NRC Public Meeting
Discuss Risk-Informed High Energy Line Break Methodology

Nuclear Regulatory Commission
January 11, 2023
NRC Headquarters Rockville, MD (& Virtual)

Agenda

United States Nuclear Regulatory Commission
Protecting People and the Environment

- **Purpose:** The purpose of the meeting is to discuss risk-informed high energy line break (HELB) methodology covering, but not limited to, overview of the supporting topical report, review of relevant regulations, and intended licensing applications, and related NRC staff activities

Time	Topic	Speaker
1:00pm	Introductions/Opening Remarks	All
1:10pm	Risk-informed HELB/BER Presentation	Industry/EPRI
2:00pm	NRC Research Activities related to HELB/Cumulative Usage Factors	NRC
2:45pm	Discussion	All
3:00pm	Break	All
3:15pm	Brainstorming Session – Approaches/Applications for Risk-Informed HELB/Break Exclusion	All
4:00pm	Opportunity for Public Comment	Public
4:15pm	Wrap Up / Action Items / Next Steps	All
4:30pm	Adjourn	All

NRC Activities Related to Revising High Energy Line Break Methodology

Rob Tregoning
Bruce Lin
Stewart Bailey
Nuclear Regulatory Commission

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Background: Prior Public Meetings

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- June 11, 2019: Category 2 Public Meeting
  - Meeting summary - ML19214A095
  - NRC presented report 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 outcome**: continue the effort to re-evaluate the BTP 3-4 criteria
- March 1, 2021: Category 2 Public Meeting
  - Meeting summary – ML21089A005
  - NRC discussed current HELB guidelines, proposed strategies for alternative criteria, and potential alternative approaches/technical considerations for operating and new LWRs
  - EPRI summarized their HELB activities since the 2019 meeting
  - Actions
    - **NRC**: Evaluate possibility of phased approach, provide recent HELB submittals, consider other piping configurations (i.e., bolted and flanged connections)
    - **Industry**: Evaluate possibility of conducting a pilot-plant submittal
    - **All**: Inform advanced non-LWR vendors and designers and consider their feedback

Framework for Recent NRC Efforts

- Important considerations (discussed in 2019 public meeting)
  - No strong technical basis for existing BTP 3-4 criteria
  - Both CUF and stress criteria can be challenging to meet
  - Significant design challenges may arise in meeting existing criteria
  - EPRI's 2011 proposed risk-informed approach contains relevant, applicable concepts (Report No. 1022873)
  - Leverage both operating experience and insights from related risk-informed initiatives

- Formed working group to evaluate changes to BTP 3-4 and develop alternative framework and associated acceptance criteria for postulating pipe break and leak locations

Revising BTP 3-4: Underlying Philosophy

- Significantly revamp existing BTP and provide as a voluntary alternative for existing or new reactors
  - Eliminate stress criteria, relax CUF criterion
  - Consider other degradation mechanisms
  - Consider operating experience
  - 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 additional measures 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
- Adopt a similar approach for both high-energy and moderate-energy breaks

Approach: Philosophy Consistent with both Deterministic and Risk-Informed Evaluations

