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Proposed Rule: Increased Enrichment of Conventional and Accident Tolerant Fuel Designs for Light-Water Reactors

January 16-17, 2025

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Opening Remarks

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Draft Regulatory Guide DG-1428
(Proposed Regulatory Guide RG 1.258, Rev. 0)

Plant-Specific Applicability of the Transition Break Size

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ACRS Regulatory Rulemaking, Policies and Practices Subcommittee
January 16, 2025

Background

- Technical Basis for Transition Break Size (TBS)
  - **NUREG-1829**: Used 10^{-5}/yr conservative LOCA frequency results as starting point
  - Selected based on operating experience, piping geometries, and to promote regulatory stability
  - **NUREG-1903**: Verified that risk associated with seismic-induced breaks > TBS is acceptable
- NUREG-1829
  - Generic evaluation intended to provide best estimate LOCA frequencies accounting for uncertainty and variability
  - Only broad differences among reactor types and vendors considered
- NUREG-1903
  - **Direct piping failure**: Subset of PWRs analyzed using available information
  - **Indirect piping failure**: Scoping study of main loop piping support failure which partially updated mid-1980s estimates for two PWRs
  - Both directs and indirect failures likely have a mean failure probability on the order of 10^{-6}/yr or less, but both analyses are strongly plant specific

Initial Motivation for Regulatory Guidance

- Plant-specific attributes can strongly influence LOCA frequencies so important to ensure TBS is applicable at each plant
- Commission Direction in SRM-SECY-07-0082 (ML072220595)
  - "The final rule should require licensees to justify that the generic results in the revised NUREG-1829, 'Estimating Loss-of-Coolant Accident Frequencies Through the Elicitation Process,' are applicable to their individual plants."
  - "The staff should develop regulatory guidance that will provide a method for establishing this justification."
- Staff has interpreted that this guidance extends to NUREG-1903
- Staff developed DG-1216, "Plant-Specific Applicability of Transition Break Size Specified in 10 CFR 50.46a" (ML100430356)

DG-1216 Scope and History

- Scope
  - Only applies to primary loop piping (PLP) systems and reactor coolant pressure boundary (RCPB) components whose failure could result in breaks greater than the TBS
  - Initial NUREG-1829 Applicability
  - Initial NUREG-1903 Applicability for direct piping failures
  - Effect of plant changes on NUREG-1829 and 1903 Applicability
- History
  - Initial public meeting discussing DG white paper (ML090350757) – February 20, 2009
  - Issued for public comment (75 FR 36698) - June 28, 2010
  - ACRS Subcommittee meeting on Regulatory Policies and Practices – September 22, 2010
  - Public meeting – September 30, 2010
  - ACRS Main Committee meeting – October 7, 2010
  - End of public comment period – November 25, 2010
  - Scheduled Commission Briefing – March 24, 2011
  - DG-1216 withdrawn (81 FR 88615) – December 8, 2016

DG-1216 ACRS Feedback

- ACRS Letter on draft final 10 CFR 50.46a rule (October 20, 2010): ML102850279
  - Provides acceptable methods and acceptance criteria for evaluating NUREG-1829 applicability
  - Provides an evaluation framework and acceptance criteria to demonstrate the NUREG-1903 applicability for direct piping failures
  - Should include assessment of NUREG-1903 applicability for indirect piping failures
  - Should explore methods to reduce required effort

- Staff adopted ACRS recommendation to add guidance pertaining to indirect piping failures
  - Modified the FRN in draft final rule to require this demonstration
  - Presented initial ideas for DG-1216 modifications - September 30, 2010 public meeting
  - Planned to evaluate acceptability of planned guidance as part of pilot study

DG-1216 Public Feedback

- NEI Comments (ML103160267)
  - Guidance too complex and proposed simple checklist
  - Concerned about expanding DG-1216 to account for seismically induced indirect piping failures
  - Place more reliance on existing programs (e.g., 50.59) to reduce plant change analysis
  - Leverage existing TBS margin to provide confidence that it applies to all plants
  - Conduct a pilot study of the process prior to issuance
- PWROG Comments (ML103140567)
  - 20 specific comments; several echoed the NEI comments
  - Current inspections and examinations provide adequate protection against a large LOCA
  - Recognized reduced complexity for plants completing license renewal but concerned about burden for other plants
  - Plants in low seismic zones can be eliminated from demonstrating NUREG-1903 applicability
  - Unclear requirements or acceptance criteria associated with several regulatory positions

