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NRR Perspectives on Probabilistic Fracture Mechanics Calculations

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Risk-Informed Decision Making

- The NRC has been using probabilistic risk assessments to guide decision making in several areas for many years
- The NRC has used probabilistic fracture mechanics (PFM) code FAVOR to develop the alternate Pressurized Thermal Shock Rule (10CFR50.61a)
- The NRC is cooperatively developing the "Extremely Low Probability of Rupture" (xLPR) Probabilistic fracture mechanics code to evaluate the leak before break methodology
- The NRC is open to evaluating and using PFM codes in the future to assist in regulatory decision making and recognizes the powerful insights provided by PFM

Nexus Between PFM and PRA

- A PFM will produce probabilities of some event
  - Crack reaching 75% through wall extent
  - Leakage
  - Pipe Rupture
  - Nozzle Ejection
- Some events may be used to determine the Core Damage Frequency (CDF) or Large Early Release Frequency (LERF)
- If a PFM calculation is to be used to calculate CDF and LERF, a review by Probabilistic Risk Assessment (PRA) experts should be performed to assure that the PFM will provide appropriate information

Defense in Depth

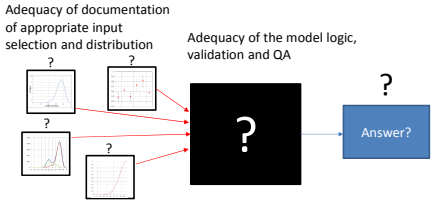
- From Regulatory Guide 1.174
  - The use of PRA technology should be increased in all regulatory matters to the extent supported by the state-of-the-art in PRA methods and data and in a manner that complements the NRC's deterministic approach and supports the NRC's traditional defense-in-depth philosophy.
- Many inspections of nuclear components are performed under the "Defense in Depth" strategy, and not on a strict risk basis
- The impact of inspections on risk is challenging to quantify, as many unknowns are involved
- Using PRAs or risk calculations to eliminate or severely reduce inspections must be considered with respect to the defense-in-depth strategy

Misunderstanding of N-729 Approval

- In recent public meetings members of industry view the NRC acceptance of ASME Code Case N-729-1, with an inspection regime detailed in MRP-105, as an acceptance of the PFM work performed in MRP-105
- The NRC issued Order EA-03-009 to provide reasonable assurance of leak tightness and structural integrity of PWR top heads
- ASME Code Case N-729-1 describes a very similar inspection schedule as order EA-03-009
- NRC acceptance of N-729-1 was based on deterministic calculations that validated the inspection scheme in N-729-1
- PFM calculations were considered complimentary but not sufficient to establish reasonable assurance of leak tightness and structural integrity

Challenges with Probabilistic Fracture Mechanics

- Unlike deterministic calculations that the NRC staff can reproduce, PFM calculations present NRC reviewers with computer programs that can be very difficult to review
- Absent an extensive review of the code and inputs by the NRC staff, it is very challenging for to determining if the PFM calculations are adequate to determine reasonable assurance



Challenges with NRC Reviews of PFMs

- NRR staff need to reconcile selection of distributions and uncertainties for inputs such as flaw initiation probabilities
  - Submittals must provide clear documentation
- NRR staff need to validate the methods and outputs used to determine or establish success/failure criteria
- NRR staff needs to evaluate the codes and modeling methods
  - Need a clear understanding of how the code works

Review Timeliness Affected By:

- Submitting a PFM calculation based on inputs that are adequately and appropriately documented
- Use of codes that have an existing NRC safety evaluation or NUREG
  - e.g. FAVOR
- Submitting a PFM and using a code with which we are unfamiliar
  - Evaluating the code is challenging
- Submitting a PFM calculation based on a code that we have not yet accepted, such as components of xLPR
  - Some subcomponents may be approved earlier than others
- User modified codes
  - Need to understand the modifications
- Using a PFM to eliminate classes of volumetric inspections
  - This may be contrary to defense in depth
  - Not specific to PFM

How Can NRC Staff Double Check PFM Results?

- Aspects of PFM the staff needs to review
  - Input distributions
  - Calculation logic
  - Software QA
  - Success/failure criteria
- Possible methods for verifying the results
  - Having the code directly evaluated by NRC staff
  - Benchmarking the code against one we have developed (if it exists)
  - Independent peer review
  - Confirmatory deterministic calculations

Path Forward for PFM

- NRR is working with RES to determine the important characteristics of a PFM
- RES will develop a NUREG on the important aspects of PFMs
- RES will work to develop a Regulatory Guide on the use of PFMs for regulatory decision making
  - Provide a framework for submissions to the NRC to address issues described in this presentation
  - What level of rigor is needed for regulatory decision making?
- Continue dialogue with stakeholders