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BWRVIP Integrated Surveillance Program

Addressing Surveillance Needs for Second License Renewal (SLR)

NRC Public Meeting
November 30, 2016

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Agenda

- Introduction
- Meeting Purpose and Objectives
- Background on the Existing ISP
- Options Evaluated for SLR and Proposed Approach
- Evaluation of Existing ISP Data and Identification of Data Needed for SLR
- Future Plans
- Discussion / Feedback

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Introduction

- Since 2002, the U.S. BWR fleet has been using an integrated surveillance program (ISP) to provide reactor vessel (RV) surveillance data and satisfy 10 CFR 50 Appendix H requirements.
- The ISP was designed and is managed by the EPRI Boiling Water Reactor Vessel and Internals Project (BWRVIP).
- All U.S. BWRs have amended their operating licenses to implement the BWRVIP ISP.
- The current version of the ISP addresses 60 years of operation and was approved by the NRC in 2006 (via BWRVIP-116).
- BWR owners have expressed an intention to pursue SLR.
- The BWRVIP, in coordination with the EPRI Long-Term Operation (LTO) program, has initiated a program to investigate options for providing RV surveillance data in the SLR period.

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Meeting Purpose and Objectives

- Provide background on the development of the existing NRC approved ISP
- Identify challenges for obtaining BWR RV surveillance data in the SLR period
- Explain options considered for addressing BWR surveillance data needs in SLR and the rationale for ranking of options
- Present proposed “ISP for SLR” approach
- Share results of initial data evaluation and gap identification
- Identify future plans and actions
- Obtain NRC feedback

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Background on the Existing ISP

Robert G. Carter
EPRI Technical Executive

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Introduction

- Surveillance programs serve several purposes:
  - Monitor the embrittlement of reactor vessel (RV) materials and provide data that can be used in the development of plant pressure-temperature limit curves and leak test temperatures
  - Provide data for the development of embrittlement trend curves that can then be used to predict the embrittlement of RV materials not included in surveillance programs
  - Enable the validation of fluence projections
- In 1997, NRC requested BWRVIP assistance in resolving issues associated with missing or incomplete data for various BWR surveillance plate and weld materials
- The BWRVIP initiated a project in 1999 to develop a BWR integrated surveillance program (ISP) to address these issues
- The ISP was patterned after other integrated programs using host reactors to gather surveillance data for the fleet of BWR vessels

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Background and History of BWR Surveillance Program Design

- Requirements for surveillance programs are specified in 10CFR50, Appendix H
  - A plant-specific surveillance program must be in place meeting the requirements of ASTM E-185, or
  - The plant must be part of an approved integrated surveillance program using representative materials and host reactors of sufficiently similar design and operating features
- Early versions of ASTM E-185 (prior to 1979) specified that selected capsule materials should represent one base, one weld, and one HAZ material from the vessel beltline region.
- Many BWR surveillance programs were designed prior to Reg. Guide 1.99, Revision 1 (1977) when embrittling effects of copper were not yet known.
- As a result, many BWR surveillance programs met regulations but did not include the vessel materials that are now known to be limiting by improved embrittlement correlations.

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Issues Related to BWR Plant-Specific Surveillance Programs

- Materials in some plant-specific surveillance programs do not match limiting vessel beltline materials
- Specific identity of surveillance materials is not known in some cases, so the surveillance data cannot be used directly. Examples include:
  - Unknown heat numbers for welds
  - Missing or incomplete chemistry data
  - Lack of baseline (unirradiated) data and/or limited archival materials
- Such limiting surveillance material information restricts use of Reg. Guide 1.99, Rev. 2 and application of data to predict RPV embrittlement

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Why Did the BWRVIP Develop an Integrated Surveillance Program?

- Increase technical quality and make most effective use of existing BWR surveillance capsules and data
- Improve overall quality of the BWR fleet surveillance data by including the BWRVIP Supplemental Surveillance Program (SSP) capsule data (next slide)
- Address regulatory concerns regarding some cases of inadequate or missing data
- Collectively monitor and manage embrittlement in BWR vessels
  - Share data between all BWR utilities
  - Avoid surprises from BWR surveillance data
  - Avoid excess conservatism in pressure test temperatures

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Supplemental Surveillance Program (SSP)

- Began in late 1980's by the BWROG to supplement database of BWR embrittlement data
- 9 capsules inserted into host reactors:
  - Cooper (Capsules A, B, and C)
  - Oyster Creek (Capsules D through I)
- 25 materials (13 plate and 12 weld); 84 sets of weld and plate Charpy specimens, including EPRI-contributed materials
- Material chemistries and target fluences chosen to span the range of BWR vessel beltline materials
- Excellent characterization of baseline data
- All capsules have been tested and capsule reports have been published and transmitted to the NRC