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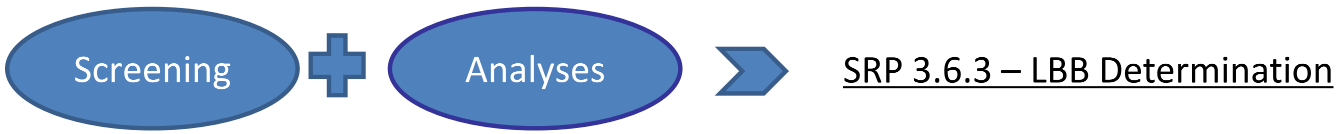
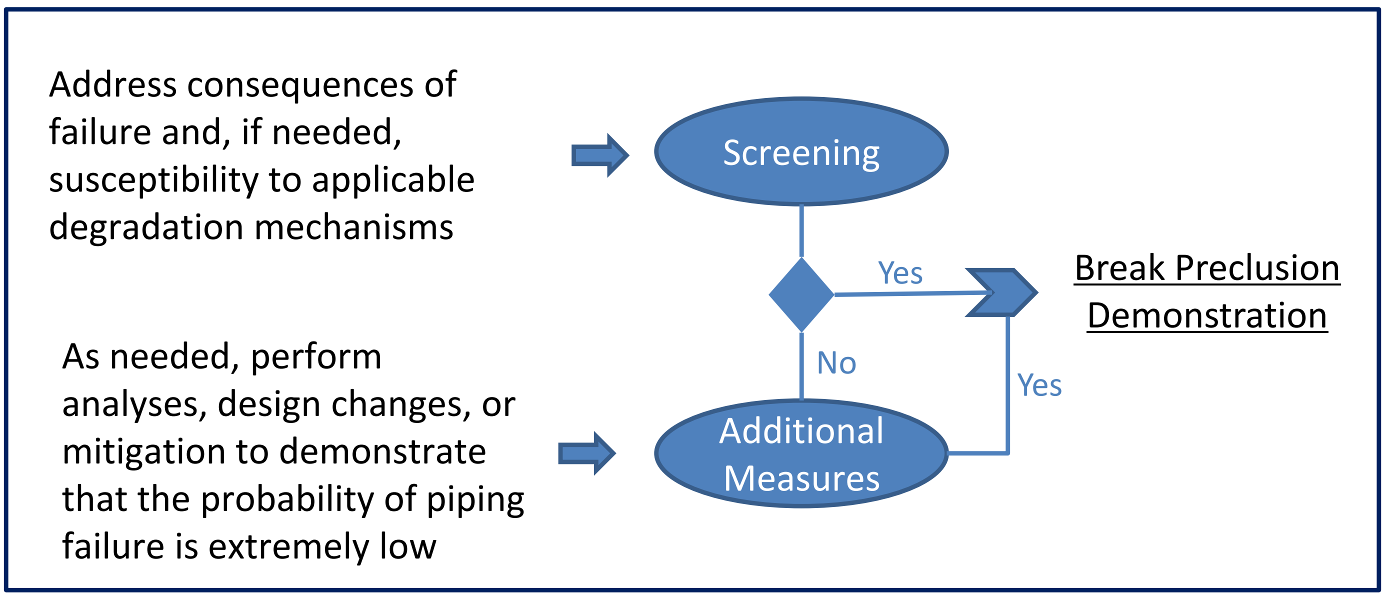
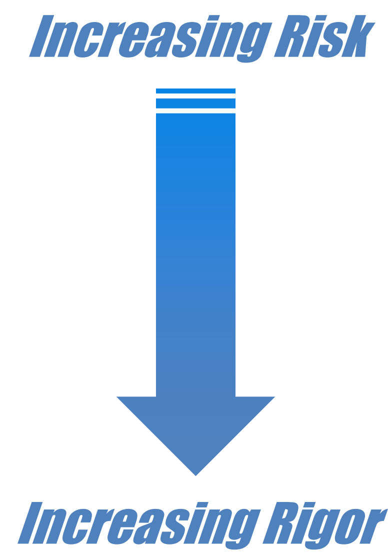






Alternative Framework: Scope and Objectives

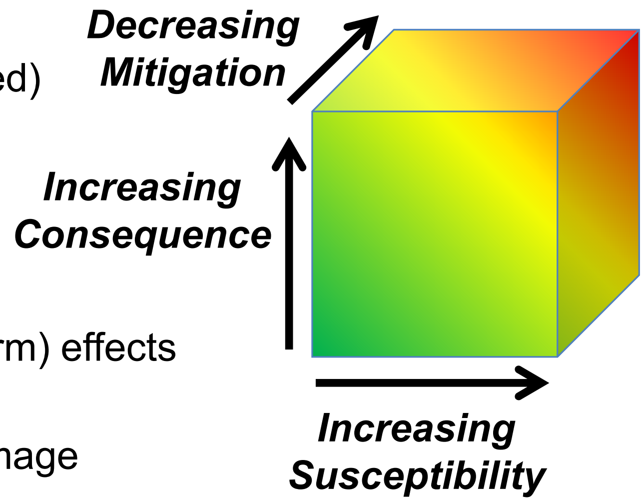
- Scope
  - Provide alternative method to determine rupture locations in accordance with SRP 3.6.2 to demonstrate that GDC-4 requirements are met
  - Not intended as a substitute to 10 CFR 50.46 requirements
- Specific Objectives
  - Change CUF < 0.1 criterion to $CUF_{en} < 1.0$
  - In lieu of current stress criteria in BTP 3-4, require compliance with ASME Section III and predecessors (e.g., B31.1)
  - Leverage to the extent possible existing design (e.g., ASME Section III Appendix W) and operational (e.g., GALL, ASME Section XI/O&M) aging management practices/programs
  - Eliminate mandatory postulation of breaks at terminal end locations, at "high-stress" intermediate locations, and intermediate locations with CUF > 0.1
  - Provide alternative, risk-informed guidance for postulating break locations for use in plant design and safety analyses

Alternative Framework: Applicability

- Light water reactors operating below 360 ºC
  - While the initial applicability is limited to LWRs, this framework is intended to ultimately support establishing break locations for other reactor types (e.g., ANLWRs) as well.
- High and moderate-energy Class 1 and 2 piping systems within the break exclusion region (BER) and high and moderate-energy Class 1, 2, and 3 piping systems outside of the BER.
- Nominal Pipe Size - 2” and greater
  - Although it is recognized that demonstration of low-likelihood of rupture associated with degradation is more challenging for smaller piping and connections.
- Piping systems that are joined using welded or bolted flanged connections
- Piping systems designed using NRC-approved codes and standards (i.e., ASME Section III or B31.1)

