beltline material for that vessel, and Option 2 is when two or more surveillance data sets with matching heat numbers are available for the limiting beltline material. The Electric Power Research Institute (EPRI) indicated that these options are consistent with BWRVIP-86, Revision 1-A.

Section 2.1, "Historical Background of the BWRVIP ISP," of BWRVIP-321 states, in part, the following about the purpose and development of the ISP:

- Instead of using the plant-specific surveillance data from a given plant, the data from all BWR surveillance programs has been evaluated to select the ***"best" representative*** material to monitor radiation embrittlement for that plant. *Emphasis added*
- Development of the ISP consisted of the following general activities:
    - Identification of the limiting materials in each reactor vessel that the program would be designed to monitor, and
    - Selecting the best surveillance material from all available candidates to ***represent*** each limiting material. *Emphasis added*

The basis for the ISP was established in "BWR Vessel and Internals Project, BWR Integrated Surveillance Program Plan (BWRVIP-78)," which indicates that the ISP will "provide for data sharing, and an extensive high-quality database for improved monitoring of embrittlement trends," and that the BWR Supplemental Surveillance Program (SSP), which is integral to the

ISP, "was designed to supplement the available vessel embrittlement database and to examine BWR specific irradiation trends." In addition, the staff noted an inconsistency between the options for applying the measured surveillance data identified in BWRVIP-86, Revision 1-A, and BWRVIP-321.

Given the proposal in BWRVIP-321 to extend the current ISP for SLR and the original purpose of the ISP, respond to the following so the NRC staff can assess the continued adequacy of the EPRI's approach for data utilization during the SLR period:

1. Discuss how the surveillance data from "representative materials" will be evaluated and used to inform the embrittlement trends for the plant(s) they represent for the SLR period?

2. Discuss the consistency of the surveillance data from "representative materials" that do not specifically match the heat or composition of beltline material [welds and base] for a particular RPV with the RG 1.99 Rev. 2 projections?

3. Justify that the statement below, which is in BWRVIP-86, Revision 1-A, is not part of "Option 1" in BWRVIP-321.
    - "Data from the representative material will be analyzed to confirm that the measured Charpy ΔT_{30} shift is within the normally expected scatter in the predicted shift."

BWRVIP Response to RAI #7, item #1

The evaluation and application of surveillance data will continue to follow the established methodology documented in Reg. Guide 1.99, Rev. 2, BWRVIP-86, Rev. 1-A and Reference 2. This is described in Section 5.6 of BWRVIP-86, Rev. 1-A. Surveillance data will only have plant specific applicability if 1) there are two or more credible data points per Reg. Guide 1.99, Rev. 2 position 2.1 and 2) the surveillance material is a heat match to that in the vessel. If neither 1) or 2) are satisfied, the data will only be used for assessment of embrittlement trend correlations (ETCs). Surveillance data that has a matching heat to the vessel material will not be used if only one data point exists. For this situation, the shift in ΔT_{30} will be determined using the chemistry factors in Reg. Guide 1.99, Rev. 2.

All BWRVIP ISP data is made publicly available and has been used to inform embrittlement trends and in the development of alternate ETCs. If approved by the NRC, these improved ETCs could be used for prediction of shift for those materials where a heat match does not exist.

In conclusion, the BWRVIP follows the NRC issued regulatory guidance as written and will continue to do so until such time as the guidance is revised.

BWRVIP Response to RAI #7, item #2

All surveillance data from the BWRVIP ISP, regardless of heat match is documented in surveillance capsule reports. An example of such data is shown in Table 1 (Table 5-2 from [3]) which shows the actual measured shift compared to the predicted shift using Reg. Guide 1.99, Rev. 2. In this case, the RG shift prediction is conservative. There may be cases where the opposite is true. Such variability is common amongst both BWR and PWR surveillance data. Methods for application of surveillance, whether the measured values are conservative or non-conservative, are provided in Reg. Guide 1.99, Rev. 2 and [2]. Evaluation or "consistency" of all BWR surveillance data is treated as part of industry efforts to periodically assess the ETCs.

