PFM Estimation of LOCA Frequencies for New Fuel Licensing

MRP-480

Nate Glunt
Principal Technical Leader, EPRI Materials Reliability Program

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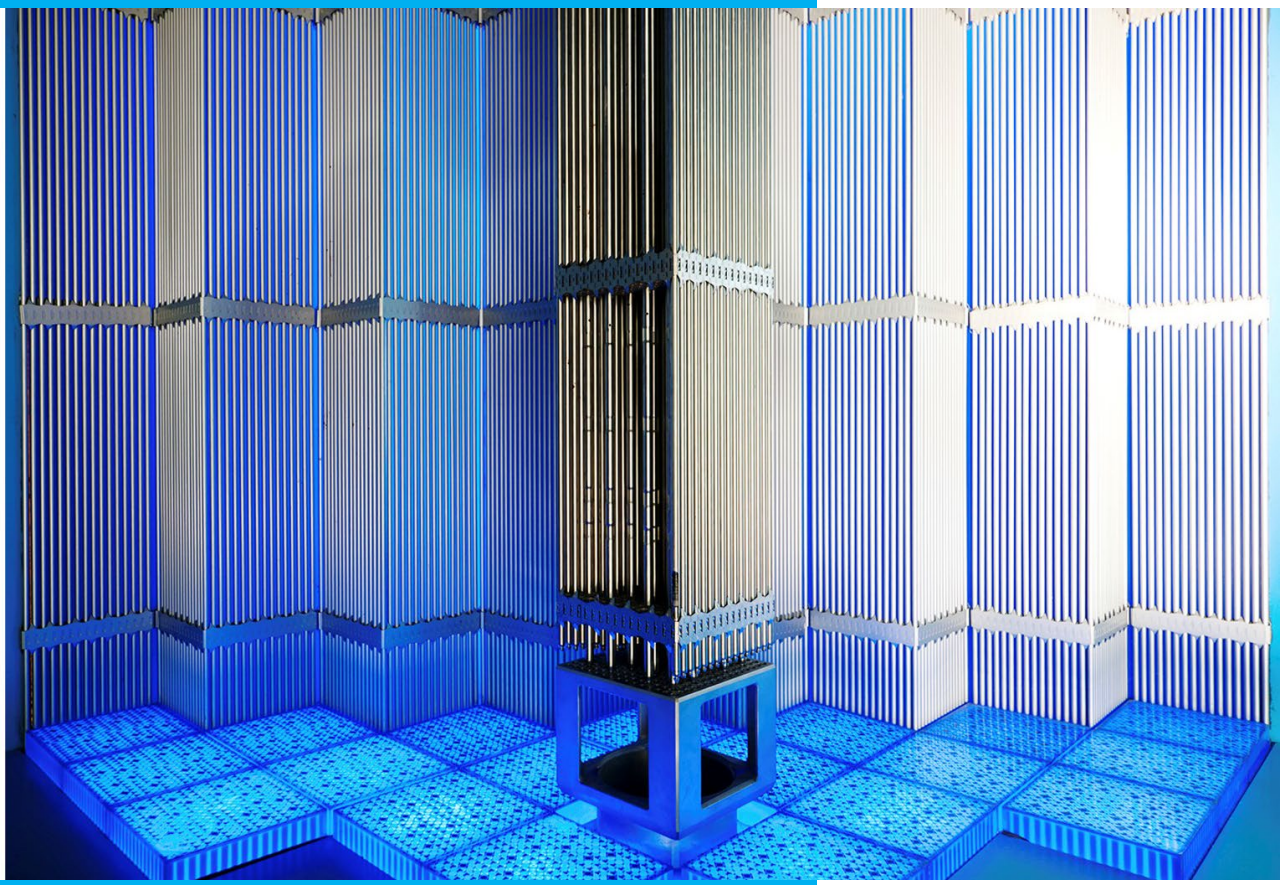
Introduction