DG-1216: Planned Next Steps

- Wait until Commission vote on SECY-10-0161 (draft final rule) before proceeding further
- Planned activities
  - Add method to address indirect seismic analysis
  - Conduct pilot plant study
    - Evaluate guidance
    - Estimate implementation costs
    - Develop evaluation template
    - Establish change process for determining impact of future plant modifications
  - Address public comments
  - Modify guidance
  - Present draft final guidance to ACRS
- However, as stated earlier, in 2012, the Commission approved the staff's request to discontinue rulemaking (SRM-SECY-10-0161) and DG-1216 was withdrawn in 2016

Increased Enrichment Rulemaking

- In 2021, staff requested to pursue rulemaking and develop a regulatory basis to amend requirements for the use of light water reactor fuel containing uranium enriched to greater than 5.0 weight percent uranium-235
- Commission approved via SRM-SECY-21-0109, but stated Fuel Fragmentation, Relocation, and Dispersal (FFRD) should be appropriately addressed
- Staff's regulatory basis included five options for FFRD, and based on industry feedback the staff chose Alternative 2 began development of a proposed rule to implement this alternative, 10 CFR 50.46a
- This effort was described in detail at the December 2024 ACRS subcommittee meeting
- To support this proposed rule, the staff developed DG-1428, "Plant-Specific Applicability of the Transition Break Size" (ML24341A159, ACRS version)

Related Proposed Rule Requirements[1] Supported by DG-1428

- Application: 50.46a(c)
  - Existing plants: demonstrate applicability of TBS
  - New plants
    - Demonstrate similarity of plant design to existing plants
    - Recommend and justify plant-specific TBS
  - Both existing and new plants
    - Demonstrate that TBS remains applicable after initially proposed plant changes
    - Demonstrate acceptable leak detection program [Section (d)]
    - **Optional:** Describe process for demonstrating TBS applicability for changes without prior NRC approval
- Programmatic: 50.46a(d)
  - Identify, monitor, and quantify primary pressure boundary leakage
  - Perform evaluation to demonstrate that the TBS remains applicable after planned facility changes
- Changes to facility: 50.46a(h)
  - Proposed changes enacted with or without prior NRC approval demonstrate continued applicability of TBS
- Reporting (every 24 months): 50.46a(j)
  - Document basis for determining that changes enacted without prior NRC approval do not invalidate the TBS

[1] 1/16/25 – 1/17/25 – Predecisional Information to Support – ACRS Public Meeting – Draft Federal Register Notice to Support Increased Enrichment of Conventional and Accident Tolerant Fuel Designs for Light-Water Reactors (ML25013A080)

Purpose of DG-1428

- Proposed 10 CFR 50.46a requires an evaluation to demonstrate plant-specific applicability of the TBS
- This draft guide provides one acceptable way to meet that regulation
- If applicability can not be demonstrated, the entity needs to determine a plant-specific TBS. This draft guide may also aid in the development of that TBS.

DG-1428 Overview

- Used DG-1216 as the starting point for development
- Leverages required inspections and license renewal lessons-learned to streamline and simplify guidance
- Considers DG-1216 comments
- Provides guidance to address indirect seismic failures
  - Address recommendation in 2010 ACRS letter on draft final 10 CFR 50.46a rule
  - Consistent with rulemaking requirements and leverages DG-1426[2] guidance
  - Separate evaluation for NUREG-1903 applicability not necessary
- Provides several options to demonstrate TBS applicability for maximum flexibility
  - Plan to work with stakeholders to identify most viable options and further refine before finalizing
  - Propose to pilot the guidance before finalizing

[2] DG-1426, "An Approach For A Risk Informed Evaluation Process Supporting Alternative Acceptance Criteria For Emergency Core Cooling Systems For Light Water Reactors," - ACRS Version Rev 1 (ML25010A417)

