Use of Probabilistic Fracture Mechanics in Licensing of New Fuels

RG_08

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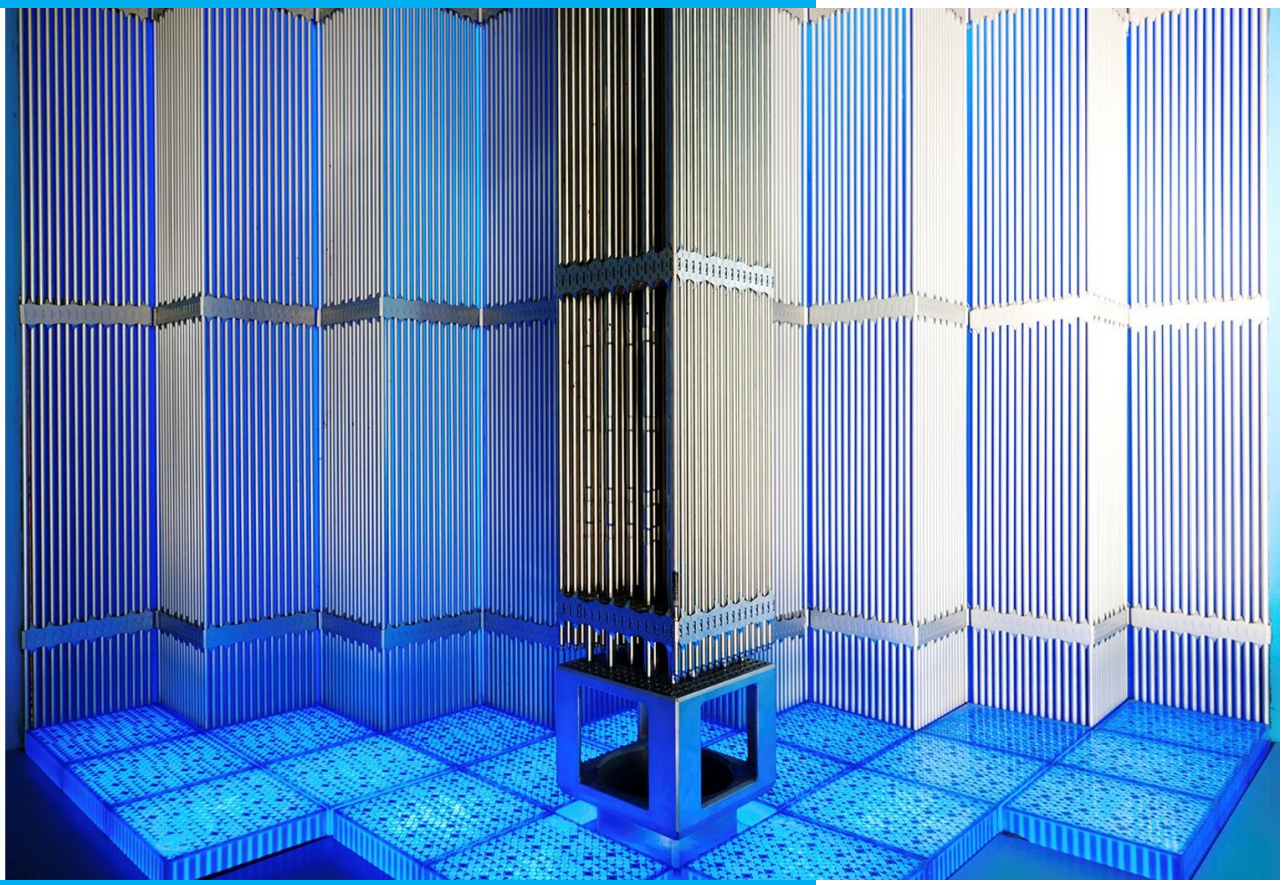
Introduction

