NRC Pre-Application Meeting
TN-B1 Package Amendment
Docket No. 9372

December 13, 2022

Agenda

1. Framatome Team
2. Project Description
3. Contents >5 wt.% ^{235}U Enrichment
4. Fuel Assembly Details
5. Criticality Evaluation
   a) Methods of Analysis
   b) Benchmarking
6. Structural Evaluation
7. Thermal, Containment, and Shielding Discussion
8. Proposed Schedule
9. Opportunity for Public Comment
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Framatome Team

- **Framatome**
  - Tim Tate, Manager, Environmental, Health, Safety, and Licensing
  - Calvin Manning, Manager, Licensing and Compliance
  - Bryan Flanagan, Packaging Engineer, Licensing and Compliance
  - Kevin Elliott, BWR Product Engineer
  - Michelle Guzzardo, Nuclear Criticality Safety Engineer
  - Ben Nelson, Nuclear Criticality Safety Engineer
  - Colin Weber, Health Physicist
- **ORANO Federal Services**
  - Rob Machen, Project Manager
  - Phil Noss, Licensing Manager
  - Slade Klein, Engineering Manager
  - John Scaglione, Nuclear Criticality Safety Engineer
  - Donald Mueller, Nuclear Criticality Safety Engineer

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Project Description

Advanced Fuel Management (AFM) Project

- Significantly reduce the utility customer's operating costs in the near term by bringing to market technologies which increase cycle lengths and capacity factors (PWR)
- Reducing the number of fresh fuel assemblies (BWR)
- Improving fuel cycle economics
- Framatome is working in conjunction with a US reactor site to realize these benefits
- Following the same evaluation process used for the MAP package amendment (Docket 71-9319)

NRC License Amendment Request

- Increase allowable enrichment above 5 wt.% ^{235}U for 11x11 fuel assemblies
- Includes BWR 11x11 and PWR 17x17 Type 3 loose fuel rod configuration above 5 wt.% ^{235}U

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Contents >5 wt.% ^{235}U Enrichment

- **Type A and Type B Contents**
  - Both Type A and Type B contents shall remain the same material, fuel pellets loaded in rods are uranium oxides primarily as ceramic UO_2 and U_3O_8. The maximum enrichment is being increased up to 8.0 wt.% ^{235}U, within high assay low enriched limits.
- **New Contents Tables for >5 wt.% ^{235}U material**
  - Table for < 5.0 wt.% ^{235}U will remain unchanged
- **Basis for Primary Radionuclides**
  - Source for new material will conform to ASTM standard being developed for Uranium Hexafluoride (ASTM number not yet assigned). Same as used for MAP package.

Enriched Commercial Grade UF_6			
	with ^{235}U <6%	with ^{235}U <7%	with ^{235}U <8%
^{232}U	0.0001 µg/gU	0.0001 µg/gU,	0.0001 µg/gU,
^{234}U	11.910×10^3 µg/g^{235}U	12.020×10^3 µg/g^{235}U	13.0×10^3 µg/g^{235}U
^{236}U	250 µg/gU	250 µg/gU	250 µg/gU
^{99}Tc	0.012 µg/gU	0.014 µg/gU	0.017 µg/gU

Enriched Slightly Contaminated Uranium with Trace Quantities Limits UF_6			
	with ^{235}U <6%	with ^{235}U <7%	with ^{235}U <8%
^{232}U	0.080 µg/gU	0.095 µg/gU	0.110 µg/gU
^{234}U	5650 µg/gU	6650 µg/gU	7650 µg/gU
^{236}U	Not specified	Not specified	Not specified
^{99}Tc	6 µg/gU	7 µg/gU	8.5 µg/gU