Alternative Framework: Screening Evaluation
(One Potential Risk-informed Approach)

- Identify failure locations
  - Higher design basis or operational stresses
  - Higher likelihood of damage (during fabrication or serviced induced)
  - Less failure margin (i.e., ratio of design requirement to material properties)
- Perform rupture 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
- Conduct degradation susceptibility analysis (as needed)
  - 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
  - Credit effects of operating experience and past inspection results (existing plants), and aging management programs or mitigative measures



Alternative Framework: Additional Measures

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- Options available if it cannot be demonstrated that consequences are insignificant or significant degradation is extremely unlikely
  - Enact design changes or other mitigative measures (e.g., pipe whip restraints) to decrease failure consequences
  - Enact additional mitigative measures (e.g., increased inspection periodicity) to make it extremely unlikely that degradation will cause pipe rupture
  - Perform a more rigorous risk analysis to demonstrate that risks are insignificant
  - Conduct an advanced deterministic leak-before-break (LBB) analysis to demonstrate that the likelihood of a rupture is extremely low
- Other options, as proposed by licensee or applicant, may also be acceptable if they demonstrate that probability of piping/connection rupture is extremely low such that GDC 4 is met.

↓ Consequences

↓ Rupture Likelihood

↑ Analysis Complexity

Alternative Framework: Requirements and Additional Considerations

- Requirements
  - Approved system design (e.g., protection against overpressure transients), fabrication, (e.g., no partial penetration welds unless justified), and inspection (e.g., pre-service and in-service) practices
  - System has no active degradation mechanisms unless appropriate aging management or other mitigative measures are in place
  - Approved leak detection systems, as applicable (e.g., meeting RG 1.45 requirements)
- Additional considerations
  - Specific acceptance criteria and technical basis are coupled
    - 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)
  - Technical basis development
    - Complexity increases with the number of possible degradation mechanisms
    - Complexity increases as the pipe size decreases
    - Crediting time to initiate flaws will be more challenging, especially at welds
  - Graded analysis approaches are appropriate
    - Simpler deterministic bounding or binning analyses
    - Probabilistic analyses

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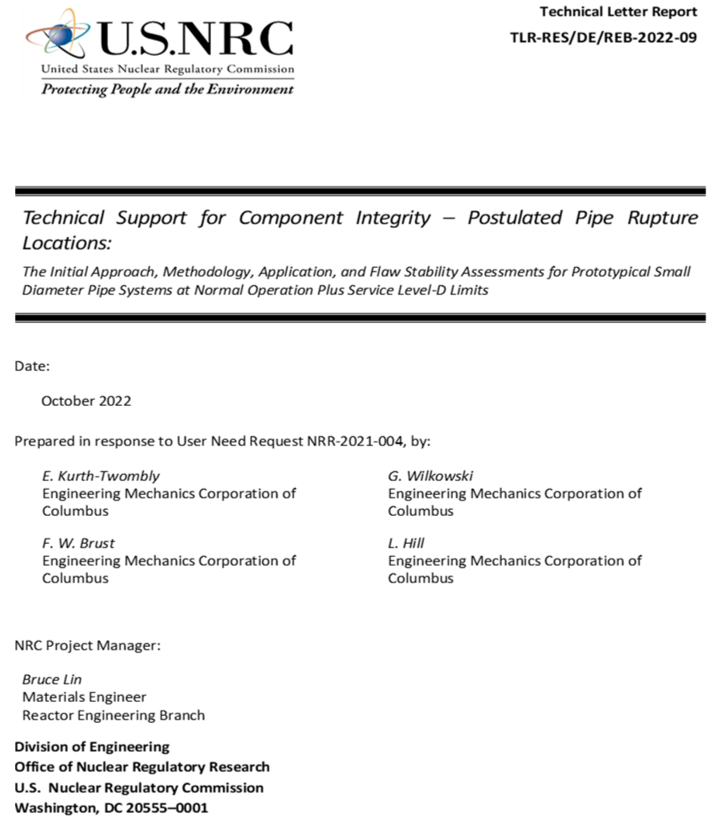
Advanced LBB Evaluation

- Conducted piping analyses using advanced leak-before-break (LBB) evaluation to demonstrate robustness of piping systems
- Selected challenging but representative systems/locations for analysis
  - Smaller diameter systems
  - Low toughness and high inertial loading
- Conducted analysis on actual piping systems
  - PWR case – NPS 3” Schedule 160, TP304, CVCS – charging line
  - BWR case – NPS 4” Schedule 160, A106B, RCIC system - Test to HPCI test line
- Report documenting the initial approach, methodology, and flaw stability assessment issued Oct 2022 (ML22277A504)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Technical Letter Report
TLR-RES/DE/REB-2022-09