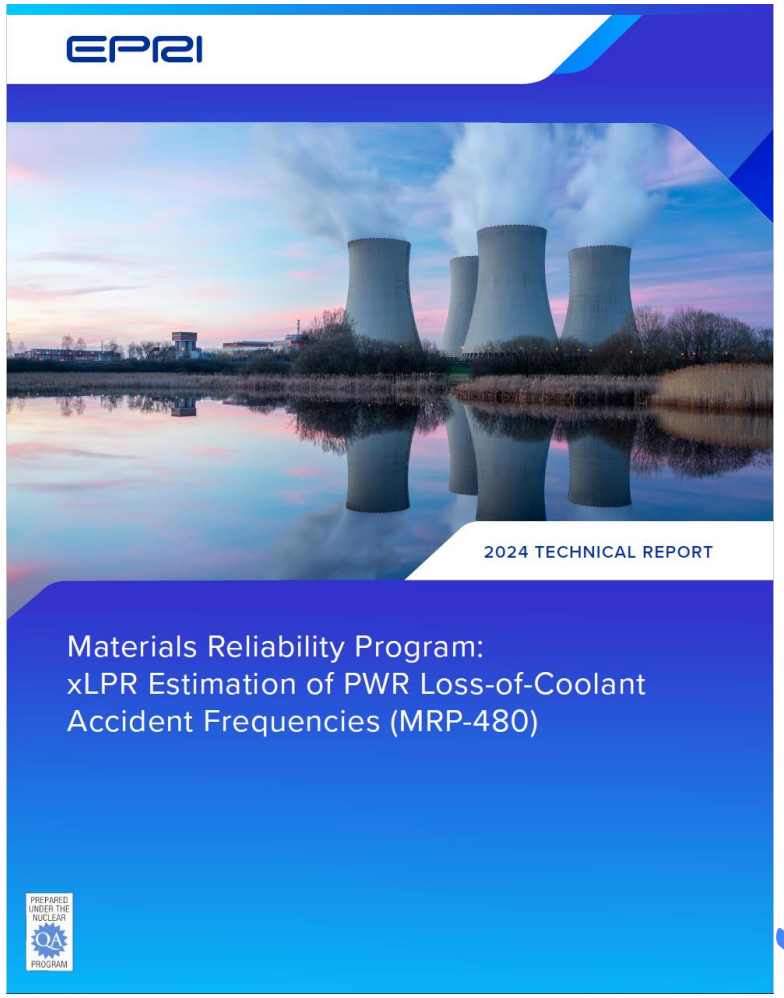


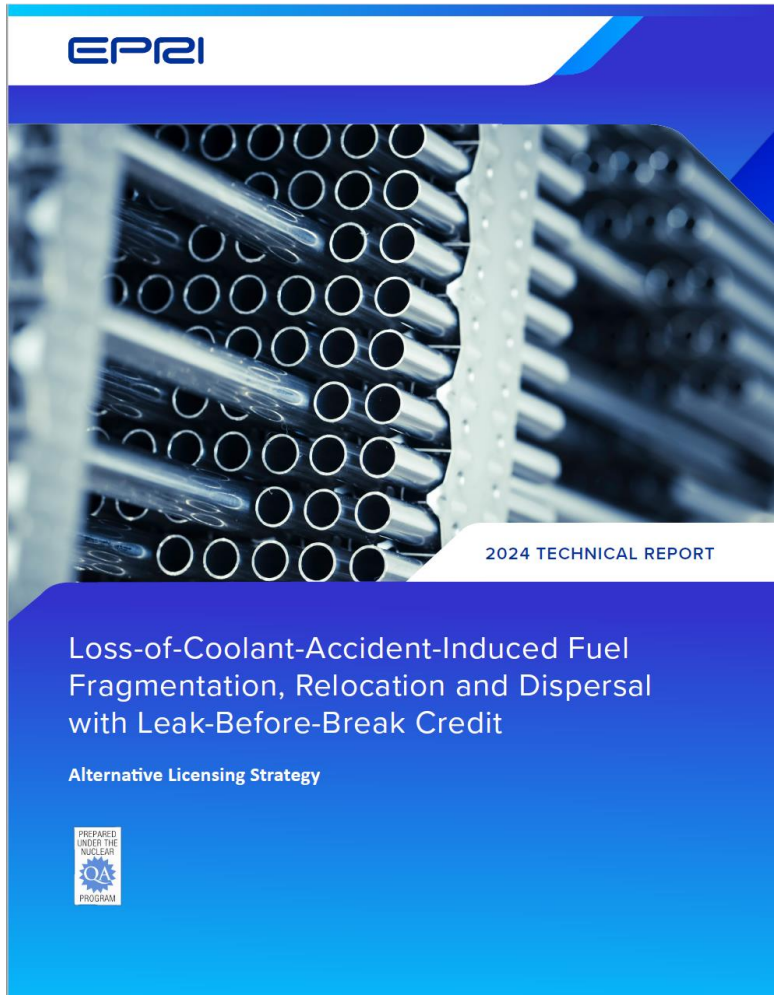
- Key challenge to increasing the maximum allowable burnup of fuel is the potential for a loss of coolant accident (LOCA) to induce fuel fragmentation, relocation, and dispersal (FFRD)
- The conventional licensing approach relies on fuel testing and measurements
- Limited test facilities and challenges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