DG-1428 Overview

NUREG-1829 applicability

- Aging Management
- Adequate Leak Detection
- Plant-Specific Attributes

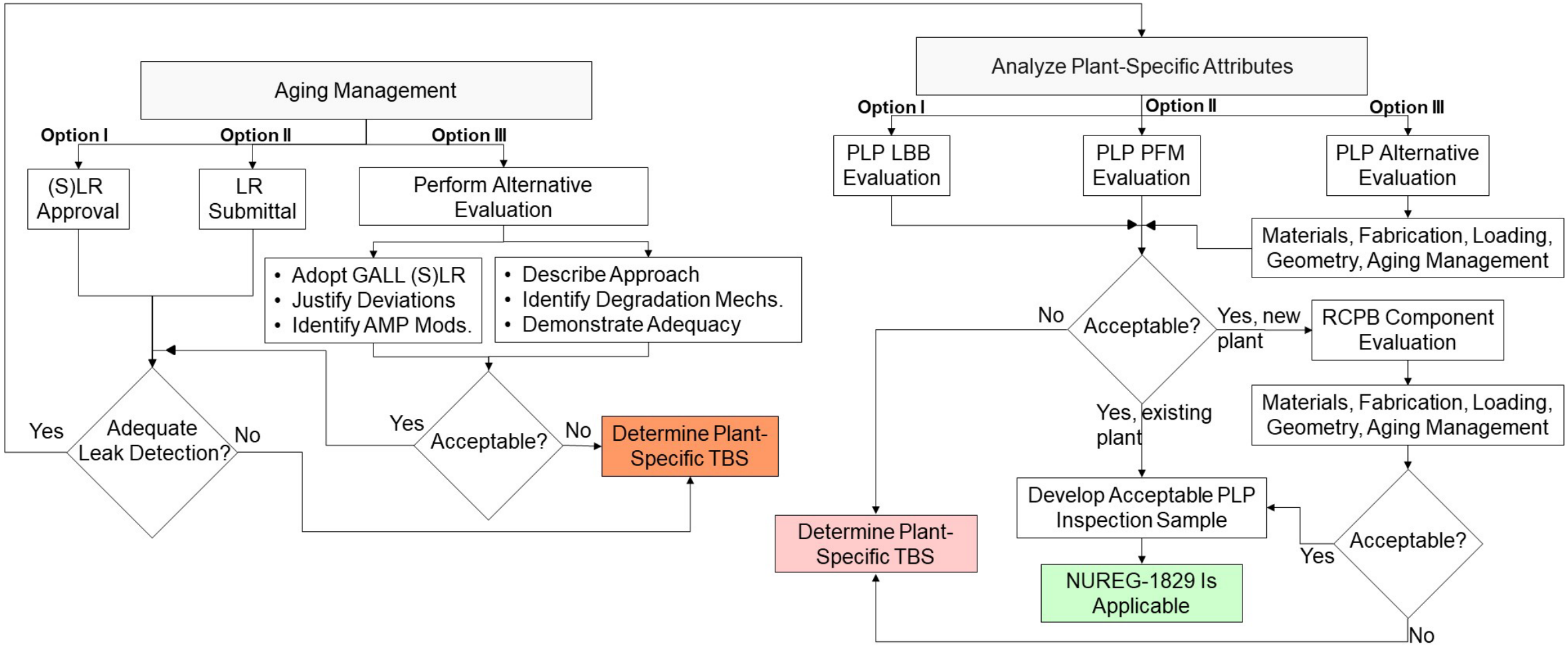
NUREG-1903 applicability

- Limiting Locations Selection
- Material Properties
- Applicability Though ISI Program
- Surface Flaw Analysis
- Component Stresses
- Seismic Risk of Indirect Failures

Plant changes and LOCA frequencies

- Direct Failures
- Indirect Failures

NUREG-1829 Applicability – General Approach



NUREG-1829 Applicability

Aging Management	**Option I**: Credit license renewal (LR) or subsequent license renewal (SLR) approval **Option II**: If first LR submitted, adopt relevant aging management programs **Option III**: Demonstrate that Part 54 requirements met for applicable PLP and RCPB components
Adequate Leak Detection	**Option I**: Demonstrate adherence to RG 1.45, "Guidance on Monitoring and Responding to Reactor Coolant System Leakage" **Option II**: Demonstrate compliance with GDC 30 and 10 CFR 50.46a(d)(2) criteria
Plant-Specific Attributes	1. Ensure PLP attributes are acceptable 2. Conduct RCPB component evaluation (new plants only) 3. Develop acceptable risk-informed PLP inspection sample

