NRC Public Meeting
Alternative Acceptance Criteria for Postulating Pipe Break Locations

Nuclear Regulatory Commission

March 1, 2021

NRC Headquarters Rockville, MD (Virtual Meeting)

Agenda

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Purpose: The purpose of the meeting is for the NRC staff to discuss strategies to develop alternative criteria and associated guidance for postulating pipe break locations in piping systems and the corresponding technical basis.

Time	Topic	Speaker
1:00pm	Introduction	NRC
1:10pm	Summary of June 2019 Public Meetings	NRC
1:25pm	Activities and Responses to Action Items	EPRI
1:50pm	NRC Approach to Developing Alternative Acceptance Criteria and Technical Basis	NRC
2:30pm	BREAK	All
2:40pm	Discussion on Operating Reactors	NRC/Industry
3:40pm	Discussion on New Reactors	NRC/Industry
4:40pm	Public Comments	Public
4:50pm	Wrap Up / Action Items / Next Steps	NRC
5:00pm	Adjourn	All

Summary of June 2019 Public Meeting

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PUBLIC MEETING ON ALTERNATIVE CRITERIA FOR POSTULATING PIPE BREAK LOCATIONS

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June 2019 Public Meeting

- NRC held Category 2 Public Meeting on June 11, 2019
  - Meeting summary - ML19214A095
  - NRC presented TLR on background and history of BTP 3-4
  - EPRI presented contents of EPRI Technical Report No. 1022873, “Improved Basis and Requirements for Break Location Postulation”
  - Westinghouse presented impact of BTP 3-4 CUF criterion on design process for AP1000
- Key result: continue the effort to re-evaluate the BTP 3-4 criteria

TLR on BTP 3-4

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- "Criteria for Postulating Pipe Rupture Locations: Background and History" [ML19144A089], May 2019
- Summarizes current guidelines

Section of BTP 3-4	Criteria	Notes
		Class 1 Piping
B.1.(iii)(1)(a)	If $S_n > 2.4S_m$, then $S_e > 2.4S_m$ or $S_n' > 2.4S_m$	See Equations 2, 3, and 4.
B.1.(ii)(1)(b)	Cumulative Usage Factor (CUF) ≥ 0.1	In 2016, the NRC staff added, "For new reactor design certification reviews, the staff has considered a CUF limit of 0.4 to be acceptable when the effects of environmental assited fatigue (EAF) are considered in the piping design."
B.1.(ii)(1)(c)	$S > 2.25\ S_m$ or $S > 1.8S_y$	-BTP 3-4 provides exceptions to these criteria for the loads associated with pipe failure outside containment. -See Equation 1.
		Class 2 Piping
B.1.(ii)(1)(d)	$S + S_n > 0.8(1.8S_h + S_A)$	-S_h and S_A are allowable stresses defined in ASME Section III, paragraph NC-3600 [11]. -See Equations 1 and 2.
B.1.(ii)(1)(e)	$S > 2.25\ S_h$ or $S > 1.8S_y$	-See Equation 1. -The same exceptions discussed in B.1.(ii)(1)(c) apply here.

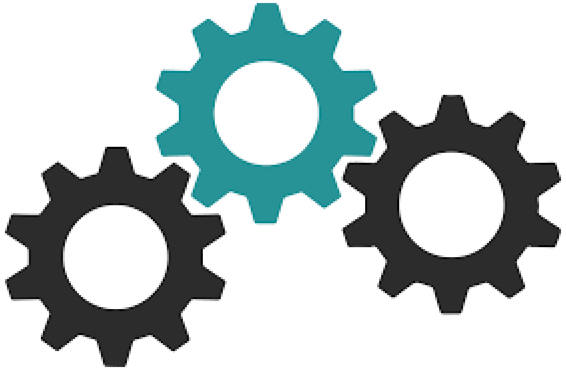
TLR on BTP 3-4

- Summarizes historical development of BTP 3-4
  - Discusses precursors to BTP 3-4
  - Compares the different version and discusses how the criteria has evolved over time
  - In many cases, staff rationale behind the updates is not currently known
- Fatigue and stress criteria were updated last in MEB 3-1, Rev. 1

Title	Revision	Date
MEB 3-1	0	Sept. 1975
MEB 3-1	1	July 1981
MEB 3-1	2	June 1987
BTP 3-4	2	March 2007
BTP 3-4	3	July 2016

TLR on BTP 3-4

- Discussion of the basis of the CUF criterion
  - Known technical basis
  - Alternative approaches
- Conclusions and Recommendations
  - Technical basis behind the CUF criterion is unavailable
  - Develop and document a technical basis for the CUF criterion, including revising if appropriate