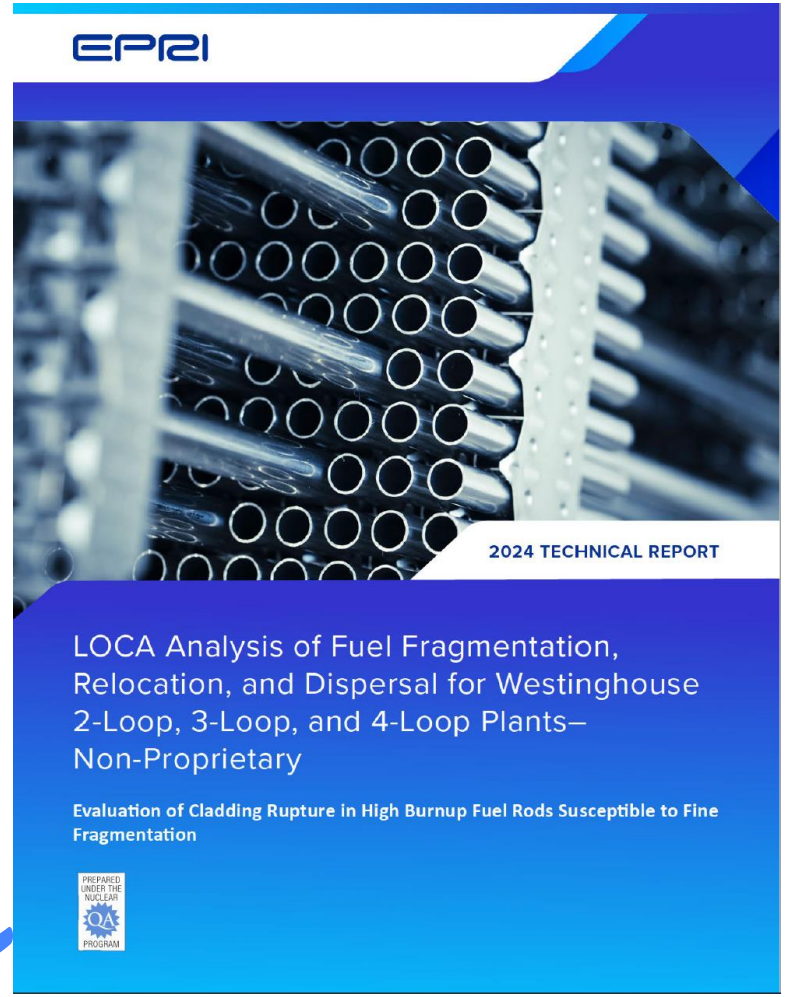
Alternative Licensing Strategy

- 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

ALS Submittals