Table 1. Comparison of Measured and Predict Shift

Identity	Material	Fluence (E>1.0 MeV, x10[17] n/cm²)[1]	Measured Shift[2] °F (°C)	RG 1.99 Rev. 2 Predicted Shift[3] °F (°C)	RG 1.99 Rev. 2 Predicted Shift+Margin[3,4] °F (°C)
C8554 (LT orientation)	Hatch Unit 2 surveillance plate	2.67	14.7 (8.2)	24.8 (13.8)	49.6 (27.5)
51912	Hatch Unit 2 surveillance weld	13.9	-6.3 (-3.5)	32.6 (18.1)	65.1 (36.2)

Additionally, the NRC has evaluated the consistency of surveillance data for BWR and PWR data compared to Reg Guide 1.99, Rev. 2 predictions [4]. Figure 2-6 of [4] shows a plot of ΔT41J (predicted by the RG) minus the measured value from surveillance capsules for both base and weld metal. This evaluation shows that the majority of surveillance data lies within the 2σ criteria specified in the RG up to a fluence of ~1.5E19 n/cm^2 which is greater than maximum 1/4T fluence for a BWR at 80 years.

BWRVIP Response to RAI #7, item #3

Following many years of implementing the BWRVIP ISP, this statement was determined to be erroneous and thus, removed because the regulations and regulatory guidance do not require such actions to be taken if measured data exceeds the scatter criteria in the RG.

RAI #8 – Associated with Section 9

Figure 9-1, "Flowchart illustrating procedure for determining need for additional surveillance data for a given target plant based on updated 80-year RPV fluence projections," guides an ISP participant to review Tables 4-6 and 4-7 of BWRVIP-321 to determine if the ratio of ISP and ISP(E) capsule fluence to 80-year 1/4 T target fluence and determine if its greater than or less than 100%. The staff noted that the information in Tables 4-6 and 4-7 are based on the *projected* fluences for ISP and ISP(E) capsules and that at the time a licensee decides to pursue SLR it is possible that these ISP and ISP (E) capsules have already been pulled. In addition, based on the current environment of plants shutting down early, the staff noted it would be prudent to verify the as tested ISP and ISP(E) capsule fluence (i.e., Duane Arnold withdrawing ISP capsule ~7 years early) because the *projected* fluences for ISP and ISP(E) capsules may not be reached. Thus, it appears that a verification step is necessary for a licensee that implements BWRVIP-321 to ensure the actual tested capsule fluence has been accounted for in determining if additional surveillance data is needed for SLR.

> For Figure 9-1, "Flowchart illustrating procedure for determining need for additional surveillance data for a given target plant based on updated 80-year RPV fluence projections," and the licensee respons bilities in Section 9.2, "Licensee Responsibilities," justify the absence of a step for licensees to verify the actual neutron fluence of ISP and ISP(E) capsules that were withdrawn subsequent to the submission of BWRVIP-321 at the time of the Subsequent License Renewal Application is submitted and prior to entering the subsequent period of extended operation.

BWRVIP Response to RAI #8

Figure 9-1 has been revised as show below to include a verification step to ensure that the actual tested capsule fluence has been accounted for in determining if additional surveillance data is needed for SLR. This revised figure will be included in a revision to BWRVIP-321.

RAI #9 – Associated with Section 10

Section 10.3.1, "Host Plant Selection and Withdrawal Schedule," states, in part, the BWRVIP will notify the NRC of any changes to the SSLR capsule withdrawal schedule.

The staff's review of the withdrawal schedule in BWRVIP-321 is based on the assumptions made by EPRI in Section 8, "Schedule for SSLR Capsule Insertion, Withdrawal, and Testing," that SSLR capsules will be installed in the host vessel in 2022, and the needed catch-up fluence and the target flux range for the SSLR capsules, as discussed in Section 4 and 6, respectively. Therefore, changes to the withdrawal schedule of SSLR capsules beyond what is identified during the NRC staff's review of BWRVIP-321 must be approved prior to implementation consistent with III.B.3 of Appendix H.

Justify that changes to the SSLR capsule withdrawal schedule do not require approval prior to implementation in accordance with III.B.3 of Appendix H.

BWRVIP Response to RAI #9

To address this RAI, three capsule insertion and withdrawal scenarios have been developed. The scenarios considered minimum, intermediate, and maximum flux values that are expected for the potential host plants, and insertion dates ranging from 2022 to 2024. The BWRVIP proposes to include these scenarios in Section 8 as a means to provide flex bility in the selection of insertion and withdrawal dates. NRC acceptance of these scenarios should obviate the need for BWRVIP to submit a request for approval, per III.B.3 of Appendix H, prior to implementation of the SSLR plan.