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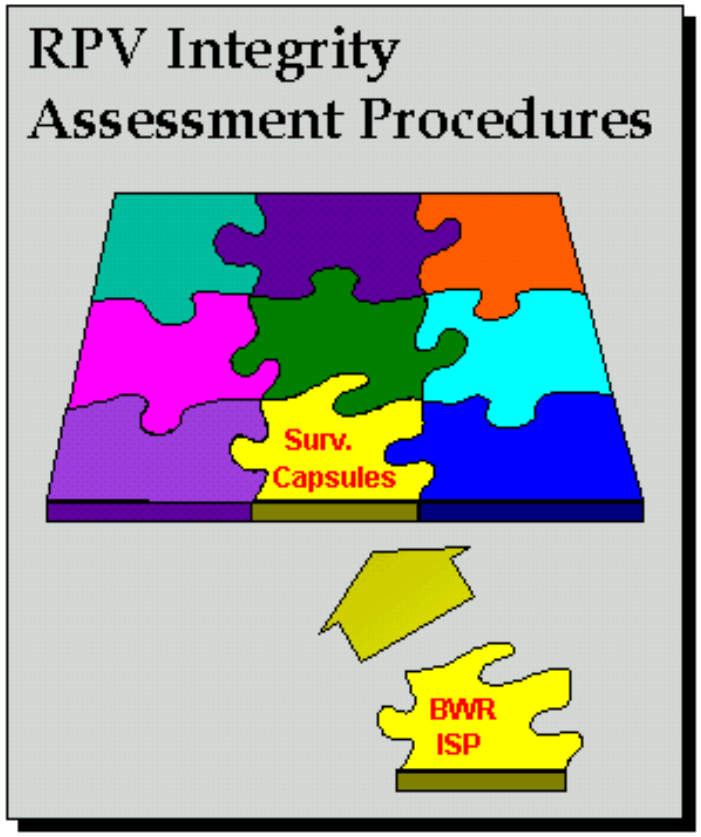
Purpose of BWR ISP Program

Replace Existing Surveillance Data with ISP Capsule Data



Purpose of the ISP is to replace one piece of the puzzle without disturbing the entire picture.

VG 10

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Process of Identifying Limiting Materials

- Identify the limiting vessel beltline materials (plate and weld) for each BWR vessel
- Basis:
  - Unirradiated material properties (initial reference temperature),
  - Chemical composition (weight percent copper and nickel), and
  - Projected neutron fluence at the 1/4t depth for the highest fluence location for that material
- End of Life (EOL) 1/4t Adjusted Reference Temperature (ART) was calculated using the correlations in NRC Regulatory Guide 1.99, Revision 2

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Selecting Best Representative Material

- Identify all available BWR surveillance materials that have baseline data
  - Plant surveillance capsules (vessel wall capsules only)
  - Supplemental Surveillance Program (SSP) capsules
- Identify up to 6 candidate materials for each target material
- Selection of the final best representative material was an iterative process
  - Find best solution that optimizes overall number of surveillance materials in ISP
  - Consider multiple rounds of NRC Staff recommendations
- Document the final selection of the best representative material in an Individual Vessel Evaluation (IVE)
  - The candidate materials listed in the IVEs provide the contingency plan required by 10CFR50 Appendix H III.C.1.d in case the selected material is affected by future plant shutdown, etc.
- The final pairing of a representative material to the target vessel plate and target vessel weld in each BWR constitutes the ISP Test Matrix

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Current ISP Material Assignments

- For each plant there is a:
  - Target vessel plate and a target vessel weld
  - Representative surveillance material heat number for each target vessel material
  - Representative surveillance material source capsules for each target vessel material

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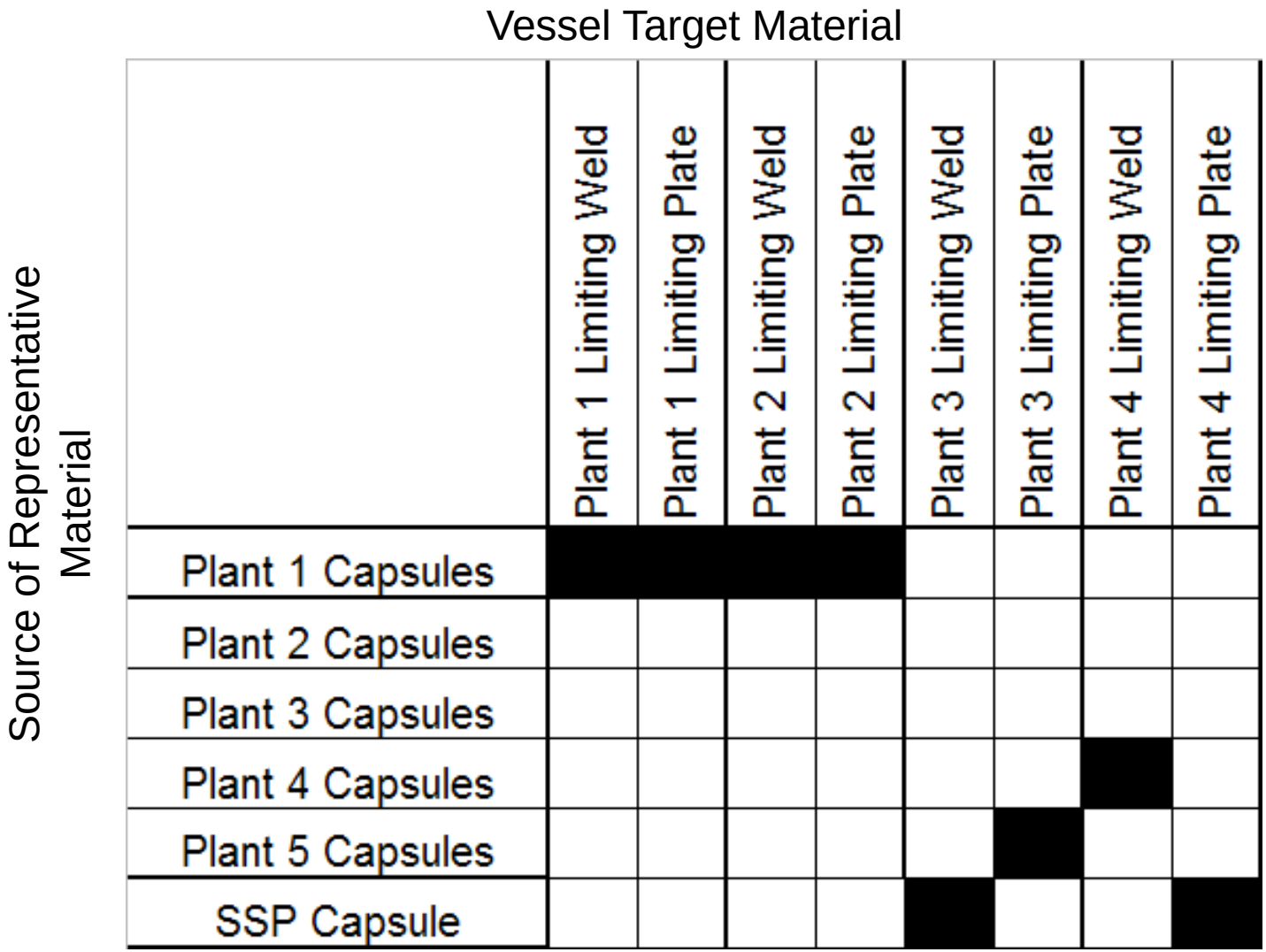
ISP Test Matrix - Example