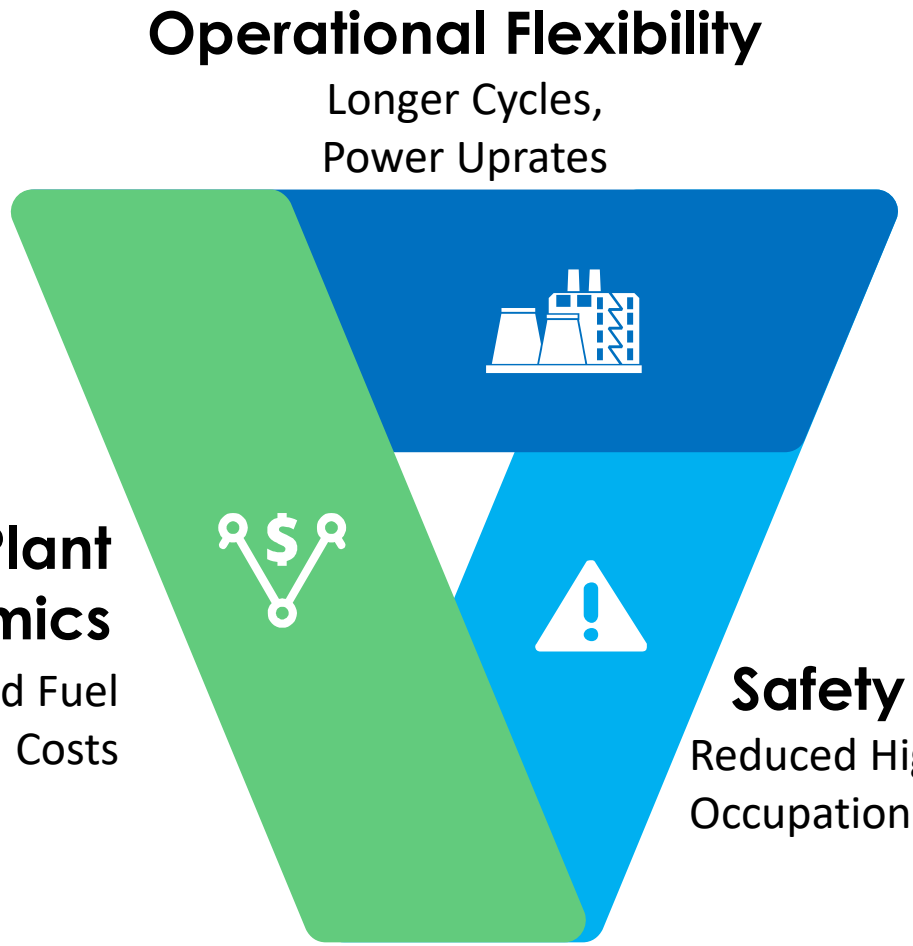






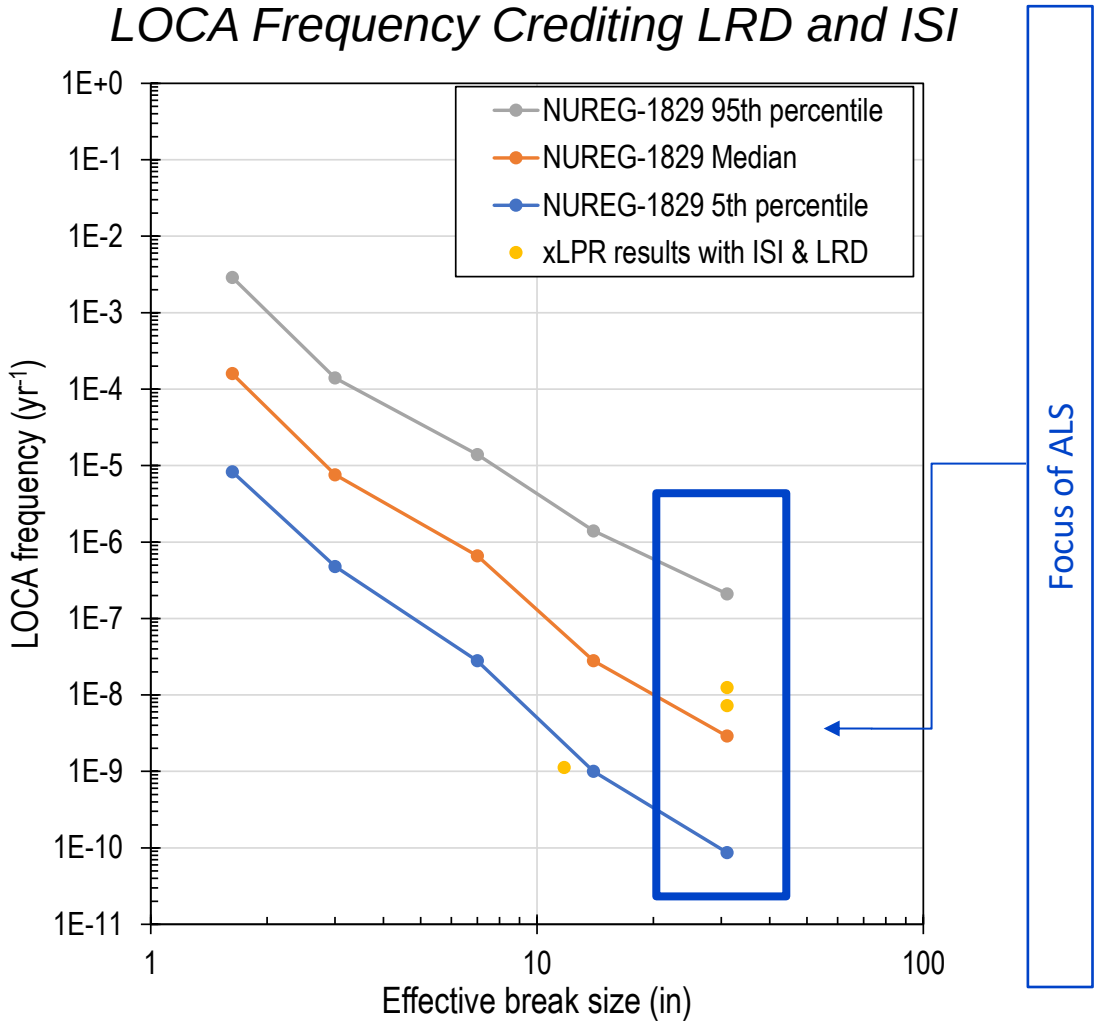
Value of ALS

Implementation of increased fuel burnup allows for:



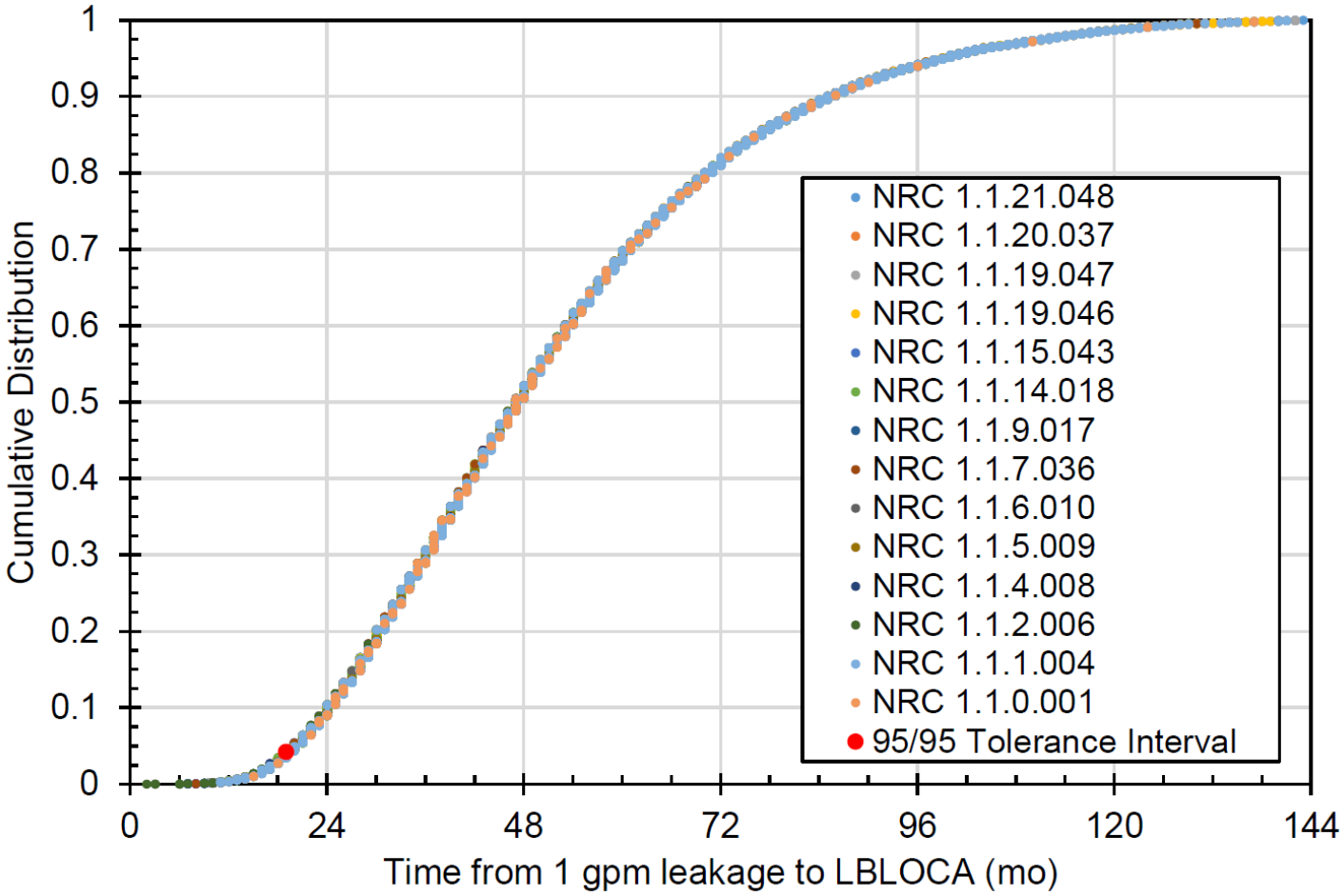
xLPR Involvement

- 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



Next Steps

- Regulatory Review Status
  - EPRI submitted a topical report addressing LOCA induced FFRD in PWRs to the U.S. NRC on April 30, 2024
  - NRC has accepted the submittal for review and has planned the review of all three documents over the next two years
- Utility planned implementation
  - Licensees desiring to implement increased fuel burnup limits will be required to submit a license amendment request (LAR) to address regulatory requirements for showing acceptable performance for the range of possible piping break sizes and locations

Conclusions

- The ALS provides a basis for excluding fuel dispersal for PWR LOCA events.
  - 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

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