To that end, the BWRVIP proposes to modify the third paragraph on page 8-1 of BWRVIP-321 as follows (new text in italics and underlined):

> "The anticipated timeframe for SSLR capsule insertion and withdrawal is compared with license periods for BWRs impacted by the capsule data in Figure 8-1, Figure 8-2, and Figure 8-3 for the three SSLR capsule groupings. It is assumed in the construction of these figures that capsules will be installed in the host vessel in 2022. These plots have been constructed for scoping and planning purposes, and the irradiation schedule will depend on the outage schedule of the selected host plant. The plots show that irradiation of all three SSLR capsules will be completed well before the end of the second PEO for all BWRs, and for nearly all BWRs before the end of the first PEO *Additionally, Tables 8-1, 8-2 and 8-3 provide a range of possible insertion and withdrawal dates (2022, 2023 and 2024) for three flux values (minimum, intermediate and maximum). The final scenario chosen will depend on the host plant that is selected for the irradiation campaign.* The actual irradiation schedule *(selected from Table 8-1, 8-2, or 8-3)* will be provided to the NRC upon program approval and host plant selection. *NRC acceptance of these scenarios as part of the ISP SLR program plan are expected to comply with the requirements of 10 CFR50, Appendix H, paragraph III.B.3."*

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RAI #10 – Associated with Section 10

Section 10.3.2, "Test Plan and Reporting on Test Results," states, in part, "[e]ach material test report will be distributed to the NRC before the affected plant(s) enter the SLR period, or within two years of capsule withdrawal in the event the plant enters SLR before capsule withdrawal."

The staff noted that once a SLR application that references BWRVIP-321 is accepted, the surveillance data obtained from materials in the SSLR capsules are credited for demonstrating adequate aging management. It is the staff's understanding that EPRI's proposed timeline for submitting the material test reports may be inconsistent with the reporting requirements in Section IV of Appendix H to 10 CFR Part 50. Specifically, in certain circumstances the timeline for submitting the material test reports can exceed the amount of time permitted by Appendix H and would require a licensee to request a plant-specific extension or exemption.

If the staff's understanding of EPRI's proposal is accurate, a condition on the use of BWRVIP-321 will be necessary. Based on plant-specific circumstance, this condition may cause a licensee to request an extension for submitting material test reports in accordance with Section IV of Appendix H to 10 CFR Part 50 during the licensing action that proposes the use of BWRVIP-321.

If the staff's understanding is not accurate – justify that the proposal in BWRVIP-321 for submitting material test reports aligns with the timeframe established in Section IV of Appendix H to 10 CFR Part 50.

BWRVIP Response to RAI #10

Regarding the timeline for submittal of material test reports, the BWRVIP proposes to revise the last paragraph of Section 10.3.2 as follows:

> "Each material test report will be transmitted to the NRC before the affected plant(s) enter the SLR period, or in accordance with the reporting requirements of Section IV of Appendix H in the event the plant enters SLR before capsule withdrawal."

References:

1. BWRVIP-332: BWR Vessel and Internals Project, Testing and Evaluation of the Peach Bottom Unit 2 30° Surveillance Capsule. EPRI, Palo Alto, CA: 2020. 3002018177.
2. K. Wichman, M. Mitchell, and A. Hiser, USNRC, Generic Letter 92-01 and RPV Integrity Workshop Handouts, *NRC/Industry Workshop on RPV Integrity Issues*, February 12, 1998.
3. BWRVIP-319NP: BWR Vessel and Internals Project, Testing and Evaluation of the Hatch Unit 2 120° Surveillance Capsule," EPRI Technical Report 3002013103, August 2018.
4. "Assessment of the Continued Adequacy of Revision 2 of Regulatory Guide 1.99," Technical Letter Report, TLR-RES/DE/CIB-2019-2, July 2019.

Revised Tables 4-1, 4-2, 4-3, 4-4, 4-6, 4-7, 4-15 and 4-16

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Revised Tables 5-1 and 5-2

The footnotes in Table 5-1 and 5-2 remain unchanged.