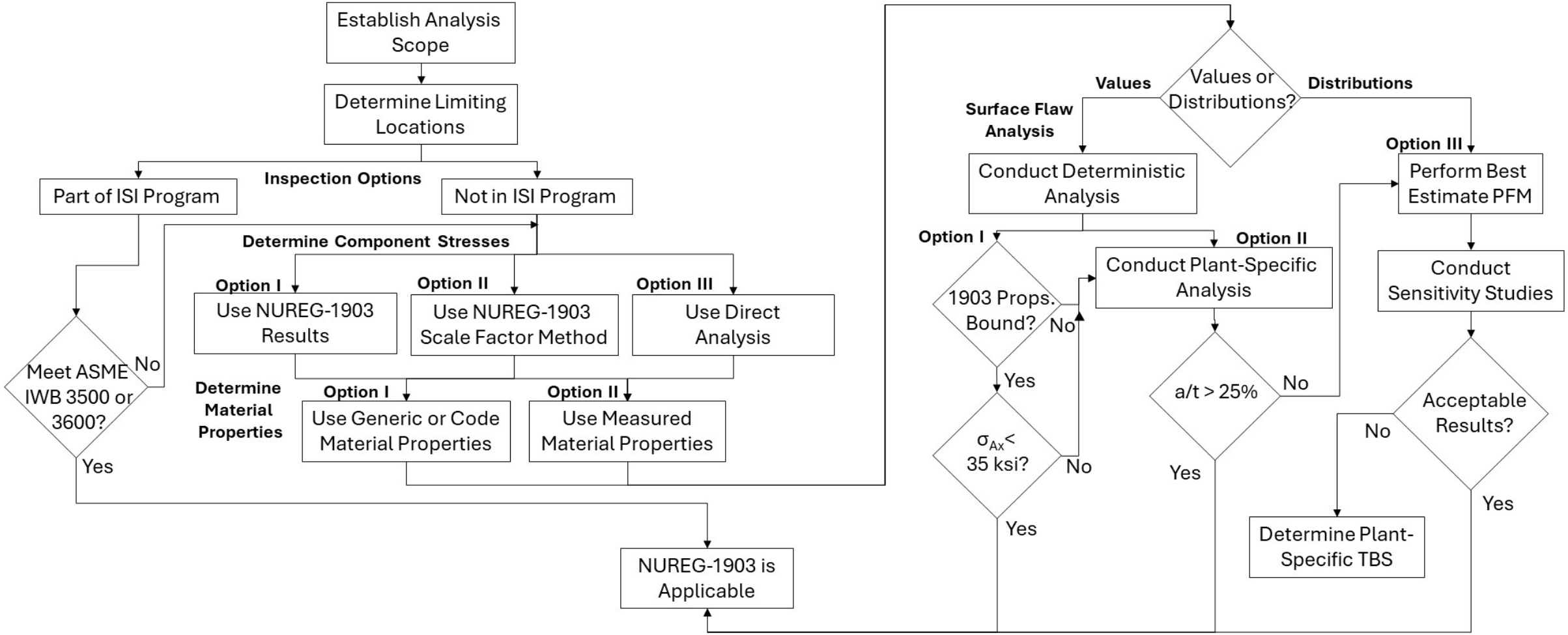
Plant-Specific Attribute Analysis

PLP Attribute Evaluation	**Option I**: Credit existing or conduct new LBB evaluations **Option II**: Conduct PFM evaluation **Option III**: Identify unique attributes* *materials; fabrication practices; loading sources, frequencies, and magnitudes; geometries and system configurations; material and component degradation; aging management
RCPB Component Evaluation (new plants only)	• Identify unique plant-specific attributes • Assess impacts of differences on TBS applicability
Risk-Informed Inspection Sample	• 10% of similar metal piping circumferential welds (PWR) or IGSCC Category A welds (BWR) with diameters greater than the TBS. Ongoing inspection programs may be leveraged. • Highest failure potential: combination of lowest toughness and susceptible materials and highest applied and residual stress loads

NUREG-1903 Applicability

- General Approach
- Limiting Locations Selection
- Applicability Demonstration Through ISI Program
- Component Stresses
- Material Properties
- Surface Flaw Analysis
- Seismically Induced Risk of Indirect PLP or RCPB Component Failures

NUREG-1903 Applicability: General Approach



Limiting Locations Selection

- All piping locations with inner diameter greater than TBS
- Represented by the combination of high component stresses and low material fracture toughness, accounting for aging effects over the licensing period
- Susceptibility to service-induced cracking should be considered
- Multiple limiting locations may be needed
- Strive to include all limiting locations in ISI program

Applicability Demonstration Through ISI Program

- For the limiting locations that are part of the plants ISI program, NUREG-1903 applicability is demonstrated through successful application of that program
- No additional analyses are needed if
  - No indications larger than the Section XI, IWB-3500, acceptance criteria are identified
  - No preexisting or new indications are present that are larger than IWB-3500 acceptance criteria

Applicability Demonstration Through ISI Program

- Additional analyses are needed if any identified indication exceeds IWB-3500
  - Follow IWB-3600 but include mean 10^{-6}/yr seismic stress using a structural factor of 1 or
  - Use an alternative approach to conduct a probabilistic analysis
- If limiting locations are not part of an ISI program, then analyses must be used to demonstrate applicability

Component Stresses

Option I: Use NUREG-1903 Results

- Critical piping location in LBB submittal are still applicable
- Normal and SSE stresses from LBB analyses still conservative
- 10^{-6}/yr seismic stresses still applicable

Option II: NUREG-1903 Scale-Factor Method

- Determine seismic hazard information
- Determine service level A & D stresses
- Calculate scale factor per NUREG-1903 to extrapolate SSE stresses to 10^{-6}/yr stresses

Option III: Direct Analysis

- Develop a hazard curve for the site
- Model the site-specific foundation properties for the 10^{-6}/yr seismic hazard.
- Construct a reactor building dynamic model
- Perform a soil, structure interaction analysis
- Address modeling and input uncertainties