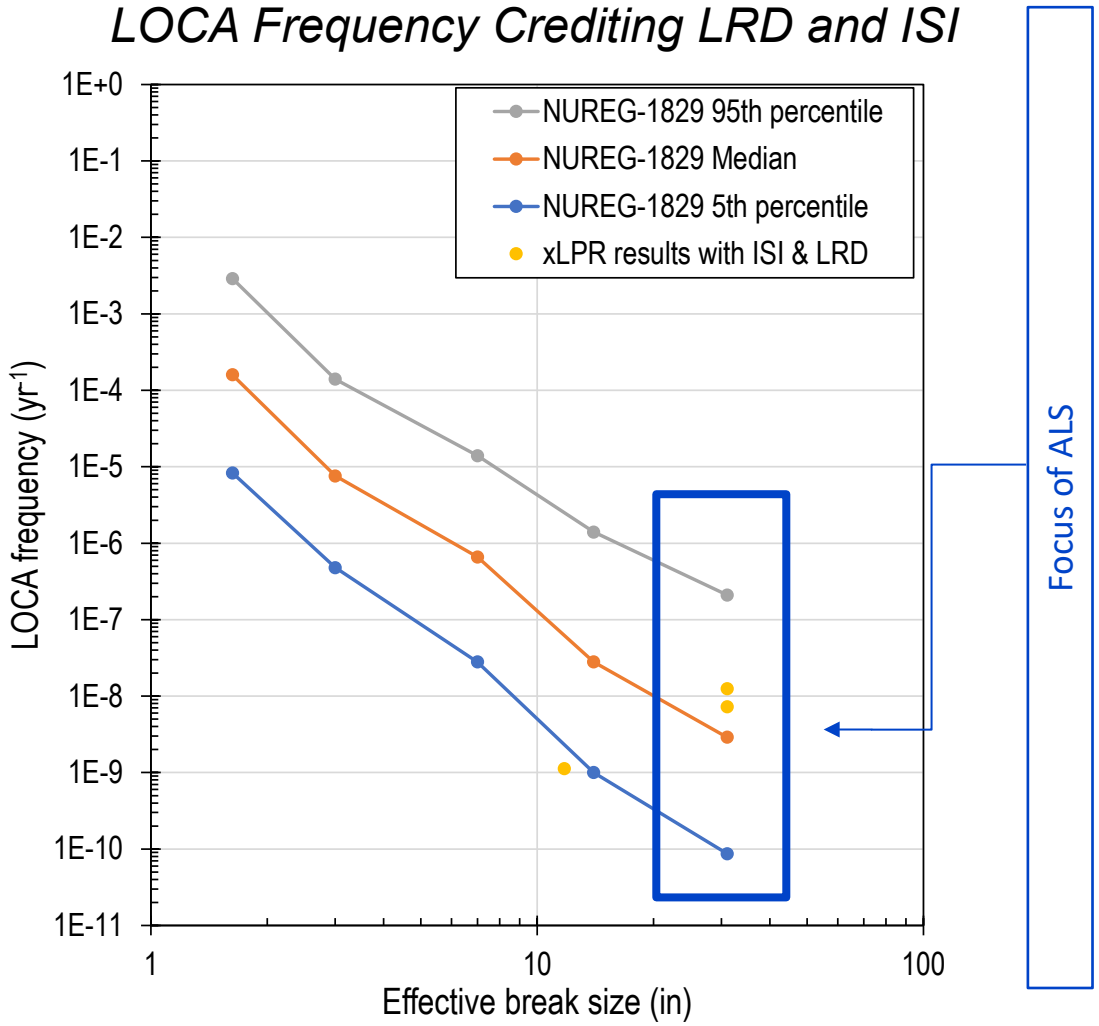
- Key challenge to increasing the maximum allowable burnup of fuel is the potential for a loss of coolant accident (LOCA) to induce fuel fragmentation, relocation, and dispersal (FFRD)
- The conventional licensing approach relies on fuel testing and measurements
- Limited test facilities and challenges in obtaining high burnup fuel for testing create schedule and regulatory risks

Alternative Licensing Strategy

- An alternative licensing strategy (ALS) to address FFRD was instead developed
  - This proposed alternative evaluates the credibility of fuel dispersal during a postulated large-break LOCA (LB-LOCA)
    - Partially relies on probabilistic fracture mechanics (PFM) analysis using the Extremely Low Probability of Rupture (xLPR) code
  - Also evaluates the potential likelihood of cladding rupture and fuel dispersal for higher burnup fuel rods during small-break and intermediate-break LOCA conditions