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ISP Test Matrix – ISP Host Plant Data

- At least two host plant capsules will be tested for each representative surveillance material for the original 40-year license period
- At least three host plant capsules will be tested for each representative surveillance material for the extended 60-year license period
- In many cases, three or four irradiated data points will be available, because representative materials are often in more than two capsules and also in the SSP
- ISP capsule test schedule established to obtain data near the limiting target material's EOL 1/4t fluence

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Current ISP Structure

- 13 host plants and 9 SSP capsules constitute the ISP
  - 13 plant capsules to be withdrawn and tested during the original plant license period by the ISP
  - All 9 SSP capsules were tested; 6 representative surveillance materials were in the SSP capsules only
  - 15 representative plate heats and 15 representative weld heats provide data for the BWR fleet
- ISP was extended into the License Renewal period by testing one additional capsule from each of the 13 host plants, for a total of 26 plant capsule tests through the extended life period
  - BWRVIP-116, subsequently incorporated into BWRVIP-86, Rev. 1-A
- Testing of remaining capsules will be deferred or designated as contingencies

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Responsibilities of the BWRVIP

- Overall management of the ISP
- Coordinate ISP capsule withdrawal per the approved ISP capsule withdrawal schedule
- Procure the services of qualified vendors for:
  1. Testing of ISP capsule mechanical test specimens,
  2. Analysis of capsule dosimetry, and
  3. Determination of irradiation effects

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Responsibilities of the BWRVIP, continued

- Make appropriate arrangements to ship withdrawn capsules to testing laboratories
- Develop and submit to NRC a capsule test report per 10CFR50 Appendix H
- Evaluate ISP surveillance data using consistent methods and publish results
- Inform NRC and affected BWR plants whenever changes must be made to the approved ISP capsule withdrawal schedule
- Provide for storage of tested ISP capsules (broken Charpy specimens)

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Responsibilities of the Utility

- Maintaining a reactor vessel surveillance program that meets current regulations
- Review of applicable ISP data published by BWRVIP
- Determination of the effects on plant operations (e.g., P-T limits and leak test temperatures)
- Notify BWRVIP of any changes that could impact the ISP including:
  - Fluence projections for host ISP capsules (extended outages, power uprates, etc.)
  - Fluence projections for RPV (I.D. and 1/4t locations)
  - Fluence values for any previously withdrawn capsules
  - Placement and location of ISP capsules or planned withdrawals outside the scope of the ISP
  - Adjusted Reference Temperature (ART) tables

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Status of BWRVIP ISP

- NRC has approved the BWRVIP ISP through 60 years
- Each U.S. BWR has modified their licensing basis to incorporate the ISP
- Status of testing
  - 9 SSP and 8 host plant capsules have been tested
  - 5 capsules to be tested from 2016 to 2018
  - First of 13 license renewal (60-year) capsules will be tested in 2022

Year	Plant	Capsule ID (Degree)	Outage Time Period
2016	Hatch 1	300	Spring
	Dresden 3	245	Fall
2017	Hatch 2	120	Spring
2018	Cooper	120	Fall
	Peach Bottom 2	30	Fall

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Summary of Current ISP

- The ISP has resolved limitations that affected some original BWR surveillance programs
- The ISP addressed the initial concerns raised by the NRC regarding BWR surveillance materials and provides more accurate monitoring and assessment of embrittlement for the U.S. BWRs for 60 years of operation
- Close coordination between the BWRVIP and the plants ensures that all Appendix H reporting requirements are met