Public Meeting Action Items/Next Steps

1. EPRI will consider formulating and then implementing an approach to identify and quantify the burdens associated with implementation of the BTP 3-4 criteria for existing reactors and new plant designs. If possible, this approach should address ASME Code Class 1, 2, and 3 piping design criteria.
2. NRC will evaluate the feasibility of making changes to the BTP 3-4 criteria and will identify a suitable approach for developing the corresponding technical basis for such changes. Possible examples are criteria related to CUF and allowable stresses for ASME Code Class 1, 2, and 3 piping.
3. NRC and EPRI will coordinate a follow-on public meeting to discuss the findings, technical and regulatory implications, and path forward associated with the work to address the above two actions.

Developing Alternative Criteria for Postulating Pipe Break Locations and Associated Technical Basis

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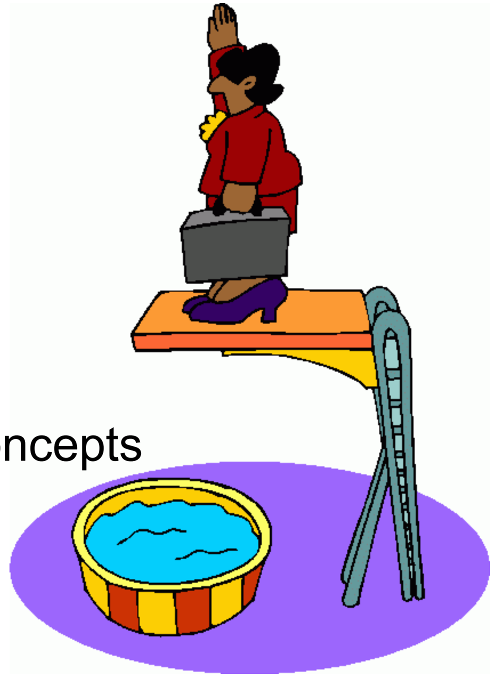
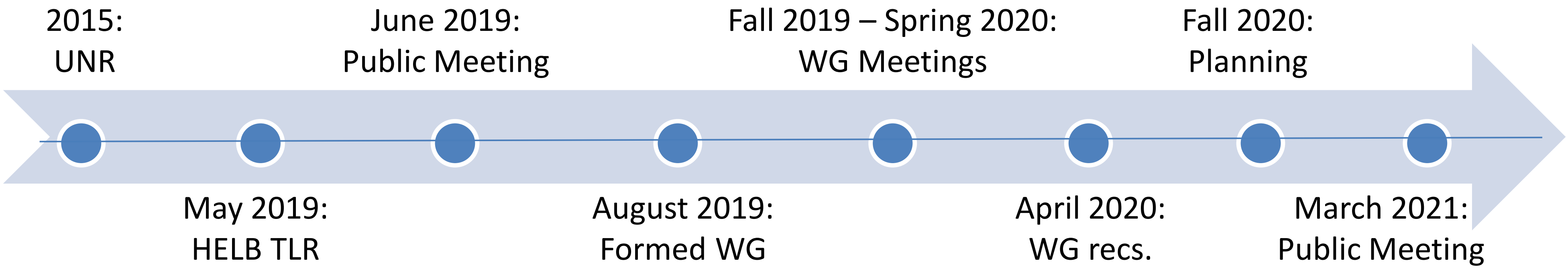
Starting Point for Recent NRC Efforts

- June 11, 2019 public meeting
  - Key takeaways
    - No strong technical basis for existing BTP 3-4 criteria
    - Both CUF and stress criteria can be challenging to meet
    - Significant design challenges for AP1000 to meet existing criteria
    - EPRI's 2011 proposed risk-informed approach contains important concepts (Report No. 1022873)
  - NRC action items
    - Evaluate feasibility of making changes to BTP 3-4 criteria
    - Identify a suitable (conceptual) approach for developing the corresponding technical basis for such changes