Material Properties

- Use the properties in NUREG-1903 if conservative or representative of limiting locations materials
- Develop plant specific properties based on ASME code or experiments
- Appropriateness of properties can be demonstrated by
  - Accounting for any age-related degradation of the strength, toughness, and, if applicable, crack growth rate properties
  - Considering effects on these material properties caused by the elevated loading rates associated with a seismic event
  - Assessing the effects of uncertainty and variability in material properties

Surface Flaw Analysis

- Two options for conducting deterministic analysis

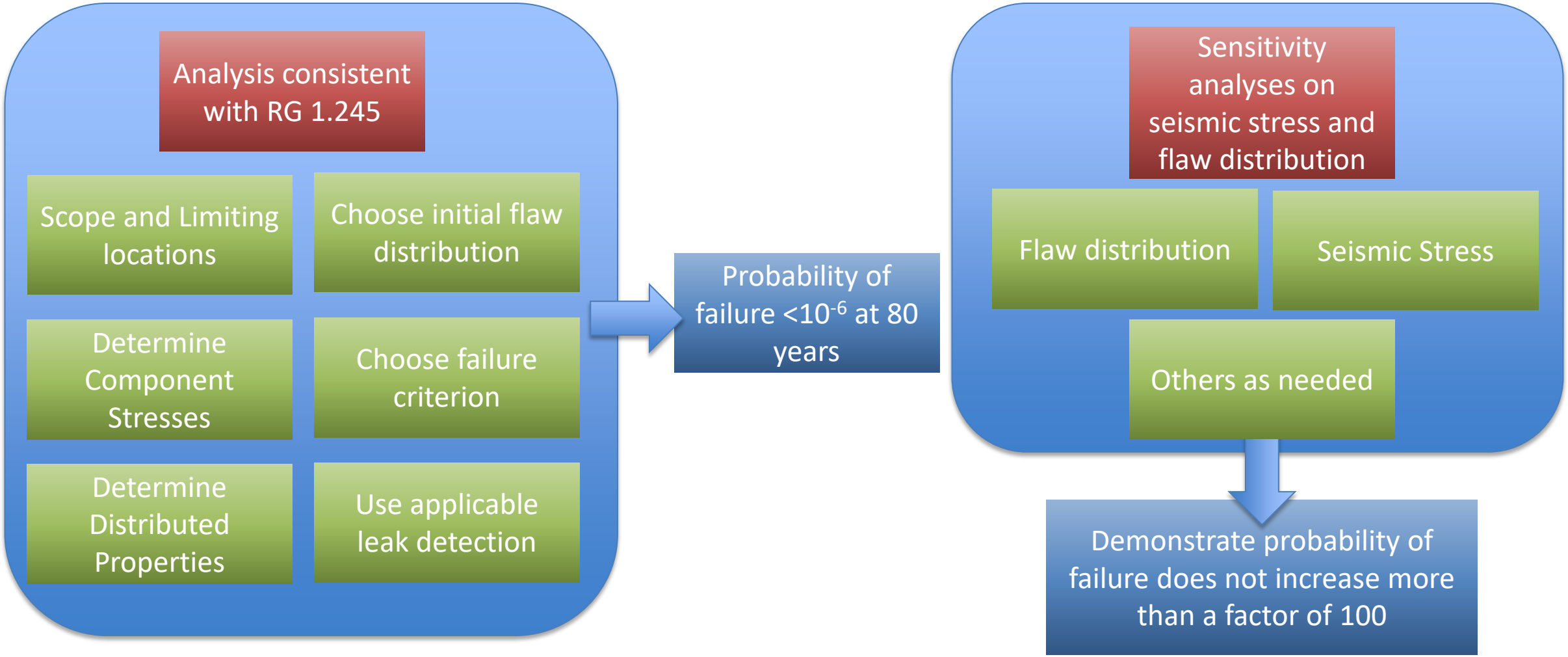
Option I: Bounding Analysis

- Directly utilizes NUREG-1903 results
- Two conditions required for use
  - NUREG-1903 material properties are bounding or representative
  - Component normal operating plus 10^{-6}/yr seismic stresses < 35 ksi
- If conditions met, then NUREG-1903 applicability is demonstrated

Option II: Plant-Specific Analysis

- Utilize plant-specific component stresses and material properties
  - Plasticity effects can be credited to reduce applied stresses above yield
- Calculate critical flaw depth for long surface flaw (i.e., 80% of circumference)
  - Corrected limit load analysis (i.e., Z-factor approach) or elastic plastic fracture mechanics can be used
- Demonstrate that critical flaw is appropriately deep (i.e., > 25% of wall thickness)