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Options Evaluated for SLR and Proposed Approach

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Introduction

- As plants began to consider the pursuit of a Second License Renewal (SLR), the need emerged to investigate RV surveillance options
- A joint effort was initiated between the EPRI LTO and BWRVIP programs to investigate options for providing BWR RV surveillance in SLR
- A “fresh look” was taken, rather than constraining the approach to the format of the existing ISP

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Considerations for Second License Renewal (SLR)

- 10CFR50 Appendix H requires that:
  - Plants maintain a material surveillance program to monitor fracture toughness of ferritic materials in the RV
  - The surveillance program must provide data at a fluence equal to 1 to 2 times the predicted RV fluence at end of operation (via ASTM E185-82)
- The GALL Report, NUREG-1801, Revision 2, specifies that additional surveillance capsules may be needed for the period of extended operation
- The GALL Report for SLR:
  - Draft was not available at the time this project was initiated
  - Guidelines are expected to be mostly consistent with GALL Revision 2
  - Expectation is that deferral of 60-year capsules in order to meet 80-year fluence values will not be endorsed
  - Final version has not been issued

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Challenges for an 80-Year ISP

- The current BWRVIP ISP relies on 13 host plants and the previous SSP to provide data for the BWR fleet
  - Many of the current host plants will have no remaining capsules after 60 years
  - The SSP is complete and no further data will be provided
- It is not clear how many or which plants will apply for SLR
  - What surveillance data will be needed?
  - Which plants will be available to serve as host plants?
  - Will the potential host plants have surveillance materials that are representative of other materials in the BWR fleet?
- BWR surveillance capsule lead factors
  - Most BWRs have low lead factors, often lag factors
  - 40 to 60 year capsules provide limited data for the SLR period

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Actions Taken

- Task group of experts formed
- Options to extend or replace ISP identified
- Feasibility study performed assessing all options
- Options ranked based on feasibility
- Recommendations made for further investigation

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Task Group Team Members

- Nathan Palm – EPRI
- Bob Carter – EPRI
- Tim Hardin – EPRI
- Tim Griesbach – Structural Integrity Associates
- Heather Jackson – Structural Integrity Associates
- Brian Hall – Westinghouse
- Brian Frew – GE-Hitachi
- George Depta – GE-Hitachi

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Options Identified

- Delay 60-Year Capsules
- Fabricate New SSP Capsules
- Improve Lead Factors
- Eliminate the Regulatory Need for a Surveillance Program
- Rank and Use Contingency Capsules to Define New Host Plants
- Reconstitute, Irradiate, and Test Previously Tested Capsule Specimens
- New Material Testing Program
- Move from RT_{NDT} to Direct Fracture Toughness Evaluation of RPV Integrity
- Irradiate BWRVIP ISP Specimens in a PWR Host Plant
- Implement Plant-Specific Surveillance Programs for the 60 to 80 year Period

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Feasibility Evaluation Considerations

- Technical Merit
  - Ability to provide heat-specific data vs. generic or less representative data
  - Capability to provide multiple data points
- Ease of Implementation
  - Utility and EPRI program management responsibilities
  - Consistency with current implementation
  - Need to make regulatory submittals or procedural changes
  - Impact to RV integrity calculations or methods
- Cost
  - Expense of approach relative to existing ISP approach
  - Testing vs. Evaluation vs. NRC Review
- Regulatory Acceptability
  - Likelihood of acceptance
  - Consistency with existing regulations

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Ranking of Options

Option #	Description	Regulatory Acceptability	Technical Merit	Ease of Implementation	Cost	Score
Weighting Factor		2	2.5	1.5	1	
6	Reconstitute, Irradiate, and Test Previously Tested Capsule Specimens	5	5	3	2	29
2	Fabrication of New SSP Capsules	5	4	3	3	27.5
3	Improve Lead Factors	4	4	3	2	24.5
1	Delay 60 Year Capsules	2	3	5	4	23
4	Eliminate the Regulatory Need for a Surveillance Program	1	3	5	5	22
9	Irradiate BWRVIP ISP Specimens in a PWR Host Plant	2	5	2	2	21.5
5	Rank and Use Contingency Capsules to Define New Host Plants	3	3	3	3	21
8	Move from RT_{NDT} to Direct Fracture Toughness Evaluation of RPV Integrity	2	4	2	3	20
7	New Material Testing Program	2	4	2	1	18
10	Implement a plant-specific surveillance program for the 60 to 80 year period	3	2	1	1	13.5

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Proposed Approach

- Maintain the critical elements of the ISP to the greatest extent possible
- Utilize already existing data to the extent possible
  - SSP capsules had lead factors higher than typical BWR capsules
  - For some materials, specimens from many capsules, exposed to a wide range of fluence levels, have already been tested
- Reconstitute previously tested specimens to fill gaps in data
  - Specimen inserts will be irradiated prior to reconstitution (next slide)
  - Inserts will be placed in “Supplemental SLR Capsules”
- Provide 80-year fluence data for the entire set of ISP materials
- “Extend” the existing ISP versus replace

