UNITED STATES
NUCLEAR REGULATORY COMMISSION
ADVISORY COMMITTEE ON REACTOR SAFEGUARDS
WASHINGTON, DC 20555 - 0001

October 26, 2021

Mr. Daniel H. Dorman
Executive Director for Operations
U.S. Nuclear Regulatory Commission
Washington, DC 20555-0001

SUBJECT: SAFETY EVALUATION FOR FRAMATOME INC. TOPICAL REPORT ANP-10349P, REVISION 0, "GALILEO IMPLEMENTATION IN LOCA METHODS"

Dear Mr. Dorman:

During the 689th meeting of the Advisory Committee on Reactor Safeguards, October 5-7, 2021, we completed our review of the Framatome Inc. (Framatome), licensing topical report ANP-10349P, Revision 0, "GALILEO Implementation in LOCA Methods," and the associated staff draft safety evaluation (SE). Our Accident Analyses - Thermal Hydraulic and the Metallurgy and Reactor Fuels Subcommittees reviewed this topic on September 21, 2021. During these meetings, we had the benefit of discussions with the staff and representatives from Framatome. We also had the benefit of the referenced documents.

CONCLUSION AND RECOMMENDATION

1. The methodology documented in ANP-10349P, Revision 0, is a technically-sound approach for loss-of-coolant accident (LOCA) calculations for both large and small breaks within its demonstrated range of applicability.

2. The staff should issue the SE report after considering the items suggested in this letter.

BACKGROUND

Framatome requested that the NRC complete a review of ANP-10349P, Revision 0, "GALILEO Implementation in LOCA Methods," which presents a methodology for implementing the fuel performance code GALILEO into Framatome pressurized water reactor (PWR) LOCA methods. The methodology is applicable for Westinghouse and Combustion Engineering PWRs with recirculation (U tube) steam generators, fuel assembly lengths of 14 feet or less, and emergency injection in the cold legs.

The Framatome PWR LOCA methodology (both for large and small breaks) is based on the S-RELAP5 system code, which calculates the thermal-hydraulic evolution of the reactor following the break. To estimate the impact on the fuel, the existing, approved methodology uses input from two thermo-mechanical codes: COPERNIC for the realistic large break LOCA, and RODEX2 for small breaks, which uses a conservative, Title 10 of the *Code of Federal*

Regulations (10 CFR) Part 50, Appendix K approach. With ANP-10349P, Framatome requests approval to optionally implement in their LOCA methodology an additional fuel performance code GALILEO to satisfy the requirements of 10 CFR 50.46, “Acceptance Criteria for Emergency Core Cooling Systems for Light Water Nuclear Power Reactors.” The GALILEO methodology applies to both large and small breaks, and it provides a software framework for expected increases in fuel enrichment, maximum burnup, and the introduction of chromia-doped fuel pellets and chromium-coated cladding in PWRs. These options are expected to be addressed via separate topical reports.

DISCUSSION

During our October 2020 meeting, we reviewed the GALILEO methodology as applied to reload analysis for normal operation and transient analyses, and our November 23, 2020, letter recommended its acceptance. These transients, however, are generally not as challenging to the fuel as LOCAs, and the review of the adequacy of this methodology required additional review. Just as the earlier submittal, the GALILEO LOCA applicability is limited to PWRs using UO_2 and gadolinia-bearing fuel with Zircaloy-4 (Zr-4) or M5™ cladding.

The GALILEO methodology models the following coupled physical phenomena: heat production and conduction in the fuel rod; fission gas release; mechanical behavior of the pellet and cladding structures; and growth of a corrosion layer at the cladding external surface. GALILEO includes the following models: thermal conductivity degradation; hydrogen pickup in the cladding; enhanced fission gas release for a range of burnups; high burnup structure on pellet rim, and cladding ridge formation; fuel pellet cracking, creep, and pellet deformations like dish filling and hourglassing; and fuel pellet swelling. The staff completed a thorough review of the methodology implementation, including the convergence of the iterative steps between S-RELAP5 and GALILEO.

Framatome has calibrated and validated their models using extensive experimental data, enabling them to apply the GALILEO methodology to fuel types in the following bundle configurations: 14x14 Combustion Engineering; 15x15 Babcock & Wilcox; 17x17 Westinghouse; and 17x17 Framatome. The database includes both Zr-4 and M5™ cladding materials and high-burnup conditions. The staff review and comparisons were supplemented by confirmatory calculations performed with the independent NRC code FRAPCON. We reviewed the staff evaluation of these data for licensing calculations and found it acceptable in our November 23, 2020, letter.

To validate their LOCA evaluation methods with the GALILEO fuel performance code, Framatome provided comparisons against Loss-of-Fluid Test (LOFT) experimental data. For large break LOCA, the L2-3, L2-5, LP-02-6 and LP-LB-1 LOFT tests were provided. For small break LOCA, the L3-6 and L8-1 LOFT tests were provided. The staff has reviewed these validations in their SE and their audit report; they concluded that the cladding temperatures, fuel centerline temperature trends, and rod internal pressure trends are consistent with experimental data and the results of the previously approved methods (COPERNIC and RODEX2). We concur with their evaluation. However, the staff SE should state the demonstrated range of applicability (e.g., burnup, enrichment, fuel and cladding types, etc.) for which GALILEO is approved. The staff should consider incorporating by reference the applicability ranges and limitations in the earlier GALILEO topical report (ANP-10323PA).