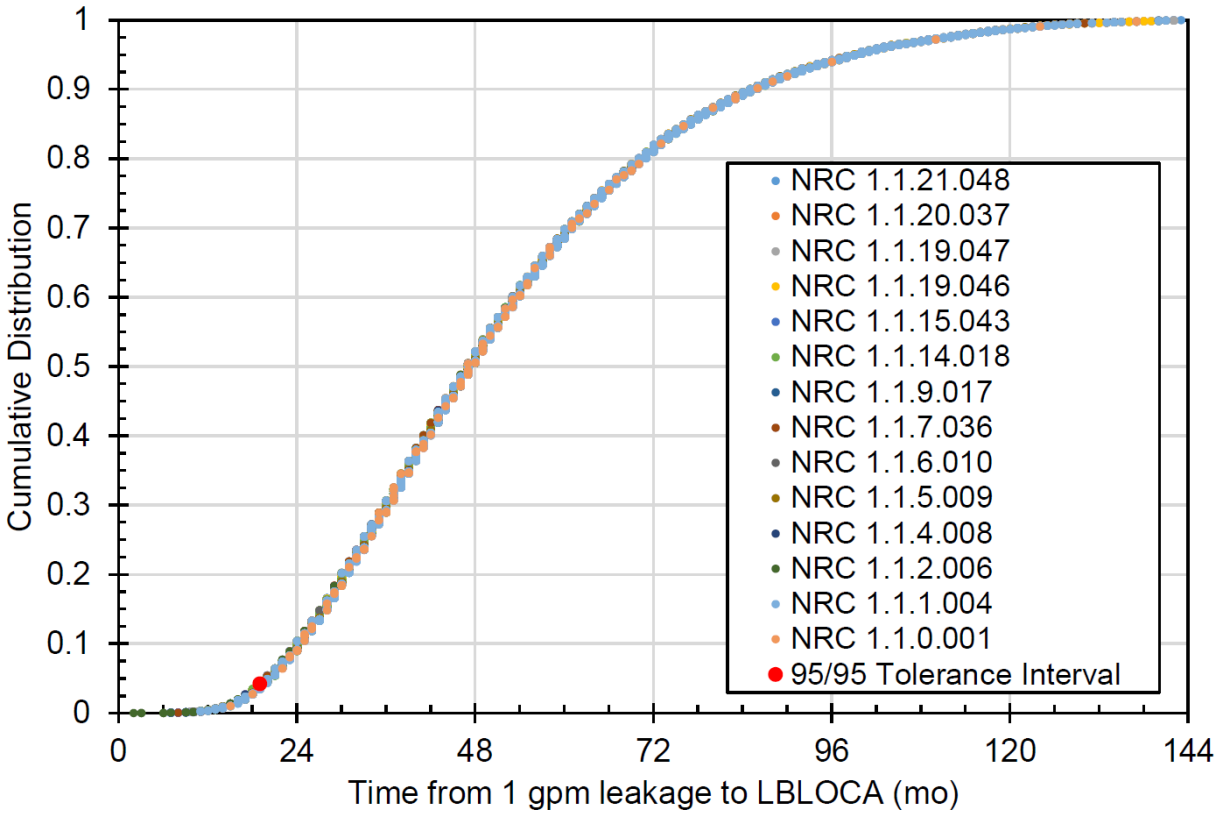
xLPR Involvement

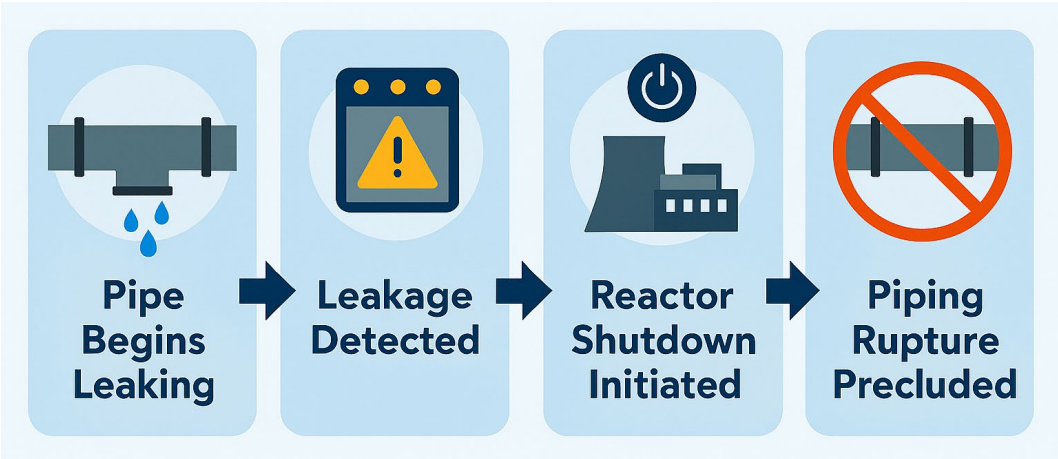
- xLPR is used to support the adoption of Leak-Before-Break (LBB) for exclusion of LB-LOCAs as related to FFRD
  - Explored probability of loss-of-coolant accidents (LOCAs) as a function of line size
    - Compared to expert elicitation process-based LOCA frequency estimates developed in NUREG-1829, Vol. 1 for pressurized water reactors (PWRs)



xLPR Involvement

- Demonstrated that leakage (as a precursor to a LOCA) will be detected in sufficient time to allow for reactor shutdown
  - Provides a statistical distribution describing the time between detectable leakage and LOCA or rupture