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Revised Figure 9-1

Flowchart illustrating procedure for determining need for additional surveillance data for a given target plant based on updated 80-year RPV fluence projections

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REVISED BWRVIP RESPONSE FOR RAI-10 TO THE REQUEST FOR ADDITIONAL INFORMATION ON BWRVIP-321

ELECTRIC POWER RESEARCH INSTITUTE

2020-058 BWR Vessel & Internals Project (BWRVIP)

(via e-mail)

July 15, 2020

Document Control Desk
U.S. Nuclear Regulatory Commission
11555 Rockville Pike
Rockville, MD 20852

Attention: Joseph Holonich

Subject: BWRVIP Docket No. 99902016 – Revised BWRVIP Response for RAI-10 to the NRC Request for Additional Information on BWRVIP-321

References: 1. Email from Joseph J. Holonich (NRC) to Wynter McGruder (EPRI BWRVIP), "BWRVIP-321 Requests for Additional Information" dated October 23, 2019 (NRC ADAMS Accession No. ML19288A052)

2. BWRVIP Letter 2020-046: "BWRVIP Docket No. 99902016 – BWRVIP Response to BWRVIP-321 Request for Additional Information (RAIs)," June 8, 2020

3. BWRVIP Letter 2020-054: "BWRVIP Docket No. 99902016 – Revised BWRVIP Response for RAI-10 to the NRC Request for Additional Information (RAIs)," July 9, 2020

Enclosed is one (1) copy of a revision to the revised BWRVIP response for RAI-10 previously submitted via Reference 3.

If you have any questions regarding this subject, please contact Wynter McGruder at EPRI by telephone at 704-595-2205 or by e-mail at wmcgruder@epri.com

Sincerely,

Nathan Palm, EPRI, BWRVIP Program Manager

Together . . . Shaping the Future of Electricity

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Request for Additional Information on "Boiling Water Reactor Vessel and Internals Project: Plan for Extension of the BWR Integrated Surveillance Program (ISP) Through the Second License Renewal (BWRVIP-321)"

The following is a revised response to RAI #10.

RAI #10 – Associated with Section 10

Section 10.3.2, "Test Plan and Reporting on Test Results," states, in part, "[e]ach material test report will be distributed to the NRC before the affected plant(s) enter the SLR period, or within two years of capsule withdrawal in the event the plant enters SLR before capsule withdrawal."

The staff noted that once a SLR application that references BWRVIP-321 is accepted, the surveillance data obtained from materials in the SSLR capsules are credited for demonstrating adequate aging management. It is the staff's understanding that EPRI's proposed timeline for submitting the material test reports may be inconsistent with the reporting requirements in Section IV of Appendix H to 10 CFR Part 50. Specifically, in certain circumstances the timeline for submitting the material test reports can exceed the amount of time permitted by Appendix H and would require a licensee to request a plant-specific extension or exemption.

If the staff's understanding of EPRI's proposal is accurate, a condition on the use of BWRVIP-321 will be necessary. Based on plant-specific circumstance, this condition may cause a licensee to request an extension for submitting material test reports in accordance with Section IV of Appendix H to 10 CFR Part 50 during the licensing action that proposes the use of BWRVIP-321.

If the staff's understanding is not accurate – justify that the proposal in BWRVIP-321 for submitting material test reports aligns with the timeframe established in Section IV of Appendix H to 10 CFR Part 50.

Revised BWRVIP Response to RAI #10

Regarding the timeline for submittal of material test reports, the BWRVIP proposes to revise Section 8, Section 9.1, Section 10.2.2, and Section 10.3.2 as follows.

1. Section 8, page 8-1

   "The specific materials to be reconstituted and tested will be determined at a later date based on the needs of plants pursuing SLR, as discussed in Section 9. The sequence of events that will trigger testing of SSLR capsule materials is described as follows. A licensee will submit an application for SLR indicating the plant intends to take credit for the ISP for SLR program and providing the projected SLR end-of-license fluence. Based on the projected SLR fluence of the target materials at that plant, the BWRVIP will evaluate whether the existing or projected ISP(E) fluence bounds the SLR fluence or whether the representative materials from the SSLR capsules need to be tested. If existing ISP or ISP(E) capsules are bounding, then the representative material would not be tested at that time. When an SLR application is submitted by a target plant whose SLR fluence is not bounded by existing ISP or ISP(E) capsules (those in bold text in Table 4-3, Table 4-4, Table 4-6, and Table 4-7), the BWRVIP

will develop a schedule for testing and reporting of results for the representative materials for those plants (see Section 10.3.2)."

