Path to Updating Spent Fuel Cladding Performance Limits

Technical Meeting on the Behaviour of Spent Fuel and Cladding During Storage and the Performance of Spent Fuel Storage Systems

Seoul, South Korea

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PIRTs - Background

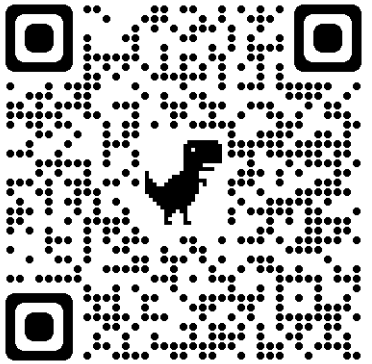
- Conducted 5 Phenomena Identification and Ranking Table (PIRTs)
  - Spent fuel cladding integrity - 3002018439 (2020)
  - Gross rupture - 3002020929 (2021)
  - Alternate fuel performance metrics - 3002023961 (2024)
  - Thermal modeling – 3002018441 (2020)
  - Decay heat – 3002018440 (2020)

- PIRTs identified options for changes/improvements
- Final step is to implement what we learned from PIRTs

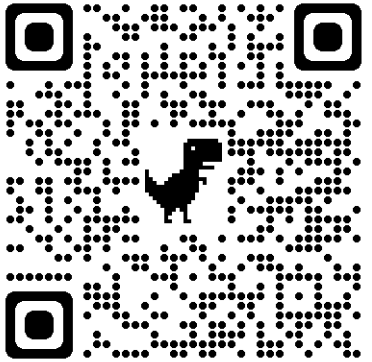
Background

- Fuel Performance PIRT
  - The onset of fuel failure is not abrupt, but rather a continuum **no cliff-edge effect** is associated with the current NRC recommended 400 °C limit (ISG-11 Rev. 3)

- Decay Heat PIRT
  - Regulatory guidance (RG. 3.54 Rev. 1) significantly **overestimates** decay heat over wide range of fuel burnups.

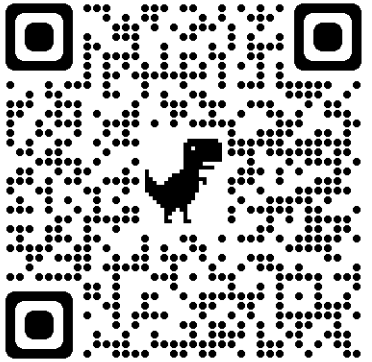


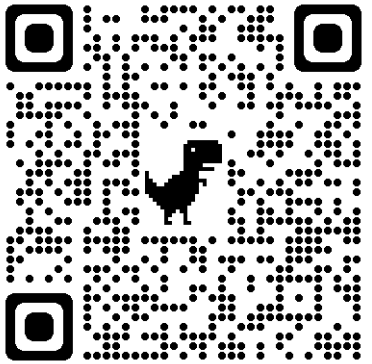
- Thermal PIRT
  - Excess conservatism in thermal calculations leads to **negative impact on worker dose** and fuel performance



Background

- Gross Rupture PIRT
  - **RCS chemistry records from operation** may be used to establish if fuel cladding gross rupture failure occurred to determine storage requirements
- Alternate Fuel Performance Metrics PIRT
  - **Increasing peak cladding temperature (PCT) limit** to 450°C or 500°C are potentially acceptable metrics to pursue
    - Other metrics considered but not recommended: hoop stress, average cladding temperature



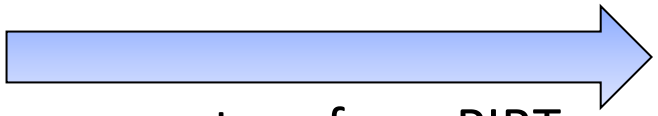


PIRT Implementation

- Team of industry champions assembled
  - Reviewed PIRT results
  - Identified industry priorities and implementation path forward