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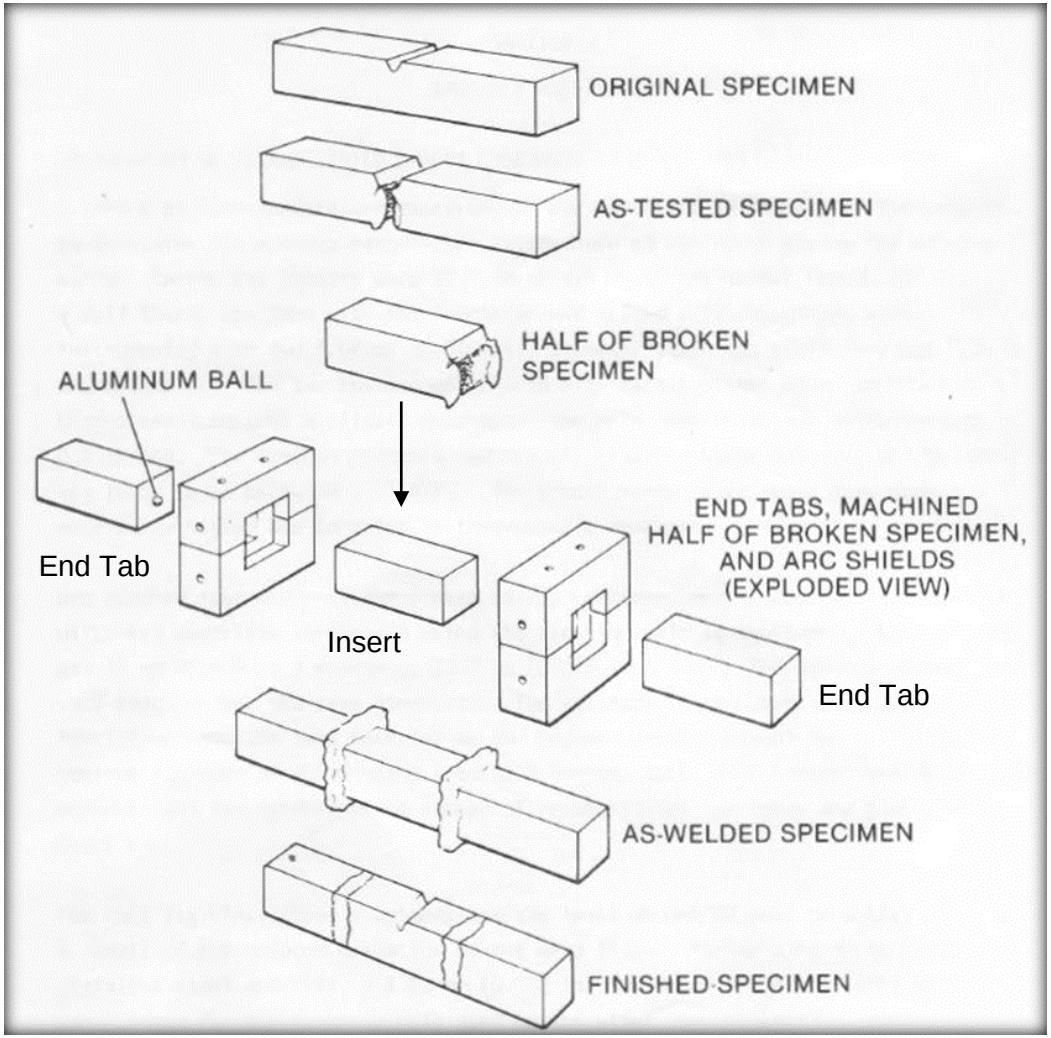
Specimen Reconstitution

- Reconstitution process established in ASTM E1253
- Two options:
  - Irradiate Complete Specimens
    - Fabricate inserts
    - Weld end tabs
    - Irradiate
    - Test
  - Irradiate Inserts Only
    - Fabricate inserts
    - Irradiate
    - If material is needed for a target plant that opted for SLR, weld end tabs
    - Test



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Irradiation of Inserts Only

- Irradiation of inserts prior to welding of end tabs has several advantages for the ISP for SLR
  - Many materials can fit into a single capsule
  - Cost of completing specimen fabrication is deferred
    - Irradiation may need to begin prior to plants' decisions to pursue SLR being made
    - If certain plants do not pursue SLR or shutdown early, fabrication of specimens for some materials may not need to be completed
- Although irradiating the inserts prior to specimen fabrication increases dose, dose will still be less than normal PWR dose levels

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Benefits of Proposed Approach

- Definitions of representative and target materials, as defined in approved ISP test matrix, will remain unchanged
- Responsibilities of utilities to implement ISP data will remain unchanged
- No changes to existing ISP test schedule
- Satisfies Appendix H requirements and GALL expectations
- Reduces uncertainty associated with not knowing which plants may implement SLR
- **Only change to ISP is addition of 80-year data where such data does not currently exist**

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Areas Identified for Further Evaluation

- Assess Data Needs
  - Investigate the extent to which the existing SSP materials and ISP host plants capsules (tested and planned) can provide 80-year data
  - Determine the extent to which the other options are needed to provide 80-year data (gaps)
- Define the extent to which reconstitution of available ISP capsule specimens (Supplemental SLR Capsules) can address SLR data gaps
  - Identify additional fluence needed to reach SLR fluence values for target materials
  - Identify materials for which Supplemental SLR Capsules will not provide sufficient SLR data