Technical Support for Component Integrity – Postulated Pipe Rupture Locations:
The Initial Approach, Methodology, Application, and Flaw Stability Assessments for Prototypical Small Diameter Pipe Systems at Normal Operation Plus Service Level-D Limits

Date:

October 2022

Prepared in response to User Need Request NRR-2021-004, by:

E. Kurth-Twombly
Engineering Mechanics Corporation of Columbus

G. Wilkowski
Engineering Mechanics Corporation of Columbus

F. W. Brust
Engineering Mechanics Corporation of Columbus

L. Hill
Engineering Mechanics Corporation of Columbus

NRC Project Manager:

Bruce Lin
Materials Engineer
Reactor Engineering Branch

Division of Engineering
Office of Nuclear Regulatory Research
U.S. Nuclear Regulatory Commission
Washington, DC 20555–0001

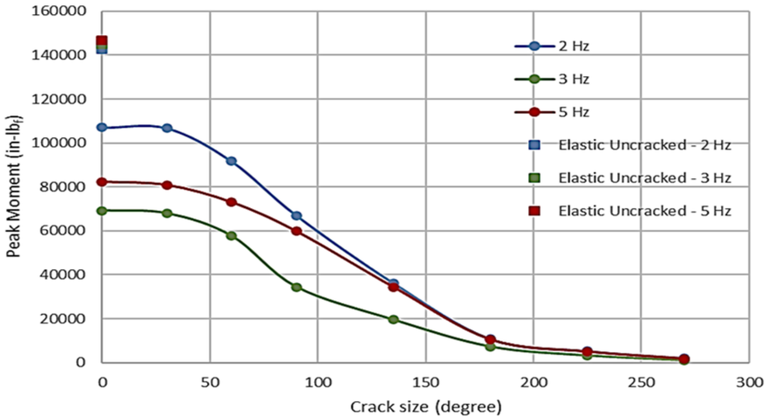
Advanced LBB Analysis Approach

- A robust LBB procedure developed from the IPIRG (International Piping Integrity Research Group) program
  - Uses FE analysis of pipe system to get elastic uncracked pipe stresses
  - Allows for nonlinear stress-strain curve of the material
  - Inserts the circumferential TWC at the worst location in the FE analysis

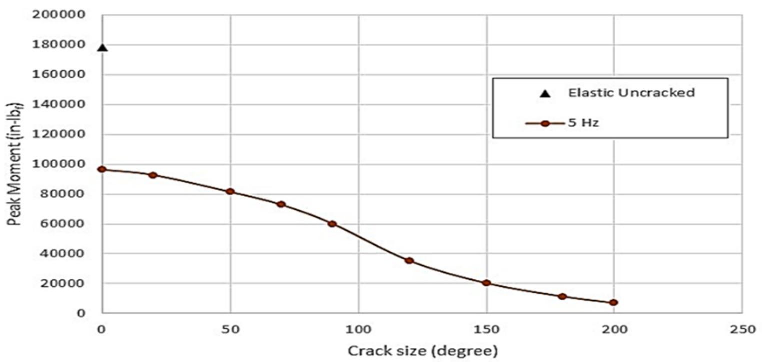
- Analysis Steps
  - Develop and verify finite element models
  - Check ASME Code stress limits (Primary, Primary + Secondary, Service Level D)
  - Perform uncracked analysis using elastic and elastic-plastic materials properties
  - Perform cracked analysis using elastic-plastic material properties at highest stress location

Initial Results

- As crack becomes larger, the applied moments drop from system flexibility changes
- Results show that even with the upper-bound allowable SL-D stresses, when accounting of non-linear material behavior and changes in system compliance, piping failure requires extremely long circumferential TWC lengths
  - No crack instability even for TWC of 270-degrees (75% of circumference)
  - At TWC=75%, the applied moment is about 1.5% of the uncracked elastic SL-D moment
- Currently conducting limited sensitivity studies to better understand the implications of the results



Peak moment as a function of crack size for the PWR system at different applied frequencies



Peak moment as a function of crack size for the BWR system

Next Steps

- Complete technical criteria
  - Evaluate/develop guidance on degradation mechanisms (ASME Section III Appendix W, ASME Section XI, ASME O&M, GALL)
  - Review relevant operating experience
- Develop Risk-Informed Approach
  - Maintains appropriate safety margins, defense in depth, performance monitoring
- Broaden scope beyond LWR welded piping systems
- Update regulatory guidance documents