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

November 23, 2020

Ms. Margaret M. Doane
Executive Director for Operations
U.S. Nuclear Regulatory Commission
Washington, DC 20555-0001

SUBJECT: SAFETY EVALUATION FOR FRAMATOME INC., TOPICAL REPORT ANP-10323P, REVISION 1, "GALILEO FUEL ROD THERMAL-MECHANICAL METHODOLOGY FOR PRESSURIZED WATER REACTORS"

Dear Ms. Doane:

During the 679th meeting of the Advisory Committee on Reactor Safeguards, October 8-9, 2020, we completed our review of the Framatome Inc. (Framatome), licensing topical report (LTR) ANP-10323P, Revision 1, "GALILEO Fuel Rod Thermal-Mechanical Methodology for Pressurized Water Reactors," and the associated staff safety evaluation (SE). Our Accident Analyses-Thermal Hydraulic Subcommittee also reviewed this topic on September 24, 2020. During these meetings, we had the benefit of discussions with the staff, its contractors, and representatives from Framatome. We also had the benefit of the referenced documents.

CONCLUSION AND RECOMMENDATION

1. The methodology documented in ANP-10323P, Revision 1, when applied within the staff-imposed limitations and conditions, is acceptable for the calculation of pressurized water reactor (PWR) fuel rod thermal-mechanical performance.

2. The safety evaluation report should be issued.

BACKGROUND

Framatome requested in June 2018 that the NRC complete a review of ANP-10323P, Revision 1, "GALILEO Fuel Rod Thermal-Mechanical Methodology for Pressurized Water Reactors," which presents a methodology for the realistic evaluation of the performance of fuel rods for PWRs. GALILEO consolidates features of modeling capability within approved Framatome codes, including COPERNIC, RODEX, and CARO-3E, into a single methodology. Advances in modeling have also been incorporated, including new pellet mechanics models.

This topical report is a revision to the original LTR that was submitted in August 2013. Revision 0 was intended to be applicable to both PWRs and boiling water reactors using UO_2 fuel (enriched up to 5 wt%) containing up to 10 wt% gadolinium. It was also intended to be applicable to mixed oxide (MOX) fuels. Revision 0 was withdrawn for consideration by Framatome, and they issued Revision 1 in which Framatome limited the applicability review of

the GALILEO methodology to PWRs using UO_2 and gadolinia-bearing fuel with Zircaloy-4 (Zr-4) or M5 cladding. GALILEO is not intended for analysis of co-resident fuel in mixed cores.

The staff is currently reviewing one LTR covering extensions of the GALILEO methodology to generate fuel properties for the ARITA (ARTEMIS/RELAP Integrated Transient Analysis) methodology. Submittal of additional applications for the GALILEO methodology, including a methodology to provide initial conditions for Emergency Core Cooling Systems (ECCS) analysis, within the Framatome advanced methods platform is anticipated.

DISCUSSION

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, dish filling, and hourglassing; and fuel pellet swelling.

Framatome calibrated and validated their models using extensive experimental data, enabling them to apply the GALILEO methodology to their 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 calibration process involves determining the GALILEO model parameters that best fit a defined subset of the experimental database. The complete database was then used to validate the results of the calibrated correlations. A standard non-parametric statistical methodology and a PIRT (phenomena identification and ranking table) are applied to define the uncertainties of the GALILEO results including variability in operating conditions, manufacturing parameters and calibrated model parameters.

The staff SE defines the ranges of applicability for GALILEO fuel rod design and safety analyses to ensure that its use remains within the bounds of the database conditions. The SE also imposes several conditions and limitations, including: stipulation that fuel failure should be assumed when fuel temperature calculated by GALILEO exceeds the fuel melting temperature; no methodology using GALILEO has been approved for providing initial data or conditions for ECCS calculations; future changes to both the mean and standard deviation of model parameter uncertainty input data values must be reviewed and approved by the staff; and Framatome responses to staff requests for additional information must be included with the final topical report. We find the range of applicability and these limitations and conditions appropriate. Furthermore, we observe that approval of Revision 1 of ANP-10323P does not provide implicit approval of Revision 0 because it contains additional topics not reviewed by the staff.

The staff's determination of applicability ranges and limitations was based on the ability of GALILEO to accurately simulate currently available test data. Their review and comparisons were supplemented by confirmatory calculations performed with the independent NRC code FRAPCON. The review approach was thorough, and the results were convincing.