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Evaluation of Existing ISP Data and Identification of Data Needed for SLR

Heather Jackson
Structural Integrity Associates

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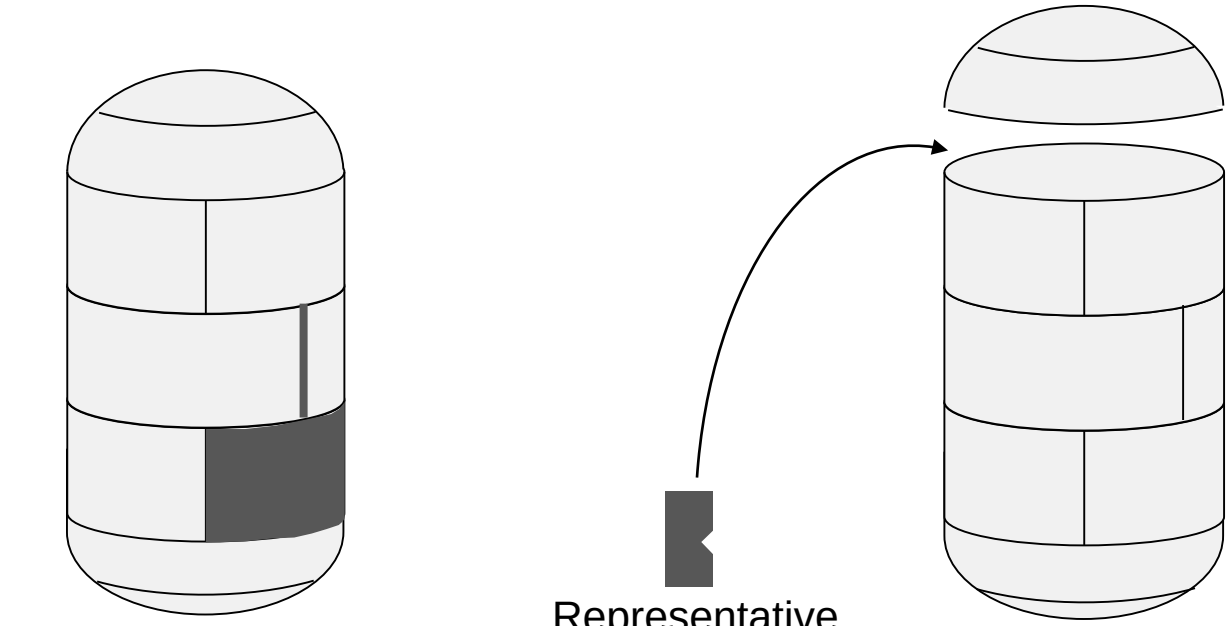
Overview: Data Needs for SLR are Determined by Evaluating Available Data from BWRVIP ISP program

- 80-year fluences are projected for vessel target materials.
- Target fluences are compared with fluences of tested surveillance capsules.
- Gaps and additional data requirements are identified to plan Supplemental SLR capsules.



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Methodology for Projecting BWR Target 80-year Fluences

- 1/4T fluence values for ISP target plate and weld materials were taken from the latest docketed P-T curve reports, or from updated fluence evaluations for tested ISP capsules.
- Fluence was estimated by projecting linearly from the reference fluence (e.g. 32 or 54 EFPY) to 72 EFPY.
- The projected 72 EFPY fluences were compared with fluences of capsules that will be tested by the ISP prior to the end of the 60-year license renewal period.
- Where gaps exist, data needs were identified for extending the ISP for SLR to bound the fleet.