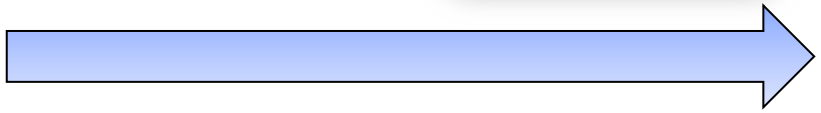
➢ Gross Rupture

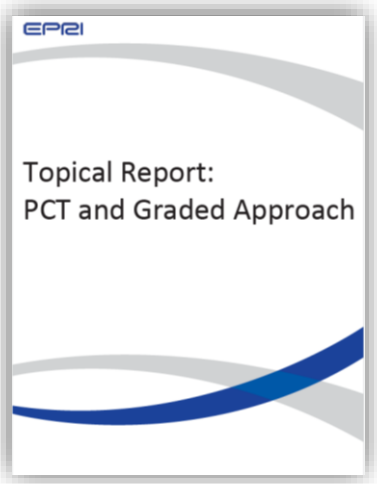
- New definition of gross rupture from PIRT



➢ PCT and Graded Approach

- Increase PCT limit to 450°C
- Include defined graded approach





- Presented planned approach to NRC 8/19/24
  - Submit fee waiver request, then withdrawn because it was too soon

Gross Rupture

Gross Rupture Topical Report - Background

- Unclear guidance in NUREG-2215
  - p xxviii: "Gross Breach. A breach in the spent fuel cladding that is larger than either a pinhole leak or a hairline crack and **allows the release of particulate matter** from the spent fuel rod."
  - p8-35 "SFAs with any of the following characteristics … are expected to be classified as damaged:

    Reactor operating records or fuel classification records **indicate** that the SFA contains **fuel rods with gross breaches**."
  - p8-36: "gross breaches should be considered to be **any cladding breach greater than 1 mm (0.04 in.)**."
- And in NUREG-2216
  - p7-26: "gross breaches should be considered to be **any cladding breach greater than 1 millimeter**."
  - p7-49: "The staff considers that adequate reactor operating records that identify **only gaseous or volatile decay products (no heavy metals)** in the reactor coolant system are acceptable evidence that **cladding breaches are no larger than a pinhole leak or hairline crack**."

Current definition of gross rupture **non-actionable** due to:

- Lack of criteria regarding use of reactor operating records
- Demonstration that 1mm criteria is met difficult to achieve

Gross Rupture Topical Report

- Implement new definition of gross rupture to use chemistry records in lieu of defect size criteria requiring fuel inspections (e.g. sipping) to demonstrate cladding integrity
  - Develop and document the technical basis
    - Use input from Gross Rupture PIRT and recent PNNL report
    - Review and analyze chemistry data against fuel performance data
      - Develop guidance regarding:
        - Key parameters and criteria (e.g. Xe ratios)
        - Applicability criteria (e.g., quality of chemistry records)
      - Include defense-in-depth analysis for impact of a loss of confinement/containment considering new gross rupture definition

PNNL-36653 - Assessment of Alternative Criteria for Gross Ruptures in Spent Nuclear Fuel, Oct 2024

Gross Rupture Topical Report - Considerations

- Need for durable guidance
  - Topical report to be approved by NRC
  - NRC issues Safety Evaluation Report
- Leverage recent work evaluating fuel failure against chemistry records
- Evaluate existing plant procedures/processes
  - Do no harm – ensure gross rupture application does not go against existing practice
  - What can be leveraged for gross rupture topical

Gross Rupture Implementation

- Benefits
  - Clarify NRC guidance inconsistencies
  - Reduce use of damaged fuel cans
    - Don’t need damaged fuel can for tight leakers
  - Eliminate sipping campaigns of fuel from leaking cores
    - If RCS chemistry indicates failure did not release fuel
      - All fuel from that discharge cycle can be loaded without damaged fuel can
      - No need to identify leaking fuel assembly
    - Reduce risk by reducing fuel moves
    - Reduce dose to workers
- Straightforward implementation
  - NRC review and approval through Safety Evaluation Report
  - Licensees reference SER – No amendment needed