To supplement the experimental data validations, the applicant provided code-to-code comparisons of GALILEO versus COPERNIC and RODEX2 for sample problems representative of typical LOCA calculations. These code-to-code comparisons add significant value to the validation effort but cannot be used to replace direct validation against experimental data. The staff should ensure that, for future assessments, code-to-code comparisons are not used exclusively. This is especially relevant for fuels with limited experimental data.

Development and benchmarking of fuel performance codes, like GALILEO, have often depended heavily on real-time data from well-instrumented test rigs at the Halden reactor for a range of test conditions and fuel burnups. We observed in our April 13, 2020 Biennial Research Review letter that, without a replacement for this lost capability, it will be difficult to confirm the adequacy of models simulating the performance of proposed accident tolerant fuels (ATFs) or evolutionary fuels for the existing fleet of light water reactors. We also continue to be concerned that, as the temperature resistance of ATFs improve, a new class of accidents may be created where the control rods fail before the fuel, leading to a potential criticality event as the core refloods. This class of events needs to be considered as part of future ATF evaluations.

SUMMARY

The methodology documented in ANP-10349P, Revision 0, is a technically-sound approach for LOCA calculations for both large and small breaks within its demonstrated range of applicability.

Prior to issuing the SE report, the staff should consider the following items:

1. State the demonstrated range of applicability of the methodology. The staff should consider incorporating by reference the applicability ranges and limitations in the earlier GALILEO topical report (ANP-10323PA).

2. State that the GALILEO methodology does not replace existing methodologies. COPERNIC and RODEX2 continue to be acceptable methodologies.

3. Emphasize that the approval is based primarily on direct comparisons against experimental LOFT data. Code-to-code comparisons are valuable to supplement experimental data benchmarks but cannot replace them completely in future submittals.

Sincerely,

M W Sunseri Signed by Sunseri, Matthew on 10/26/21

Matthew W. Sunseri
Chairman

REFERENCES

1. U.S. Nuclear Regulatory Commission (NRC), “Draft Safety Evaluation for Framatome Inc., Topical Report ANP-10349P, Revision 0, ‘Galileo Implementation in LOCA Methods’,” August 31, 2021 (ADAMS Accession Nos. (Non-Publicly Available ML21209A018 / Publicly Available ML21277A201)).

2. ANP 10323(P)(A), Revision 1, “GALILEO Fuel Thermal Mechanical Methodology for Pressurized Water Reactors,” Framatome, Inc., December 18, 2020 (ADAMS Accession Nos. (Non-Publicly Available Part 1 to 5 ML21005A032 - ML21005A037 / Publicly Available ML21005A030).

3. U.S. Nuclear Regulatory Commission (NRC), “Draft Safety Evaluation for Framatome Inc., Topical Report ANP-10323P, Revision 1, ‘GALILEO Fuel Rod Thermal-Mechanical Methodology for Pressurized Water Reactor’,” August 24, 2020 (ADAMS Accession Nos. (Non-Publicly Available ML20230A041 / Publicly Available ML20230A038)).

4. BAW 10231(P)(A), Revision 1, “COPERNIC Fuel Rod Design Computer Code,” Framatome ANP, January 31, 2004 (ADAMS Accession Nos. ((ADAMS Accession Nos. (Non-Publicly Available ML042930250 and ML042930254 / Publicly Available ML042930240 and ML042930247)).

5. EMF-92-116(P)(A), Revision 0, Supplement 1, Revision 0, “Generic Mechanical Design Criteria for PWR Fuel Designs,” December 29, 2011 (ADAMS Accession Nos. (Non-Publicly Available ML11363A131 / Publicly Available ML11363A130)).

6. XN-NF-81-58(P)(A), Revision 2, Supplements 1 and 2, “RODEX2 Fuel Rod Thermal Mechanical Response Evaluation Model,” April 2,1984 (ADAMS Accession No. (Non-Publicly Available ML081340725)).

7. NUREG/CR-7022, “FRAPCON-3.4: A Computer Code for the Calculation of Steady-State, Thermal-Mechanical Behavior of Oxide Fuel Rods for High Burnup,” March 2011 (ADAMS Accession No. ML11101A005 (Publicly Available)).

8. EMF 2103, Revision 3, “Realistic Large Break LOCA Methodology for Pressurized Water Reactors,” AREVA, June 30, 2016 and September 30, 2016 (ADAMS Accession Nos. (Non-Publicly Available ML16286A319; ML16286A322, ML16286A325 and ML16286A327 / Publicly Available ML16286A574-A578)).

9. Revised Final Safety Evaluation, Revision 0, Supplement 1 (P)(A), Revision 0, for AREVA Topical Report, EMF-2326 (P) (A), Revision 0, Supplement 1, Revision 0. “PWR Small Break LOCA Evaluation Model, S RELAP5 Based,” AREVA, February 1, 2017 (ADAMS Accession No. Publicly Available ML16356A406).

10. NUREG/IA-0028, “Review of LOFT Large Break Experiments,” U.S. NRC, October 31,1989. (ADAMS Accession No. Publicly Available ML062570206).

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Accession No: ML21292A005 **Publicly Available (Y/N):** Y **Sensitive (Y/N):** N
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