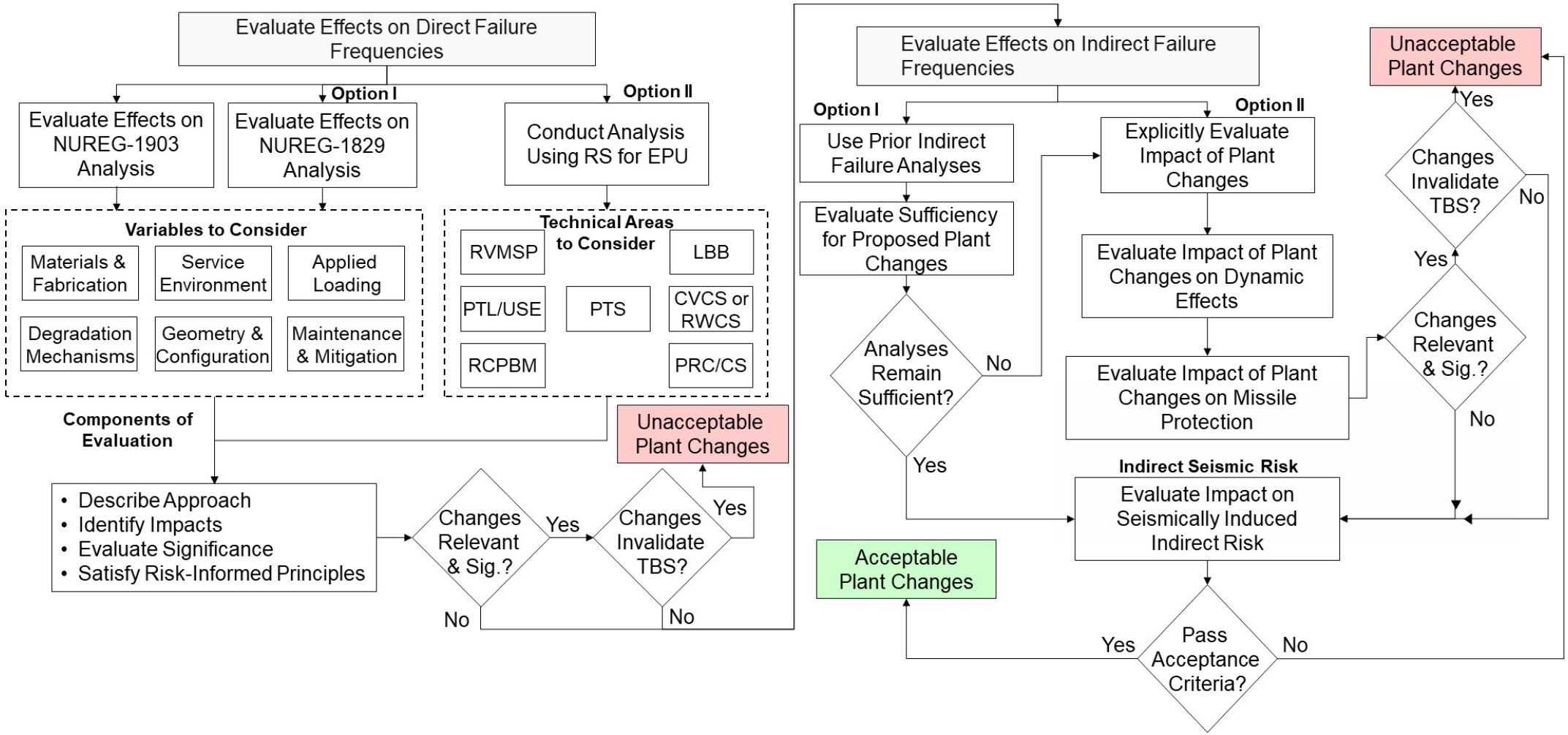
Option III: Plant-Specific Probabilistic Analysis



Seismically Induced Risk of Indirect Component Failures

- An acceptable analysis would include:
  - most up-to-date seismic hazard information
  - plant-specific component and support fragilities
  - impacts of age-related degradation
- Plant-specific seismic PRA that complies with RG 1.200 is acceptable
- Methods other than seismic PRAs may be acceptable
  - seismic margin assessment
- Risk-informed evaluation described in DG-1426 is applicable and provides additional guidance and acceptance criteria

Impact of Plant Changes: General Approach



Plant Changes and LOCA Frequencies

- Entities must demonstrate that proposed plant changes do not significantly increase LOCA frequencies such that TBS remains applicable
  - Both direct and indirect failures should be considered
  - Failures under normal loads, design basis and rare seismic loading (as in NUREG-1903) should be considered
  - Age related degradation should be considered
  - A risk-informed evaluation should be conducted to demonstrate plant changes do not significantly increase LOCA frequencies.
    - More guidance in DG-1426