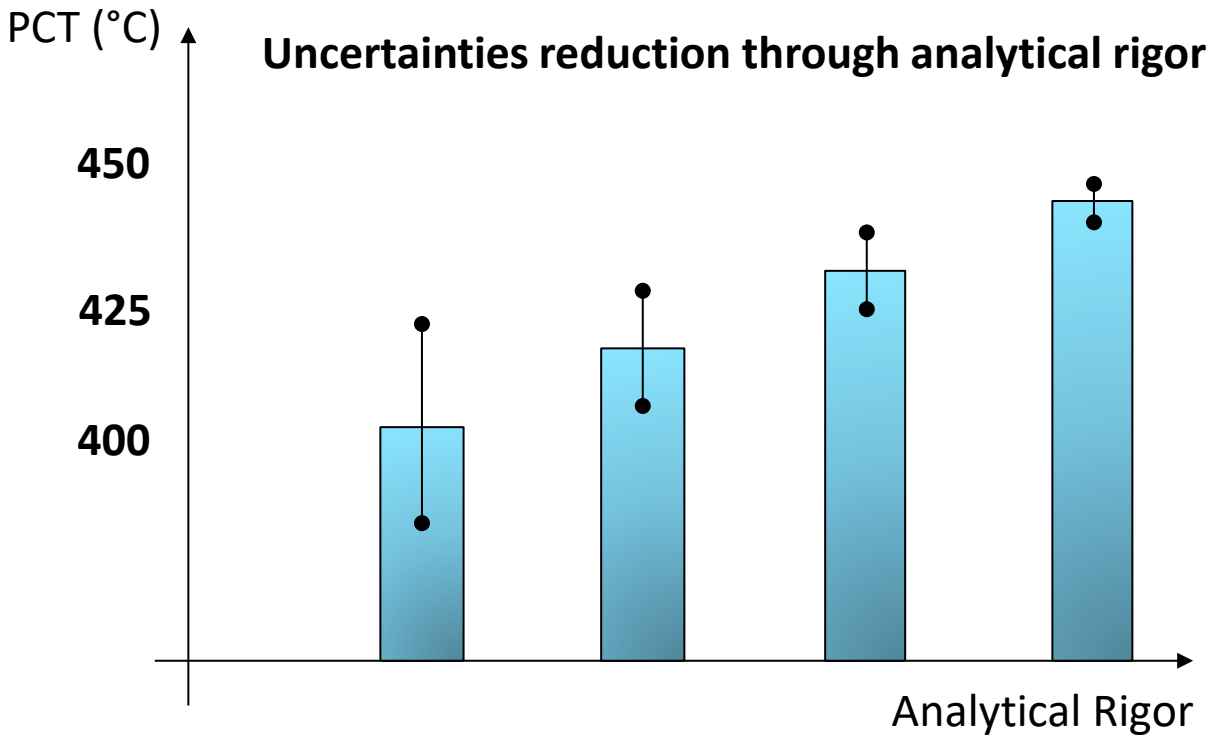
Peak Cladding Temperature and Graded Approach

PCT and Graded Approach Topical Report

- Implement increased PCT limit of 450°C
  - Include a graded approach for storage and transportation safety analyses
    - Allow less rigor when more margin exists
  - Develop and document the technical basis from:
    - Input from Alternate Fuel Performance Metrics PIRT
  - Recognized challenges
    - Limited data available above 400°C
    - Reduced yield strength due to increased annealing
      - Current NRC acceptance criteria is yield
      - Alternate criteria or approach needed

Peak Cladding Temperature – Graded Approach

Graded approach would require increased analytical rigor to tighten uncertainties as you approach 450°C limit



Objective: Develop a risk-informed and graded approach and
avoid making licensing more complicated with additional analyses where more margin exists

PCT and Graded Approach Implementation

- Benefits
  - Improve operational flexibility
    - Shorter loading times
    - More time for certain operations
    - Eliminate supplemental cooling system
    - Add shielding without impacting thermal analysis
  - Improve regulatory review process
    - Graded approach to apply resources more efficiently and effectively
- Longer term and multi-step implementation
  - NRC review and approval topical through Safety Evaluation Report
  - Cask vendors submit amendments
    - Reanalyze using higher PCT limit
    - Prepare and submit amendment referencing SER
  - NRC review and approve amendments for 450°C
  - Licensees adopt new amendment

Summary

Summary and Future Activities

- Gross rupture
  - Prepare gross rupture topical report with industry support
    - Develop criteria using fuel and chemistry data
    - Develop case study for how to implement
    - Include industry review
    - Fee waiver
  - Submit gross rupture topical report for NRC review and approval

- PCT and graded approach
  - Seek out additional data and conduct new tests to generate data
  - Prepare topical report
  - Fee waiver
  - Submit for NRC review and approval

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