

# NRC Staff Review of Framatome Topical Report ANP-10358P, Revision 0, “Increased Burnup for PWRs”

Open Presentation to the Advisory  
Committee on Reactor Safeguards

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# Review Team

The Nuclear Methods and Fuel Analysis Branch review team consisted of:

- Joseph Messina
- Richard Fu
- Jack Vande Polder
- Kevin Heller
- Patrick Raynaud (departed NRC)

# Presentation Outline

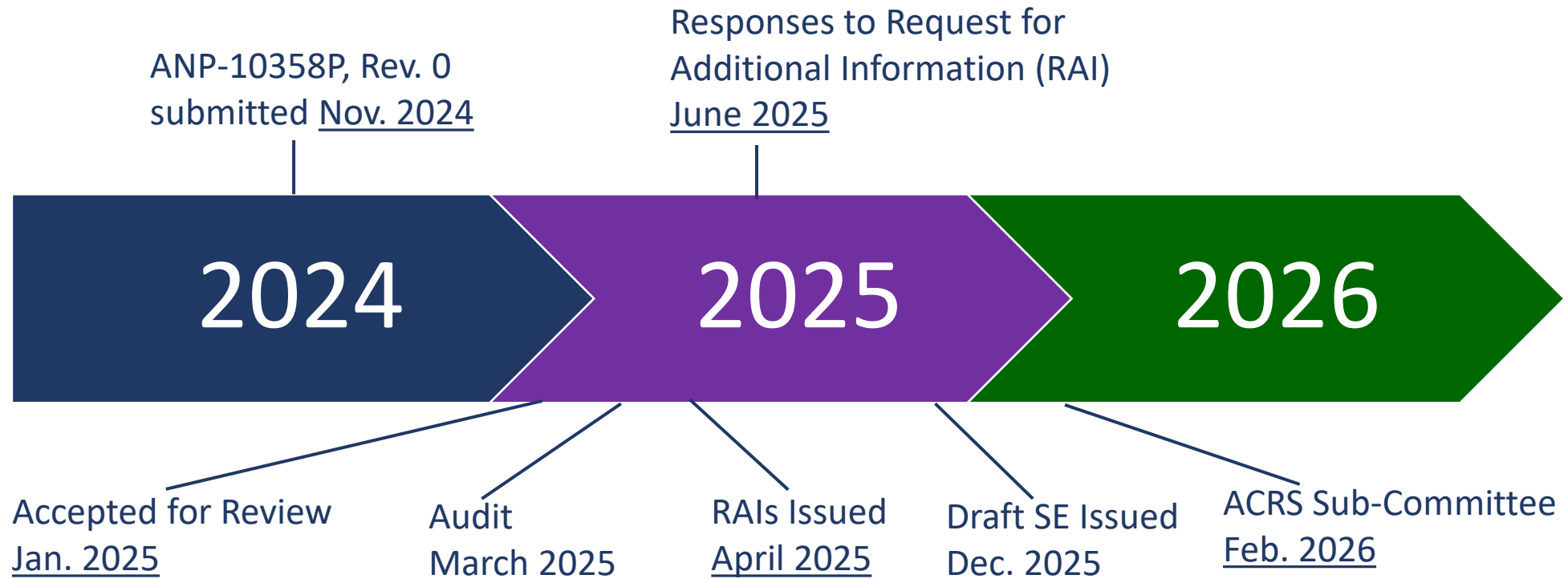
- Introduction
- Review timeline
- Key regulatory requirements and guidance
- Core and fuel design
- Non-Loss of Coolant Accident (LOCA) safety analysis
- LOCA safety analysis
- Conclusions

# Introduction

- ANP-10358P, Rev. 0 proposes to extend Framatome's codes and methods to burnups greater than 62 Gigawatt-days per Metric Ton of Uranium (GWd/MTU)
  - Framatome considers the burnup limit to be proprietary
- ANP-10358P, Rev. 0 contains a comprehensive evaluation of the capability of Framatome's analysis methods to address fuel performance up to the requested burnup limit
- ANP-10358P, Rev. 0 addresses fuel dispersal
  - Focal point of review
  - Proprietary discussion during the closed session.