Plant Changes and Direct Failure Frequencies

- Continued applicability to both NUREG-1829 and NUREG-1903 to be demonstrated

Option I: Effects on NUREG-1829 Variables

- Identify if change affects materials, environment, loading, degradation, geometry, maintenance or mitigation
- Identify if change may introduce new degradation
- Assess and describe performance monitoring program

Option II: Review Standard for Extended Power Uprates

- Use guidance for EPUs
- Focus on RPV surveillance, PT limits, USE, PTS, LBB, piping materials and supports, chemical control, etc.
- Assess and describe performance monitoring

Plant Changes and Direct Failure Frequencies

- Evaluate effects on NUREG-1903 analyses
  - Verify changes do not impact the inspections at limiting locations
  - Determine if change increases degradation rates
  - Determine if surface flaw analyses remain applicable
    - Determine if the change increases stress at limiting location
    - Determine if the change may decrease strength or toughness, or increase crack growth rate of materials
    - Determine if surface flaw analyses still meet acceptance criterion

Plant Changes and Indirect Failure Frequencies

- Ensure that GDC-4 is met and that risk of indirect seismic failures remains acceptable
- Continued adherence to GDC-4
  - Dynamic effects (e.g., pipe whip and jet impingement) and missile protection
  - **Option I**: Prior analyses unaffected by plant changes or existing analyses remain sufficient (no additional evaluation needed)
  - **Option II**
    - Supplement existing evaluations to evaluate relevance and significance of proposed changes to demonstrate that they do not invalidate the TBS
    - Utilize existing guidance in NUREG-0800 (SRP) 3.6.2 (Dynamic Effects) and 3.5.1.1/3.5.1.2 (Missile protection)
- Indirect seismic failure risk
  - Demonstrate that associated risk due to plant change meets proposed rule change requirements
  - Utilize DG-1426 guidance for assessing risks

Appendices

- Appendix A: Detailed Information for Conducting Plant-Specific Analyses Using the NUREG-1903 Approach
  - Contains information pertaining to the direct piping failure analysis in NUREG-1903
  - Table A-1 lists the PWR plants evaluated in NUREG-1903
  - Table A-2 provides the information obtained from NUREG-1488[3] to develop the seismic component stresses
  - Table A-3
    - Provides information submitted as part of LBB evaluations used in analysis
    - Provides intermediate and final analysis results
- Appendix B: Example Calculation for Hot Leg
  - **Critical location**: Girth weld of an SA312-TP304N seamless pipe to reactor pressure vessel nozzle
  - Provides step-by-step calculation of the deterministic, plant-specific surface flaw analysis using the NUREG-1903 scale factor approach (i.e., Option II on Slide 23)

[3] NUREG 1488, "Revised Livermore Seismic Hazard Estimates for Sixty-Nine Nuclear Power Plant Sites East of the Rocky Mountains," (ML20069B899)

DG-1428 Summary

- Evaluation required to demonstrate that breaks greater than TBS remain unlikely
  - **Direct failures**: primary coolant systems and components that could lead to breaks greater than TBS
  - **Indirect failures**: failures of other components that could lead to breaks greater than TBS
- DG-1428 provides guidance for conducting these evaluations
  - Uses DG-1216 as the starting point while streamlining and simplifying that guidance
  - Increases scope of DG-1216 to provide guidance on addressing indirect seismic failures
  - Comments received on DG-1216 considered during development
  - Leverages DG-1426 and other applicable long-standing guidance (e.g., SRP 3.6.3)
- DG-1428 provides several options for demonstrating TBS applicability
- Plan to work with stakeholders, ideally through a pilot study, to identify most viable options and further refine guidance before finalizing

Acronyms

ASME	American Society of Mechanical Engineers
BWR	Boiling Water Reactor
DG	Draft Guide
EPU	Extended Power Uprate
FFRD	Fuel, Fragmentation, Relocation and Dispersal
FRN	Federal Register Notice
ISI	Inservice Inspection
LBB	Leak before Break
LOCA	Loss of Coolant Accident
LR	License Renewal
NEI	Nuclear Energy Institute
PFM	Probabilistic Fracture Mechanics
PLP	Primary Loop Piping
PRA	Probabilistic Risk Assessment
PWR	Pressurized Water Reactor
PWROG	PWR Owners Group
RCPB	Reactor Coolant Pressure Boundary
SLR	Subsequent License Renewal
SRP	Standard Review Plan
TBS	Transition Break Size