- Formed intra-agency working group to address NRC action items

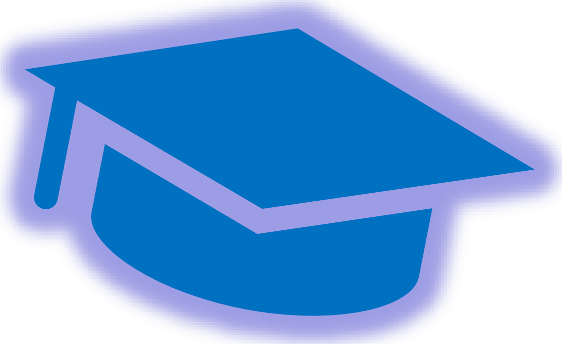
Working Group Timeline



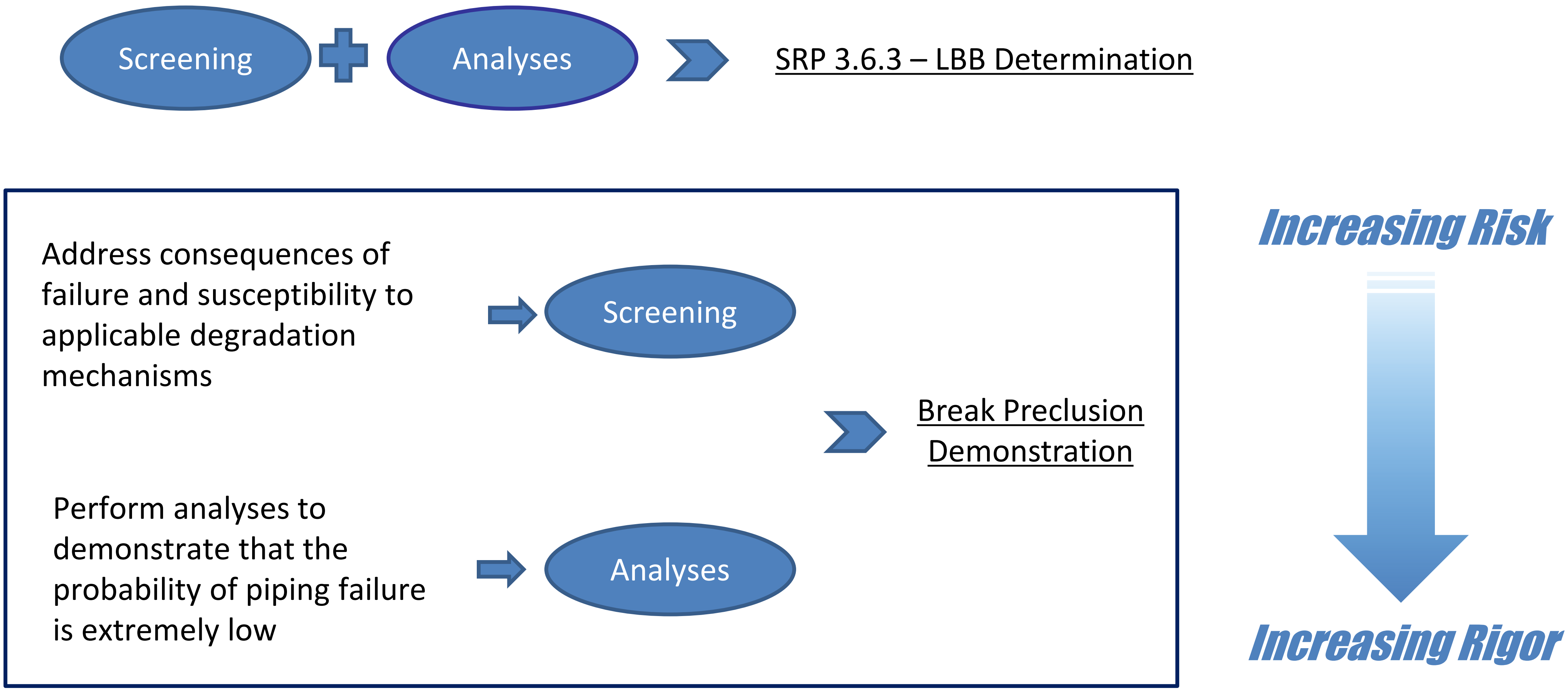
Steady Progress

Revising BTP 3-4: Underlying Philosophy

- Significantly revamp existing BTP
  - Eliminate stress criteria, relax CUF criterion
  - Consider other degradation mechanisms
  - Tailor CUF evaluations, as needed, to applicable systems/components
- Support operating reactor, new reactor, and advanced reactor applications
  - Provide identical framework and approach
  - Require unique evaluations or analysis depending on reactor type
- Approach should be risk-informed
  - Consider both failure consequences and susceptibility to degradation
  - Utilize a graded approach consistent with the risk
- Broaden scope beyond classical, LWR welded-piping systems
  - Include other types of connections (e.g., bolted)
  - Include other passive components/systems which primarily transport fluid
- While initial focus has been on high-energy breaks, a similar philosophy should be applicable for moderate-energy breaks