Contents >5 wt.% ^{235}U Enrichment

Comparison of Quantity of Radioactive Material for Shipment in TN-B1

- SAR Table 1-2

Current Table 1-2

Allowable Assembly Arrays	8x8, 9x9, 10x10 and 11x11
Main Nuclides	Low enriched uranium ≤ 5 wt% ^{235}U
State of Uranium	Uranium oxide ceramic pellet, (Solid)
Fuel Assembly Average Enrichment	5.0 wt% Maximum
Fuel Rod Maximum Enrichment	5.0 wt% Maximum
Number of Fuel Rods Containing gadolinia	See Table 6-1
Maximum mass of Uranium Dioxide Pellets	574 kg per Fuel Assembly 1,148 kg per Package
Weight of uranium dioxide pellets (per fuel assembly	235 kg (8x8), 240 kg (9x9), 275 kg (10x10), 281 kg (11x11)

New Column for >5 wt.% ^{235}U

Allowable Assembly Arrays	11x11
Main Nuclides	Low enriched uranium ≤ 8 wt% ^{235}U
State of Uranium	Uranium oxide ceramic pellet, (Solid)
Fuel Assembly Average Enrichment	8.0 wt% Maximum
Fuel Rod Maximum Enrichment	8.0 wt% Maximum
Number of Fuel Rods Containing gadolinia	See Table 6-1
Maximum mass of Uranium Dioxide Pellets	574 kg per Fuel Assembly 1,148 kg per Package
Weight of uranium dioxide pellets (per fuel assembly	281 kg

Contents >5 wt.% ^{235}U Enrichment

Comparison of Maximum Allowable Quantity of Radioactive Material

- SAR Table 1-3

Current Table 1-3

Isotope	Maximum Content	
U-232	2.00E-09	g/gU
U-234	2.00E-03	g/gU
U-235	5.00E-02	g/gU
U-236	2.50E-02	g/gU
U-238	9.23E-01	g/gU
Np-237	1.66E-06	g/gU
Pu-238	6.20E-11	g/gU
Pu-239	3.04E-09	g/gU
Pu-240	3.04E-09	g/gU
Gamma Emitters	5.18E+05	MeV-Bq/kgU

Add New Table 1-3a for >5 wt.% ^{235}U

Isotope	Maximum Content	
U-232	1.10E-07	g/gU
U-234	7.65E-03	g/gU
U-235	8.00E-02	g/gU
U-236	2.50E-02	g/gU
U-238	8.87E-01	g/gU
Np-237	1.66E-06	g/gU
Pu-238	6.20E-11	g/gU
Pu-239	3.04E-09	g/gU
Pu-240	3.04E-09	g/gU
Gamma Emitters	5.18E+05	MeV-Bq/kgU

Contents >5 wt.% ^{235}U Enrichment

- **Gadolinia Requirements for >5 wt.% ^{235}U**
  - No gadolinia requirements for loose rods
  - ATRIUM 11

Fuel Assembly Type	Type 11x11	
Parameter	# Gd Rods	Wt.% Gd_2O_3
Min Gadolinia Requirements		
Lattice Average Enrichment		
Max 8.0 wt.% ^{235}U	21	4.0
≤ 7.5 wt.% ^{235}U	19	4.0
≤ 7.0 wt.% ^{235}U	17	4.0
≤ 6.5 wt.% ^{235}U	15	4.0
≤ 6.1 wt.% ^{235}U	13	4.0
≤ 5.8 wt.% ^{235}U	13	2.0

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Fuel Assembly Details

- **ATRIUM 11 (11x11) Parameters Versus Previously Approved Fuel Assemblies**
  - No changes from existing CoC

- **Loose Rods**
  - Now includes PWR 17x17 Type 3 for >5 wt.% ^{235}U

17x17 Type 3 Fuel Rod	
Maximum Pellet OD, in	0.3254
Minimum Pellet OD, in	0.3188
Minimum Fuel Rod OD, in	0.372
Minimum Clad Wall Thickness, in	0.0205

  - For the generic PWR fuel rod parameters in the current CoC, the Fuel Rod OD is less than the current minimum. All other criteria, including Cladding Wall Thickness, is bounding.
  - The 17x17 Type 3 parameters will be distinguished within the SAR for the ≤ 8.0 wt.% ^{235}U