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Questions

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Back-up Slides

10 CFR 50.46a: Related Application Requirements

- (c)(1)(i) requires existing plants to submit "(a) written evaluation demonstrating applicability of the TBS to the entity's facility. The effects of the initial plant changes proposed in the application must be considered as part of this evaluation."
- (c)(2) requires new-plant applicants to submit "… an analysis demonstrating why the proposed reactor design is similar to the designs of reactors licensed under this part before December 31, 2015, such that the provisions of this section may properly apply. The analysis must also include a recommendation for an appropriate TBS and a justification that the recommended TBS is consistent with the technical basis for this section. The effects of the initial plant changes proposed in the application must be considered as part of this evaluation."
- (c)(1)(v)(C) requires, for making changes without prior NRC approval, "(a) description of the approach, methods, and decision-making process to be used to evaluate the continued applicability of the TBS with the acceptance criteria used in the evaluation…" from paragraphs (c)(1)(i) or (c)(2), as applicable
- (c)(1)(vii) requires "(a) written evaluation demonstrating how the leak detection program in place at the facility satisfies the criteria in paragraph (d)(2) of this section."
- (c)(3) "The NRC may approve an application to use this section if…" above evaluations, change process program, or both are acceptable, as applicable.

10 CFR 50.46a: Related Implementation Requirements

- (d)(2) requires that "(t)he entity must have leak detection systems available at the facility and must implement actions during operation as necessary to identify, monitor, and quantify leakage to ensure that adverse safety consequences do not result from leaking primary pressure boundary components that are larger than the TBS".
- (d)(4) requires that "(t)he entity must perform an evaluation to determine the effect of all planned facility changes and must not implement any facility change that would significantly increase LOCA frequencies or invalidate the evaluation demonstrating the applicability of the TBS performed pursuant to…" paragraphs (c)(1)(i) or (c)(2), as applicable.
- (h)(1)(iii) for changes without prior NRC approval requires that "(t)he change does not significantly increase LOCA frequencies or invalidate the evaluation demonstrating the applicability of the TBS to the applicant's facility, performed pursuant to…" paragraphs (c)(1)(i) or (c)(2), as applicable.
- (h)(2)(v) for changes submit for NRC approval requires "… (i)information demonstrating that the proposed change will not significantly increase the LOCA frequencies or invalidate the evaluation demonstrating the applicability of the TBS to the entity's facility, performed pursuant to…" paragraphs (c)(1)(i) or (c)(2), as applicable.
- (j)(3) Minimal changes: reporting. "No later than 24 months after NRC approval of the entity's application and every 24 months thereafter, the entity must submit … a short description of each change involving minimal changes in risk made under paragraph (h)(1) of this section in the preceding 24 months and a brief summary of the basis for the entity's determination pursuant to paragraph (h)(1)(iii) of this section that the change does not invalidate the applicability evaluation made under paragraphs (c)(1)(i) or (c)(2), as applicable.

Sample Problem (Appendix B)

- Example Plant SSE: 0.2g PGA, with Mean Annual Frequency of Exceedance (MAFE) of 5.35E-5/yr
- PGA corresponding to the 1E-6/yr MAFE: 0.876g --> (SSE PGA)/(1E-6 PGA) = 0.876g/0.2g = 4.38
- Highest SSE stress location: Hot Leg (ID = 29", Thickness = 2.45"), TP304N wrought austenitic stainless steel joined by SMAW/SAW --> SSE stress = 12.96 ksi
- Normal plus 1E-6 seismic stress adjusted for seismic scale factor and nonlinear correction, using typical material properties = 26.35 ksi < 35 ksi
- Elastic-Plastic Fracture Mechanics (EPFM)-corrected stress = 43.19 ksi
- Minimum critical surface flaw depth from limit load equations = 0.335 > 0.25 --> OK for TBS

Fuel Dispersal and 50.46a – Changes Since December Meeting

Follow-Up ACRS Subcommittee Meeting
January 2025

Joseph Messina
Nuclear Methods and Fuel Analysis
Office of Nuclear Reactor Regulation

Changes

- Removed 50.46a(c)(3)(v) requirement that any non-safety related equipment credited in the LOCA analysis above the TBS be listed in a plant's Technical Specification.
  - (c)(3)(v): "Non-safety equipment that is credited for demonstrating compliance with the ECCS acceptance criteria in paragraph (e) of this section is identified in the plant's Technical Specifications or appropriate conditions require that any future license applicant lists this equipment in the plant's Technical Specifications;"
  - Licensees should perform a plant-specific analysis to determine whether any non-safety related equipment credited for LOCAs above the TBS should be placed in TS under Criterion 4 of 50.36(c)(2)(ii).
- LOCA definition in 50.46 and 50.46a restored to "breaks ***in pipes*** in the reactor coolant pressure boundary" rather than "breaks in the reactor coolant pressure boundary."

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Discussion

Discussion

- 1) Criticality
- 2) Fissile Packaging
- 3) TBS sizes
- 4) FFRD
- 5) Clad testing
- 6) RG 1.183
- 7) Control Room dose
- 8) Broader impacts