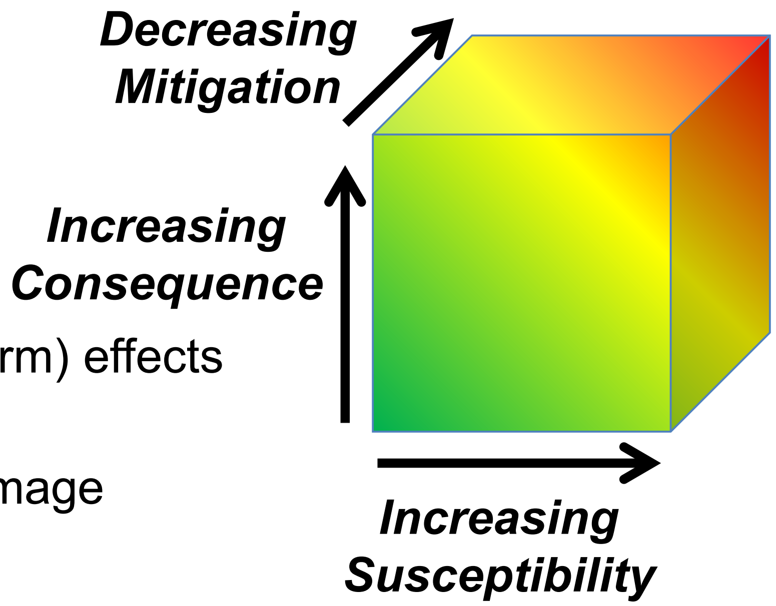


Guidance Approach: Similar Philosophy to SRP 3.6.3 – Leak-Before-Break (LBB)



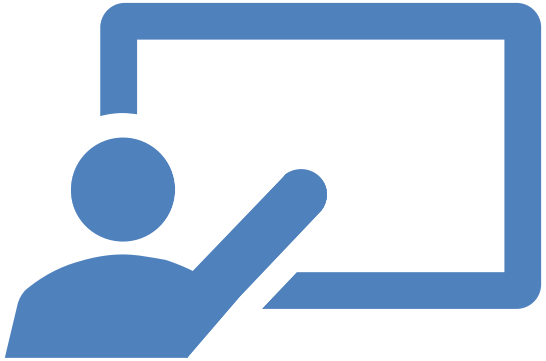
Revising BTP 3-4: Screening Considerations

- Initial assumptions/limitations
  - Design using approved codes & standards
  - Lower size limit (nominal pipe size > 1”?, 2”?, 4”?)
- Consequence analysis
  - Consider worse-case location and failure orientation
  - Evaluate both rupture and leakage (including potential for long-term) effects
  - Impacts of separation and shielding
  - Address defense-in-depth: primary failure and consequential damage
- Degradation susceptibility analysis
  - Consider all possible failure mechanisms (e.g., SCC, fatigue, embrittlement, FAC, creep)
  - Evaluate susceptibility risk factors: material, environment, stresses
  - Evaluation could be qualitative or semi-quantitative
- Mitigation and historical evidence credit
  - Operating experience and past inspection results – existing plants
  - Aging management programs (e.g., pre and in-service inspection, leakage detection, monitoring, surveillance, environmental controls, operational/design controls)



Revising BTP 3-4: Analysis Considerations and Technical Basis Development

- Acceptance criteria and technical basis are coupled
  - Meeting criteria should demonstrate “extremely low probability of rupture” (or leaking)
  - Criteria dependent on the degradation mechanism
  - Criteria could be specific (e.g., CUF_{en} < 1.0) or broad (e.g., demonstrate extremely low failure likelihood)
- Graded analysis approaches could be considered
  - Simpler deterministic bounding or binning analyses
  - Probabilistic analyses
    - May be acceptable as principal basis, but more challenging
    - Ideally would support a simpler deterministic analysis



- Acceptance criteria and technical basis
  - Complexity increases with the number of degradation mechanisms evaluated
  - Complexity increases as the pipe size decreases
  - Crediting time to initiate flaw will be more challenging, especially at welds.