2. Section 8, page 8-2

   "~~The test results will be submitted to the NRC before the target plant enters SLR, or within two years of capsule withdrawal in the event the plant enters SLR before the capsule is withdrawn~~."

3. Section 9, page 9-1

   "Working with utilities to identify those materials which will be needed to support SLR and to coordinate and support the testing of those materials and publication of test reports. ~~As an alternative to 10CFR50 Appendix H [1], test results will be reported prior to the plant entering the SLR period, or within two years of capsule withdrawal if the capsule has not been withdrawn before the plant enters SLR.."~~

4. Section 10.2.2, page 10-4

   - *10CFR50 Appendix H, Paragraph IV.A: Capsule Test Reporting ~~Deadline~~*

   10CFR50 Appendix H requires that capsule material test results be submitted to the NRC within one year of the date of capsule withdrawal. Under the ISP for SLR program, upon SSLR capsule withdrawal, all specimens will be placed into storage until it is determined that data for a given material is needed. However, all packets will be opened and dosimetry tested at the earliest opportunity following capsule withdrawal and shipment to the testing facility. Materials will be tested only for plants applying for SLR that need the surveillance data provided by those materials. ~~Test reports will be submitted before the plant enters the SLR period or, in the event the plant enters the SLR period before the capsule is withdraw, within two years of capsule withdrawal.~~

5. Section 10.3.2, page 10-5

   "Because the selection of materials to be reconstituted and tested will depend on which BWRs pursue SLR and need additional surveillance data, the BWRVIP will notify the NRC of test plans and timeline for reporting test results at a later date. The proposed process is described below.

   Upon NRC approval of an application for SLR which ~~takes~~ credits ~~for~~ the ISP for SLR program and identifies the need for additional surveillance data from the program, the BWRVIP will submit a test report for the applicable representative materials to the NRC in accordance with Section IV of Appendix H.~~a schedule for reconstituting and testing the relevant representative SSLR materials for that plant.~~ There are two scenarios that apply: 1) Appendix H reporting requirements commence at the time of SLR application approval for capsules withdrawn prior to the approval and 2) Appendix H reporting requirements commence immediately following withdrawal of the capsule when the SLR application has already been approved.

~~The BWRVIP will publish a test report for materials tested for the ISP for SLR program.~~ The report will include the results of all fracture toughness tests conducted on the surveillance material in the irradiated and unirradiated conditions and all data required by ASTM E185-82. In general, this includes mechanical test results, analyses of the test data (e.g. index temperature determinations), and evaluation of dosimetry.

~~Each material test report will be distributed to the NRC before the affected plant(s) enter the SLR period, or within two years of capsule withdrawal in the event the plant enters SLR before capsule withdrawal.~~"

E
RECORD OF REVISIONS FOR BWRVIP-321-A

BWRVIP-321-A	Information from the following documents was used in preparing the changes included in the revision of the report: 1. EPRI BWR Vessel and Internals Project (BWRVIP) Proprietary Letter No. 2020-021, "Transmittal of BWRVIP-321: BWR Vessel and Internals Project, Plan for Extension of BWR Integrated Surveillance Program (ISP) Through the Second License Renewal (SLR)," March 8, 2019 (ADAMS Accession No. ML19071A248 for the package; a non- proprietary version of the report is available to members of the general public at ADAMS Accession No. ML19071A235). 2. EPRI BWRVIP Proprietary Letter No. 2020-046, "BWRVIP Docket No. 99902016 – BWRVIP Response to BWRVIP-321 Request for Additional Information (RAIs)," June 8, 2020 (ADAMS Accession No. ML20188A355). 3. EPRI BWRVIP Proprietary Letter No. 2020-054, "BWRVIP Docket No. 99902016 – Revised BWRVIP Response for RAI-10 to the NRC Request for Additional Information on BWRVIP-321," July 9, 2020 (ADAMS Accession No. ML20191A268). 4. EPRI BWRVIP Proprietary Letter No. 2020-058, "BWRVIP Docket No. 99902016 – Revised BWRVIP Response for RAI-10 to the NRC Request for Additional Information on BWRVIP-321," July 15, 2020 (ADAMS Accession No. ML20206K867). 5. Email from Joseph J. Holonich (NRC) to Wynter McGruder (EPRI BWRVIP), "BWRVIP-321 Requests for Additional Information," October 23, 2019 (ADAMS Accession No. ML19288A052). 6. Final Safety Evaluation by the Office of Nuclear Reactor Regulation, Electric Power Research Institute, BWRVIP-321: Boiling Water Reactor Vessel and Internals Project, "Plant for Extension of the BWR Integrated Surveillance Program (ISP) Through the Second License Renewal (SLR)", November 2020. 7. EPRI BWRVIP, "Updated BWR Integrated Surveillance Program (ISP) Implementation Plan," BWRVIP-86, Revision 1-A, June 2013 (ADAMS Accession No. ML131760082). Details of the revisions can be found in Table E-1.
BWRVIP-321NP-A	Developed non-proprietary (NP) version for public disclosure.