PFM Acceptance Criteria

- International Symposium on Probabilistic Methodologies for Nuclear Applications (ISPMNA5) held in 2024
- Major point of discussion was acceptance criteria in PFM evaluations
- MRP kicked off work on a white paper investigating acceptance criteria for passive components

PFM Acceptance Criteria

- PFM analysis has become an essential tool for licensees as risk-informed submittals become more prevalent
  - Determination of appropriate acceptance criteria is a key component of analyses as well as regulatory review
  - NRC has provided guidance on acceptance criteria for risk-informed applications in terms of core damage frequency (CDF) and large early release frequency (LERF) in RG 1.174
- Licensees have successfully leveraged PFM to demonstrate the incremental change in CDF resulting from licensing basis changes is less than 1×10^{-6}/yr
  - The 1×10^{-6}/yr criterion has been widely applied but is not the only appropriate criterion
  - Failure of components analyzed by PFM may have conditional core damage probabilities less than 1

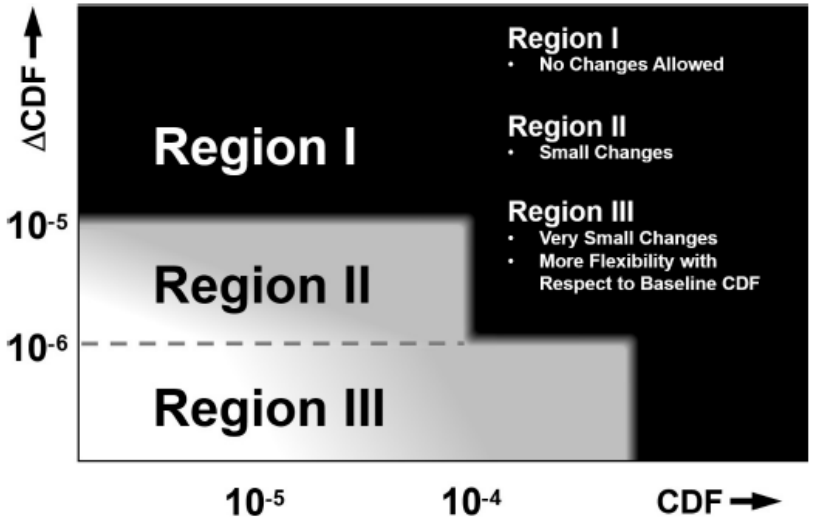


Figure 4. Acceptance guidelines* for core damage frequency

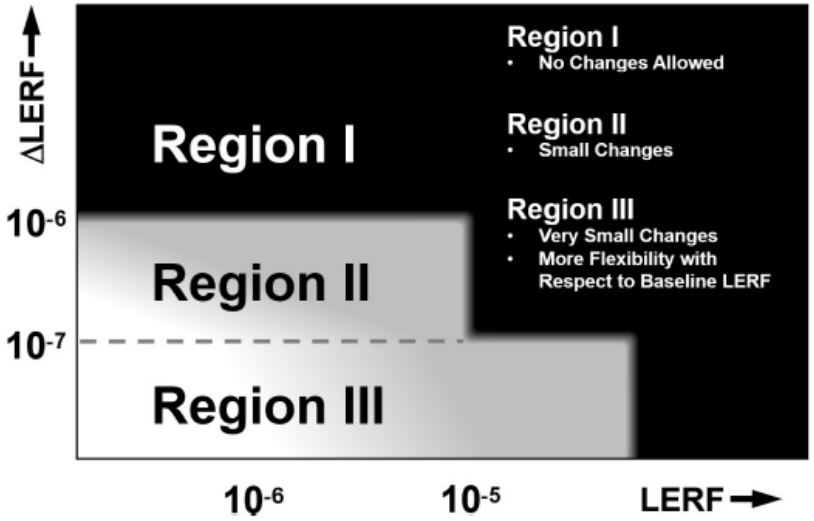


Figure 5. Acceptance guidelines* for large early release frequency

Conclusions

- PFM analysis using xLPR provides a defensible, risk-informed basis for excluding LB-LOCA-induced FFRD
  - For the RCS main loop, the ALS demonstrates that LB-LOCA induced FFRD is not credible when risk insights are applied
  - For smaller LOCA scenarios up to the largest branch line off the RCS main loop, core cooling analyses using acceptable extensions to approved evaluation models demonstrate that clad burst does not occur
  - Additionally, an assessment of LOCAs from RCS non-piping component ruptures based on design, fabrication, procedure, ISI requirements, and operating experience is performed for defense-in-depth

Materials Reliability Program: xLPR Estimation of PWR Loss-of-Coolant Accident Frequencies (MRP-480)

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