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Criticality Evaluation

Methods of Analysis

- Criticality evaluations performed using SCALE 6.2.4
  - CSAS5 (Keno-Va) Monte Carlo neutron transport code
  - Focus on same 11x11 assembly models with increasing enrichments > 5.0 wt% U-235
  - Gd_2O_3 fuel rods used for criticality control (multiple configurations evaluated for different enrichments)
- Licensing basis consistent with current SAR methodology to identify the most reactive credible configuration consistent with the chemical and physical form of the material
  - Configuration based on fuel at T.D. and preferential flooding (fully flooded fuel cavity), void in cavity between inner and outer containers for HAC array
  - 10.2 kg of polyethylene, not including cushioning foam pads

Benchmarking

- Benchmarks selected from the International Handbook of Evaluated Criticality Safety Benchmark Experiments (IHECSBE) that contains ~5,000 laboratory critical experiments performed at various critical facilities around the world
- Sensitivity/Uncertainty Analysis are being used to mathematically identify applicable critical experiments to the application model
  - TSUNAMI-3D (Scale module) used to generate sensitivity data file (SDF) for licensing basis application model
  - TSUNAMI-IP (Scale module) used to evaluate the similarity of critical experiments to application model (SDFs for critical experiments are taken from IHECSBE)
  - Bias and bias uncertainty for application model generated using k_{eff} results for applicable sets of critical experiment models and single-sided tolerance interval for 95% probability and 95% confidence level

Criticality Evaluation

- **Selection of critical experiments**
  - The critical experiments and the safety basis model need to use the nuclear data in a similar energy-dependent manner; otherwise, an incorrect bias could be generated
  - Historically, similarity has been left largely to engineering judgment using qualitative and integral quantitative comparisons to select critical experiments
- **Sensitivity/uncertainty (S/U) tools can be used to assess application and critical experiment model similarity with a quantifiable metric**
  - Uncertainty analysis is performed for the safety analysis (application) model and for each candidate critical experiment model
    - Sensitivity is the fractional change in k_{eff} due to a fractional change in a nuclear data value or $S \equiv (\Delta k/k)/(\Delta\sigma/\sigma)$
  - Energy-dependent k_{eff} uncertainties for each application model and each critical experiment are compared, producing a correlation coefficient (c_k) for each application/experiment model pair
    - The similarity of a benchmark to the application is characterized by the correlation coefficient, c_k, which is calculated by TSUNAMI-IP
    - A high c_k value of near 1 for an application/critical experiment pair indicates that both models have similar sensitivities to the same nuclear data and consequently should have similar biases
    - Low c_k values indicate that the two systems differ significantly and may have significantly different biases

Criticality Evaluation

CSI DRAFT Results

- Atrium 11 fuel assemblies with the specified maximum lattice average enrichments with each assembly containing a minimum number of UO_2+Gd_2O_3 fuel rods with minimum Gd_2O_3 loading maximum CSI is less than or equal to 3.3.

Wt% ^{235}U	#Gd rods	wt% Gd_2O_3	CSI
≤ 8.0	21	4.0	3.2
≤ 7.5	19	4.0	3.2
≤ 7.0	17	4.0	3.2
≤ 6.5	15	4.0	3.2
≤ 6.1	13	4.0	3.2
≤ 5.8	13	2.0	3.2

- Atrium 11 fuel rods with enrichments no greater than 8.0 wt% ^{235}U
  - Up to 25 loose or bundled fuel rods, CSI = 1.0
  - Up to 30 fuel rods in a 5-inch stainless steel pipe or a protective carrier (described in Section 1.2.3.4.7 of the currently approved TN-B1 SAR revision [23]), CSI = 2.3
- PWR 17x17, type 3 fuel rods with enrichments no greater than 8.0 wt% ^{235}U
  - Up to 25 loose or bundled fuel rods, CSI = 1.0
  - Up to 30 fuel rods in a 5-inch stainless steel pipe or a protective carrier (described in Section 1.2.3.4.7), CSI = 2.5