Table E-1
Detail of Revisions

Required Revision	Source of Requirement for Revision	Description of Revision Implementation
Add NRC Safety Evaluation (SE) to front of report	NRC request	Added NRC SE after Disclaimer page
Revise Acknowledgments page	Need to reference source document for revision	Revised Acknowledgment page to reference source document
Add Record of Revisions	Need to describe changes in this revision	Provided general description of changes made to this report
Revise Tables 4-1, 4-2, 4-3, 4-4, 4-6 and 4-7	BWRVIP commitment made in responses to NRC RAI #2 and #3	Tables revised to correct some incorrect percentage values. All percentages were rounded to the nearest whole number since accuracy to one significant digit is not necessary
Added notes to Table 4-5	Clarification	Added notes to address future outage dates for Browns Ferry 2, Hatch 1 and Hatch 2 and that adjustments will be made to the withdrawal schedules as necessary to achieve the estimated fluence of the ISP(E) capsule. Added notes to state that Duane Arnold capsule was withdrawn in Oct 2020 following plant closure and the Monticello capsule will be withdrawn in spring 2021.
Revise notes in Table 4-9 and 4-10	Editoral	The target plant acronyms for BF1 and BSEP1 changed to BF and BSEP.
Revise Tables 5-1 and 5-2	BWRVIP commitment made in response to NRC RAI #4, item #2	Added usable number of weld specimens as a function of insert length for Peach Bottom Unit 2 materials.
Revise Section 6.3.1	BWRVIP commitment made in response to NRC RAI #6, item #1	Section 6.3.1 changed to reflect that Plant A had the extended power uprate, not Plant D

Table E-1 (continued)
Detail of Revisions

Required Revision	Source of Requirement for Revision	Description of Revision Implementation
Add Tables 8-1, 8-2 and 8-3	BWRVIP commitment made in response to NRC RAI #9	Tables 8-1, 8-2 and 8-3 added to provide a range of possible insertion and withdrawal dates (2022, 2023 and 2024) for three flux values (minimum, intermediate and maximum). The final scenario chosen will depend on the host plant that is selected for the irradiation campaign.
Revise Section 8, pages 8-1 and 8-2	BWRVIP commitment made in response to NRC RAI #10	Revised to clarify reporting requirements
Revise Section 9, page 9-1	BWRVIP commitment made in response to NRC RAI #10	Revised to clarify reporting requirements
Revise Section 10.2.2, page 10-4	BWRVIP commitment made in response to NRC RAI #10	Revised to clarify reporting requirements
Revise Section 10.3.2, page 10-5	BWRVIP commitment made in response to NRC RAI #10	Revised to clarify reporting requirements
Add NRC Request for Additional Information (RAI) on BWRVIP-321	NRC request	Added Appendix B
Add BWRVIP response to NRC RAI on BWRVIP-321	NRC request	Added Appendix C
Add Revised BWRVIP response to NRC RAI #10 on BWRVIP-321	NRC request	Added Appendix D
Add Record of Revision for BWRVIP-321-A	NRC request	Added Appendix E

Programs:

Nuclear Power

Boiling Water Reactor Vessel and Internals Program (BWRVIP)

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