# Review Timeline

## Framatome



**NRC**

# Key Regulatory Requirements and Guidance

- Fuel and Core Performance
  - General Design Criterion 10, Reactor Design
    - Specified acceptable fuel design limits to assure cladding integrity for normal operation and anticipated operational occurrences
  - NUREG-0800, Standard Review Plan, Chapter 4.2
    - The fuel system is not damaged due to normal operation and anticipated operational occurrences
    - Fuel system damage is never so severe as to prevent control rod insertion when required
    - The number of fuel rod failures is not underestimated for postulated accidents
    - Core coolability is maintained

# Key Regulatory Requirements and Guidance

- Loss-of-Coolant Accident (LOCA)
  - 10 CFR 50.46
  - General Design Criterion 35, Emergency core cooling
  - Appendix K to 10 CFR 50
  - NUREG-0800, Standard Review Plan
    - Chapter 15.6.5, “Loss-of-Coolant Accident”
    - Chapter 15.0.2, “Review of Transient and Accident Analysis Methods”
  - Regulatory Guide 1.157, “Best-Estimate Calculations of Emergency Core Cooling System Performance”
  - Regulatory Guide 1.203, “Transient and Accident Analysis Methods”

# Key Regulatory Requirements and Guidance

- Non-LOCAs and Transients
  - NUREG-0800, Standard Review Plan, Chapter 15
  - Regulatory Guide 1.203, “Transient and Accident Analysis Methods”
  - General Design Criterion 27
    - Combined reactivity control systems capability
  - General Design Criterion 28
    - Reactivity limits
  - Regulatory Guide 1.236, “Pressurized-Water Reactor Control Rod Ejection and Boiling-Water Reactor Control Rod Drop Accidents”

# Fuel Assembly Mechanical Design

- Framatome evaluated the applicability of existing fuel designs and methodologies to higher burnups.
- The Framatome GAIA 17x17, High Thermal Performance (HTP) 14x14, HTP 15x15, and HTP 16x16 fuel assemblies is generically approved for the burnup extension.
  - Limitation and Condition 1
  - Other designs can be approved on a generic or plant-specific basis.
- The NRC staff found that the proposed assembly design criteria and evaluation methods were acceptable.

# Nuclear Design

- Framatome proposed to continue using the existing nuclear design code package, ARCADIA.
- Justification was provided for use up to the requested burnup limit with comparisons to experimental data.
  - Framatome performed an isotopic comparison of APOLLO2-A to samples with a burnup greater than 71 GWd/MTU.
  - Power distribution uncertainties were developed for moveable incore fission detectors, fixed rhodium self powered neutron detectors, and Aeroball Measurement System incore detectors.
  - Local (pin to pin) and global (assembly to assembly) predicted and inferred power distribution predictions were compared to experimental data.
- The NRC staff found ARCADIA to be acceptable up to the requested burnup limit.

# Fuel Rod Design

- Analyses will use Framatome's NRC-approved GALILEO code
- Framatome addressed the applicability of key models up to the requested burnup limit for each fuel rod design basis
  - M5 cladding material models previously reviewed and approved to the requested burnup limit in BAW-10227P-A, Rev. 2
  - Q12 (ANP-10334P-A) structural material models extended to the requested burnup limit
  - GALILEO fuel thermal-mechanical performance code previously reviewed and approved for M5 to the requested burnup limit in ANP-10323P-A, Rev. 1
- New fuel rod internal pressure limit
- The NRC staff found the fuel rod design methods to be acceptable up to the requested burnup limit.

# Thermal-Hydraulic Design

- Framatome stated that no modifications are needed for key thermal-hydraulic design methods:
  - Critical Heat Flux correlations
  - COBRA-FLX subchannel code
  - Fuel rod bow method
- The NRC staff found the thermal-hydraulic methods to be acceptable up to the requested burnup limit.

# Non-LOCA Safety Analysis

- Framatome addressed the applicability of the ARTEMIS/RELAP Integrated Transient Analysis (ARITA), ANP 10339P, Rev. 0 method to the requested burnup limit.
  - Individual codes within the methodology were found acceptable to the requested burnup limit in respective topical reports or via the current review
  - Uncertainty treatments for key neutronic parameters that are potentially affected by higher burnups were assessed and found acceptable
- Framatome justified the applicability of the ARCADIA Rod Ejection Accident (AREA) method.
- RG 1.236 applicability
- The NRC staff found Framatome's non-LOCA methods to be acceptable up to the requested burnup limit.

# LOCA

- New packing factor model
- Minor updates to Framatome's realistic large break LOCA method
- Least transient oxidation margin figure of merit to address cladding embrittlement research findings in SECY-16-0033 (draft final 50.46c rule) and NUREG/CR-7219.
- Fuel dispersal
- The NRC staff found the Framatome's treatment of LOCA and fuel dispersal to be acceptable within the current regulatory framework.

# Conclusion

- The NRC staff found the ANP-10358P, Rev. 0 increased burnup methodology provides an acceptable approach for comprehensively evaluating fuel operation within the requested burnup limit subject to the following limitations and conditions
- Limitations and conditions:
  1. Applicability ranges:
    - Framatome GAIA 17x17, HTP 14x14, HTP 15x15, and HTP 16x16 fuel assemblies in Westinghouse and Combustion Engineering PWRs
    - Standard uranium dioxide (UO<sub>2</sub>) or UO<sub>2</sub> fuel with gadolinia up to a proprietary concentration
    - Up to the proprietary burnup limit
  2. Proprietary limitation and condition to be discussed in closed session

Questions