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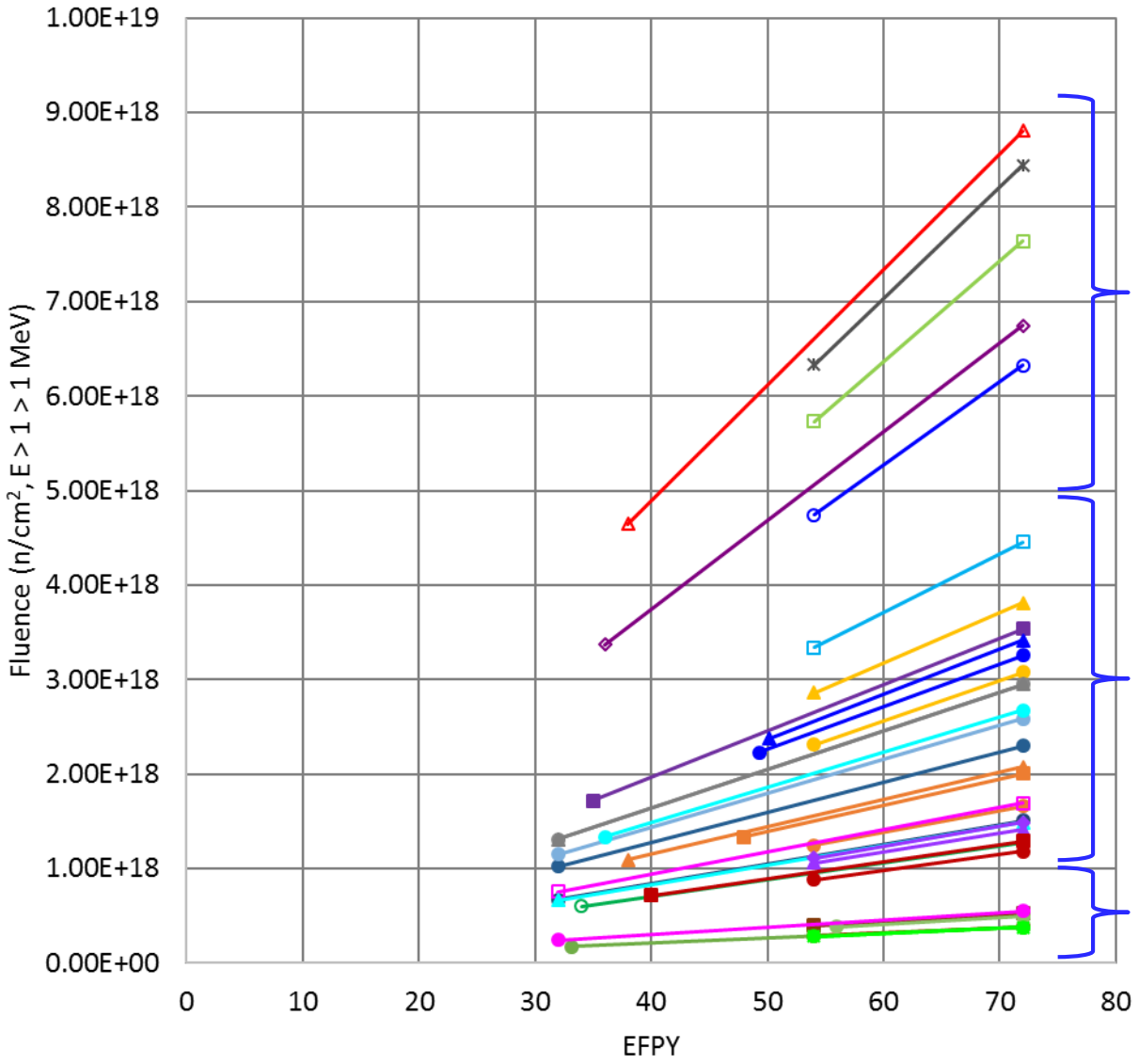
72 EFPY 1/4T Fluence Projections for BWR Target Plates



5 plates > $5x10^{18}$ n/cm^2

21 plates > $1x10^{18}$ n/cm^2 and < $5x10^{18}$ n/cm^2

8 plates < $1x10^{18}$ n/cm^2

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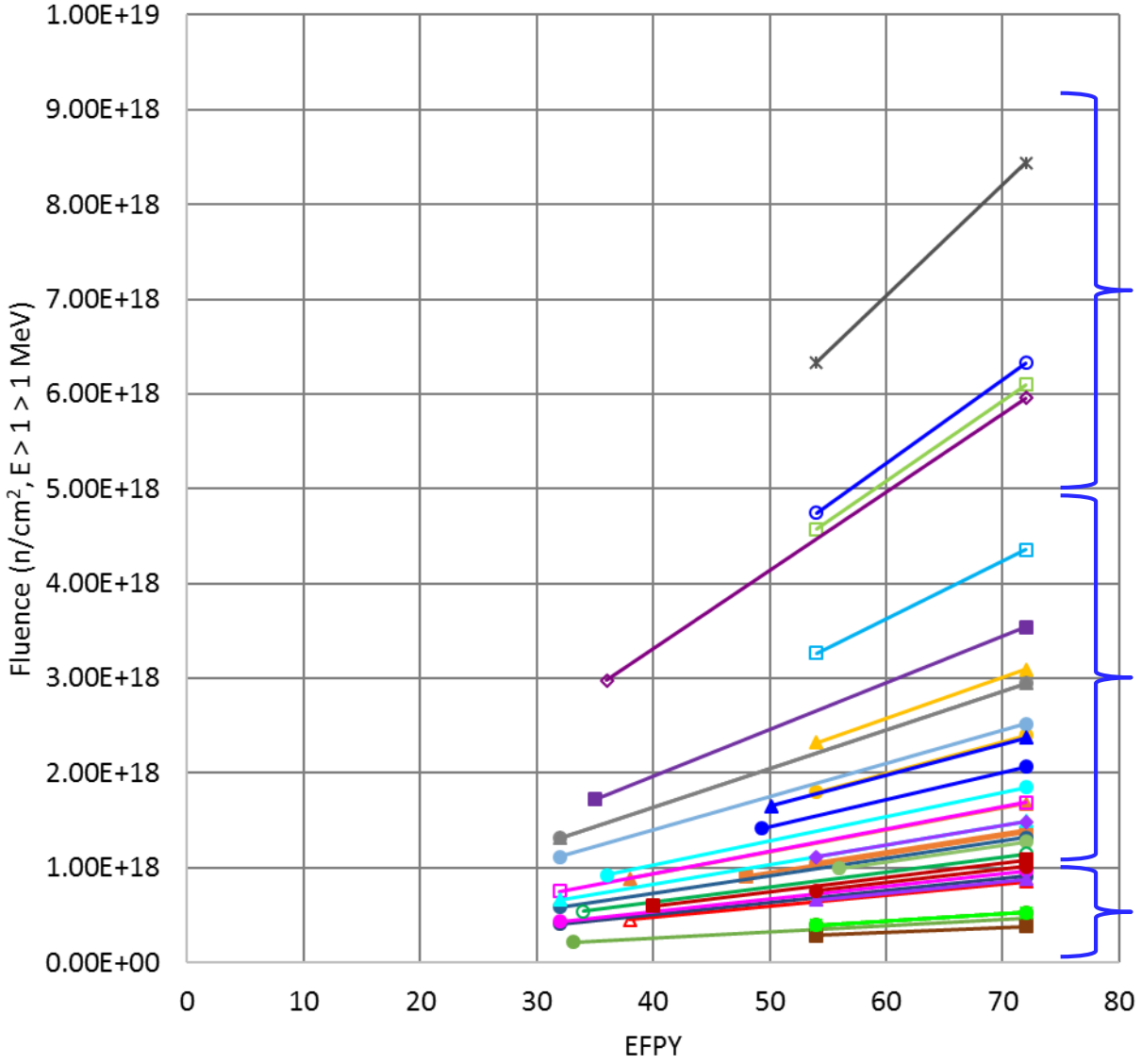
72 EFPY 1/4T Fluence Projections for BWR Target Welds