Technical Basis Development: Operating LWRs (post-design use) – Some Ideas

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- Select systems/locations for analysis
  - Highest CUFs from license renewal applications
  - Minimum break preclusion margin based on operating conditions and experience
  - Smaller diameter systems at or near the limit of proposed guidance
  - Locations most susceptible to selected degradation mechanisms
- Assess time to crack initiation (e.g., CUF_{en} = 1.0, SCC)
- Analyze post-initiation margin to failure
  - Time to initiate leakage/through-wall cracking
  - Pre and post-leakage margin against rupture
- Loading
  - ASME Service Level: A/B for sub-critical cracking, C/D for rupture
  - Alternatively, use actual design information for selected locations
  - Adopt reasonably conservative, but not bounding, weld residual stress distributions
- Cracking orientation
  - Circumferential
  - Axial to address seam-welded piping or elbows?
- If needed, evaluate applicable non-cracking degradation mechanisms (e.g., FAC)

Technical Basis Development: New/Advanced LWR Reactors (use in design) – Some Ideas

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- Select systems/locations for analysis
  - Locations and sizes will be conceptual
  - Materials and environmental combinations could be unique for each reactor type
  - Broader array of possible degradation mechanisms with more analysis uncertainty
- Assess time to crack initiation (e.g., fatigue, SCC)
- Analyze post-initiation margin to failure
  - Time to initiate leakage/through-wall cracking
  - Pre and post-leakage margin against rupture
- Loading
  - ASME Service Level: A/B for sub-critical cracking, C/D for rupture
  - Adopt reasonably conservative, but not bounding, fabrication residual stress distributions
- Cracking Orientation
  - Circumferential
  - Axial
- If needed, evaluate non-cracking degradation mechanisms

Discussion on Operating Reactors

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Operating Reactors - HELB

<u>Current Licensing Basis (CLB) for HELB for Operating Reactors</u>

- Is based on SRP 3.6.2 / BTP 3-4 or its predecessors MEB 3-1

<u>For License Renewal (60 years) & Subsequent License Renewal (80 years)</u>: Licensees may:

- Continue to use BTP 3-4 or its predecessors (considering the effects of EAF for other locations that require a CUF evaluation where EAF effects consideration is a part of licensing basis), or
- Use Alternative Approach

<u>Alternative Approach to Satisfy 10 CFR Part 50 Appendix A - GDC 4</u>

Highlights of alternative approach NRC is considering:

- 80% stress limit or CUF limit of 0.1 not required
- Review for applicable degradation mechanisms (e.g. thermal fatigue, vibration fatigue; FIV, SCC, IASCC, IGSCC, PWSCC, FAC, MIC, acoustic resonance, erosion)
- Review operating experience (e.g. cycles from fatigue monitoring, actual transients)
- Demonstrate by analysis for acceptability: LBB, & establish inspection frequency, etc. for critical locations
- Evaluate consequences

Discussion on New Reactors

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New Reactors Design Certification - HELB

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Current NRC Staff's Guidelines and Lessons Learned from New Reactors Reviews

- SRP 3.6.2/BTP 3-4 provides, in part, guidelines acceptable to the staff for meeting these GDC 4 requirements.
- The current guidelines use stress (80 percent of the ASME allowable) and fatigue (0.1 of CUF) to identify postulated break locations. When the EAF is considered in the new reactors design, the staff accepts a CUF limit of 0.4. BTP 3-4 also provides guidelines for applying break exclusion.
- The technical rational for the reduced stress limit and large margin on CUF is to provide a conservative margin to account for unforeseen causes and errors (e.g., faulty design, improperly controlled fabrication, and installation errors), uncertainties in the quality level of piping systems, uncertainties in effects of vibratory load and other degradation mechanisms (e.g., corrosive environments, water hammer), and the lack of accounting for environmental effects by the ASME Section III fatigue curves.
- Current BTP 3-4 guidelines need to be updated to address issues that arose during the review of SMRs. Those issues included bolted connections being used as break exclusion locations and changes in design configuration such as having two containment isolation valves outside containment, etc.

New Reactors Design Certification – HELB (continued)

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Alternative Approach and Technical Considerations

- The focus of the approach is to develop the technical basis for ensuring the alternative criteria satisfies GDC 4.
- The alternative acceptance criteria revises the environmentally adjusted CUF criteria to less than or equal to 1.0 and removes the stress range and max stress criteria for postulating breaks.
- The updated staff guidelines will address lessons learned from SMRs design (e.g., bolted connections, welded connection between two large vessels), including applicable joints and configurations that should be considered in addition to piping welds for new reactor applications.
- There are unique challenges for developing a technical basis for advanced reactors.
- As a part of this alternative acceptance criteria, new reactor applicants would be required to address potential piping failures due to various failure/degradation mechanisms (e.g., vibration, erosion, flow-induced vibration, intergranular stress corrosion cracking) and demonstrate that leakage detection and mitigation are appropriately considered to ensure that the probability of potential pipe failure resulting from those failure/degradation mechanisms is extremely low.