Separately, we note that the development and benchmarking of fuel performance codes, including GALILEO and its predecessors, have depended heavily on crucial 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 or evolutionary fuels for the existing fleet of light water reactors.

SUMMARY

The methodology documented in ANP-10323P, Revision 1, when applied within the staff-imposed limitations and conditions, is acceptable for the calculation of PWR fuel rod thermal-mechanical performance. The safety evaluation report should be issued.

We are not requesting a formal response from the staff to this letter report.

Sincerely,

Matthew W. Sunseri Digitally signed by Matthew W. Sunseri Date: 2020.11.23 16:56:27 -05'00'

Matthew W. Sunseri, Chairman

REFERENCES

1. 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 No. ML20230A041 (Proprietary)).

2. Framatome Inc., ANP-10323P/NP, Revision 1, “GALILEO Fuel Rod Thermal-Mechanical Methodology for Pressurized Water Reactors,” June 29, 2018 (ADAMS Accession Nos. ML18186A150 (Publicly Available) and ML18186A149 (Non-Publicly Available)).

3. Framatome Inc., Submittal of Response to Request for Additional Information ANP-10323P, Revision 0, “Fuel Rod Thermal-Mechanical Methodology for Boiling Water Reactors and Pressurized Water Reactors,” December 20, 2018 (ADAMS Package Accession No. ML18361A736).

4. Framatome Inc., Submittal of Second Response to Request for Additional Information Regarding ANP-10323P, Revision 0, “Fuel Rod Thermal-Mechanical Methodology for Boiling Water Reactors and Pressurized Water Reactors,” January 31, 2019 (ADAMS Package Accession No. ML19036A818).

5. Framatome Inc., Submittal of Third Response to Request for Additional Information Regarding ANP-10323P, Revision 0, “Fuel Rod Thermal-Mechanical Methodology for Boiling Water Reactors and Pressurized Water Reactors,” June 28, 2019 (ADAMS Package Accession No. ML19184A020).

6. Framatome Inc., Submittal of Fourth Response to Request for Additional Information Regarding ANP-10323, Revision 0, “Fuel Rod Thermal-Mechanical Methodology for Boiling Water Reactors and Pressurized Water Reactors,” September 2019 (ADAMS Package Accession No. ML19274B618).

7. Framatome Inc., Submittal of Additional Information Regarding ANP-10323P, Revision 1, “GALILEO Fuel Rod Thermal-Mechanical Methodology for Pressurized Water Reactors,” July 21, 2020 (ADAMS Package Accession No. ML20231A424).

8. FS1-0004682, Revision 4.0, “GALILEO Fuel Rod Performance Code Theory Manual,” Framatome Inc., April 12, 2018 (ADAMS Package Accession No. ML20195A041(Non-Publicly Available)).

9. FS1-0004683, Revision 3.0, “GALILEO Fuel Rod Performance Code Verification and Validation Report,” Framatome Inc., April 20, 2018 (ADAMS Package Accession No. ML13267A071(Non-Publicly Available)).

10. ANF-90-145(P)(A), Volume 1&2, Supplement 1, RODEX 3 Fuel Rod Thermal-Mechanical Response Evaluation Model, Volume, Theoretical Manual, Volume 2, Thermal and Gas Release Assessments (ADAMS Package Accession No. ML012880301(Non-Publicly Available)).

11. ANP-10339P, Revision 0, “ARITA-ARTEMIS/RELAP Integrated Transient Analysis Methodology,” Framatome Inc., August 2018 (ADAMS Accession No. ML18242A446 (Non-Publicly Available), ML18242A444 (Publicly Available)).

12. BAW-10339P, Revision 1, COPERNIC Fuel Rod Design Computer Code,” AREVA NP Inc., January 2004 (ADAMS Accession No. ML042930250, ML042930254 (Non-Publicly Available), ML042930247, ML042930240 (Publicly Available)).

13. ANP-10297P, Revision 0, “The ARCADIA® Reactor Analysis System for PWRs Methodology Description and Benchmarking Results,” March 30, 2010 (ADAMS Accession No. ML00950592 (Non-Publicly Available), ML10090596 (Publicly Available)).

14. Advisory Committee of Reactor Safeguards, “Biennial Review and Evaluation of NRC Safety Research Program,” April 13, 2020 (ADAMS Accession Nos. ML20105A447 (Non-Publicly Available) and ML26140A120 (Publicly Available)).

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