4 welds > $5x10^{18}$ n/cm^2

21 welds > $1x10^{18}$ n/cm^2 and < $5x10^{18}$ n/cm^2

9 welds < $1x10^{18}$ n/cm^2

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Target 80-year Fluences are Compared with Fluences for Surveillance Capsules

- Data for **15 plate and 15 weld materials** is available from **25 existing capsules** tested under the ISP and individual plant programs **and 9 SSP capsules**.
- Data is pending for **5 ISP capsules** tested in 2016-2018.
- Testing of **13 ISP(E) capsules** is planned during the license renewal period.
- Fluences for tested ISP and SSP capsules are obtained from published capsule test reports.
- Projected fluences for remaining ISP capsules and ISP(E) capsules are obtained from BWRVIP-86, Rev. 1-A.

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Fluences of Tested and Planned ISP Capsules Bound 13 Target Plates and 17 Target Welds for 80 years

Existing ISP data bounds 7 target plates and 9 target welds for 72 EFPY

Tested Capsule Fluence as a % of Target SLR Fluence	Number of Target Plates	Number of Target Welds
< 50%	20	18
50-99%	7	7
≥ 100%	7	9

When ISP(E) capsules are considered, an additional 6 plates and 8 welds are bounded

Projected ISP(E) Capsule Fluence as a % of Target SLR Fluence	Number of Target Plates	Number of Target Welds
< 50%	6	1
50-99%	15	16
≥ 100%	13	17

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To Bound all Target Heats for 80 years, Additional Surveillance Data is Needed for 13 Representative Plates and 10 Representative Welds

Needs additional surveillance data?	Number of Representative Plates	Number of Representative Welds
Yes	13	10
No	2	5
Total	15	15

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Methodology for Planning Proposed Supplemental SLR Capsules

- For each representative plate and weld material for which additional surveillance data is needed:
  - The tested capsule having the highest fluence is identified.
  - Some representative heats represent multiple target vessels. The corresponding target heat with the bounding projected 72 EFPY 1/4T fluence is identified.
  - The needed “catchup” fluence is determined by:

Catchup fluence for each representative heat	=	Bounding 1/4T fluence projected for 72 EFPY for corresponding target vessels	–	Highest fluence tested capsule

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Representative Materials Needing Additional Data are Grouped Based on the Range of Additional Fluence Needed

Group	Catchup Fluence Needed (n/cm^2, E > 1 MeV)	Number of Materials
1	$< 1x10^{18}$	6
2	$> 1x10^{18}$ n/cm^2 and $< 5x10^{18}$ n/cm^2	11
3	$> 5x10^{18}$ n/cm^2	6

- **Supplemental SLR capsules are proposed with catchup fluences that bound all target plates and welds for 80 years.**

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Conclusions

- 80-year fluence needs can be met with a small number of Supplemental SLR capsules, with materials grouped based on “catchup” fluence
- 7 of 34 target plates and 8 of 34 target welds are bounded for 80 years by existing ISP data
- 13 of 34 target plates and 17 of 34 target welds will be bounded for 80 years by ISP capsules tested during the license renewal period
- Additional data is needed for 13 of 15 representative plates and 10 of 15 representative welds to meet projected fluence needs for 80 years
- No major hurdles identified for obtaining 80-year data

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Future Plans

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Future Actions

- Design of Supplemental SLR capsules
- Determination of materials to be placed in each Supplemental SLR capsule
- Selection of host plants for Supplemental SLR capsules
- Determination of capsule lead factors, insertion dates, withdrawal dates, and achievable fluence levels
- Development of an ISP for SLR program plan document

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Summary and Conclusions

- No changes to the approved regulatory structure of the BWRVIP ISP are needed in order to accommodate a Second License Renewal
  - No changes to ISP Test Matrix / assigned representative surveillance materials
- 80-year surveillance data for the U.S. BWR fleet can be provided by a combination of existing ISP data, SSP data, and Supplemental SLR capsules
- Plans for design and installation of Supplemental SLR capsules remain to be developed
- Program plan document targeted for completion in 2018

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Feedback / Discussion

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