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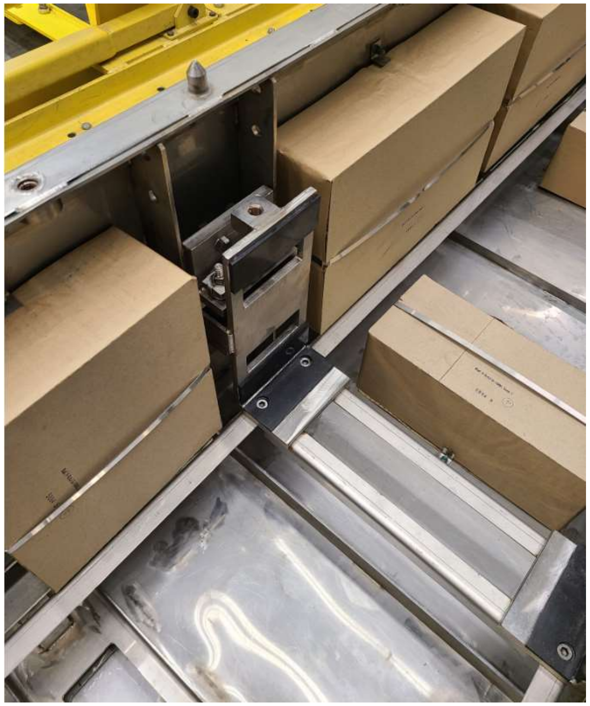
Structural Evaluation

- **Fuel Assembly Details**
  - No changes from existing CoC for ATRIUM 11 (11x11)
- **Loose Rod Details**
  - The GAIA 17x17 Type 3 AFM fuel rod design remains essentially the same as previously authorized PWR rods
    - Although the Fuel Rod OD is less than the current minimum value in the CoC (0.945 cm vs. 1.118 cm) the minimum Cladding Wall Thickness is bounded (0.052 cm vs. 0.033 cm)
    - The 17x17 Type 3 parameters will be distinguished within the SAR for the ≤ 8.0 wt.% ^{235}U
  - Weights remain bounded by existing licensing basis.

Structural Evaluation

- **Drawing Changes**
- **FS1-0042700,Outer Container Fixture Assembly Installation**
  - Add new Flag Note 4 to BOM Item 9, Vibroisolating Rubber
    - Size and quantity of Item 9 may vary depending on vibration performance factors of the rubber material
  - No impact on NCT or HAC package performance as the vibroisolator's function is to reduce normal transportation road vibrations that affect fuel rod fretting



Structural Evaluation

- **Drawing Changes (Continued)**

- **FS1-0042699, Outer Container Fixture Assembly**
  - Replaces 105E3739 to comply with Framatome procedures
  - “Natural Rubber” material call-out changed to “Rubber” for Items 7, 8, and 11 to allow use of various rubber materials for replacement.
  - Legacy change from previous amendment (CoC Rev. 3)

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Thermal, Containment, and Shielding Discussion

- **Thermal**
  - An update of this section shall be provided based on >5.0 wt% ^{235}U specific criteria to be performed for the likely small increases in decay heat for the new contents. No change to the results are anticipated.
- **Containment**
  - There is no change to the containment criterion as the fuel rod cladding remains the containment boundary. Each fuel rod is demonstrated to have a leakage rate less than 1E-07 ref-cc/sec during fabrication.
  - Clarification will be added distinguishing the difference between ≤5.0 wt% ^{235}U, >5.0 wt% ^{235}U, and Type B contents.
- **Shielding**
  - An update of this section shall be provided based on >5.0 wt% ^{235}U specific criteria to be performed of the likely small increases in radiation for the new contents. No change to the results are anticipated.

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Proposed Schedule

- **Schedule:**
  - **NRC Submittal – January 31, 2023**
  - **Amendment Request – January 31, 2024**

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Opportunity for Public Comment

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Conclusion

Thank You