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

June 28, 2024

Mr. Raymond V. Furstenau
Acting Executive Director for Operations
U.S. Nuclear Regulatory Commission
Washington, DC 20555-0001

SUBJECT: DRAFT SAFETY EVALUATION OF TERRAPOWER TOPICAL REPORT, "PRINCIPAL DESIGN CRITERIA FOR THE NATRIUM ADVANCED REACTOR," REVISION 1

Dear Mr. Furstenau:

During the 716th meeting of the Advisory Committee on Reactor Safeguards, June 5 through 6, 2024, we completed our review of the TerraPower Topical Report (TR), "Principal Design Criteria for the Natrium Advanced Reactor," Revision 1, and the associated Nuclear Regulatory Commission (NRC) staff safety evaluation report (SER). Our TerraPower Subcommittee reviewed this matter on May 15, 2024. During these meetings, we had the benefit of discussions with the NRC staff and representatives of TerraPower. We also had the benefit of the referenced documents.

CONCLUSIONS AND RECOMMENDATIONS

1. The Principal Design Criteria (PDC) proposed by TerraPower adapt the advanced reactor design criteria provided in NRC guidance to the Natrium plant design. Additionally, TerraPower stated they continue to assess the potential for additional PDC as part of the licensing process.

2. As we stated in 2018, we support application of the functional containment concept to advanced reactors like Natrium and note that establishing the details of a functional containment can be complex.[1] TerraPower has not yet fully developed the Natrium functional containment design, and the concept described by TerraPower results in a set of barriers that share many similarities with previous sodium-cooled fast reactor (SFR) designs. Therefore, the functional containment approach is expected to maintain significant defense-in-depth capability comparable to prior SFRs.

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[1] From ACRS letter dated May 10, 2018, "DRAFT SECY PAPER, 'FUNCTIONAL CONTAINMENT PERFORMANCE CRITERIA FOR NON-LIGHT WATER REACTOR DESIGNS'": "We find the methodology proposed by the staff to be worthy of further development. It appears that, if it can be successfully developed, it could provide a rational basis for developing functional containment performance criteria for new designs. Development of these performance criteria is no easy task and implementing them to ensure sufficient reliability of functional containment may be even more difficult. To be effective and workable, a means must be provided for addressing uncertainties remaining in the calculated results to decide where additional structuralist defense-in-depth barriers or barrier enhancements should be applied."

3. The Safety Evaluation Report should be issued.

BACKGROUND

The General Design Criteria (GDC) for Nuclear Power Plants, Appendix A to Title 10 of the *Code of Federal Regulation*s (10 CFR) Part 50, are the minimum requirements for the PDC for water-cooled nuclear plants to provide reasonable assurance that a facility can be operated without undue risk to the health and safety of the public. The GDC were developed to focus attention on the most prominent issues and improve the predictability and efficiency of NRC reviews of licensing applications. Design criteria are established to provide a solid basis for the staff review and ensure that a given facility can be operated safely. They provide assurance that structures, systems, and components (SSCs) important to safety will remain functional during and following identified design basis events.

Regulatory Guide (RG) 1.232, "Guidance for Developing Principal Design Criteria for Non-Light-Water Reactors," provides guidance on how the GDC can be adapted for non-light-water reactor (non-LWR) designs. It includes generic advanced reactor design criteria, technology-specific sodium-cooled fast reactor design criteria (SFR-DC) and modular high temperature gas-cooled reactor design criteria (MHTGR-DC). The criteria established in this regulatory guide are based on extensive interactions among NRC, the Department of Energy (DOE), and experts in the nuclear community in each of the technologies. The regulatory guide notes that applicants may need to develop entirely new PDC to address unique design features. Early engagement and agreement on plant specific PDC facilitate a more effective design development and regulatory review.

The proposed TerraPower Natrium reactor is an 840 megawatts thermal sodium-cooled fast reactor that transfers heat to a molten-salt system for further use in power conversion. TerraPower developed the Natrium PDC primarily by adapting the SFR-DC from RG 1.232, with changes further described below and wording changes to better reflect the licensing process described by RG 1.233, "Guidance for a Technology-Inclusive, Risk-Informed, and Performance-Based Methodology to Inform the Licensing Basis and Content of Applications for Licenses, Certifications, and Approvals for Non-Light Water Reactors."

The most significant change TerraPower made to the SFR-DC is the approach to containment. While numerous SFR-DC reflect use of a pressure-tight containment similar to the GDC in 10 CFR Part 50, TerraPower instead proposes use of functional containment criteria consistent with design criterion MHTGR-DC Number 16 of RG 1.232. TerraPower observes that the functional containment concept is risk-informed and performance-based, and complements the mechanistic source term, use of Specified Acceptable System Radionuclide Release Design Limits (SARRDLs), and overall Licensing Modernization Project methodology endorsed in RG 1.233. Additionally, TerraPower observes the Commission has found the functional containment concept generally acceptable. TerraPower proposes using one design criterion that requires a functional containment, along with two MHTGR-DC associated with reactor building integrity, in lieu of the 15 SFR-DC that pertain to containment requirements.

The TR also uses the SARRDL concept to bound acceptable radionuclide release from fuel, in lieu of "specified acceptable fuel design limits" (SAFDLs) historically used for SFRs. During our Committee meeting on June 5, 2024, TerraPower clarified that they intend to demonstrate

SARRDLs are met during normal operation and anticipated operational occurrences (AOOs) by meeting SAFDLs. In this way, there is no degradation in safety associated with use of SARRDLs in lieu of SAFDLs.

The staff draft SER includes a Limitation and Condition No. 2, restricting use of the TR to those applicants using the risk-informed, performance-based licensing process endorsed by RG 1.233. This limitation and condition also requires applicants or licensees referencing the TR to address PDC for events other than normal operation, AOOs, and design basis accidents. In a staff audit of the TR, TerraPower stated that the proposed PDC are associated with normal operation, AOOs, and design basis accidents. The draft SER observes that RG 1.253, "Guidance for a Technology-Inclusive Content of Application Methodology to Inform the Licensing Basis and Content of Applications for Licenses, Certifications, and Approvals for Non-Light-Water Reactors," endorses a process that requires PDC to also address other situations. For example, PDC are required to address safety-significant SSCs whose safety functions relate to beyond design basis events or are needed for defense-in-depth adequacy. Principal Design Criteria to support these additional situations are referred to as "complementary design criteria," which add to PDC that cover "required functional design criteria." Limitation and Condition No. 2 requires applicants or licensees to augment the list of PDC from the TR to account for all SSCs that are defined as safety-significant.

DISCUSSION

Completeness of the PDC

RG 1.232 states it "*is the applicant's responsibility to develop the PDC for its facility based on the specifics of its unique design, using the GDC, non-LWR design criteria, or other design criteria as the foundation.*" The approach documented in the TR does not include an assessment of whether unique features of the Natrium reactor would require design criteria beyond those documented in RG 1.232; rather, the process described in the TR considers only the design criteria tabulated in RG 1.232.

While not described in the TR, TerraPower stated they are considering the need for additional or revised PDC as they proceed through the Licensing Modernization Process as endorsed by RG 1.233. This process requires consideration of PDC as plant-specific required functional design criteria are developed during design iterations. This evaluation is expected to result in a complete set of PDC as the licensing basis is finalized. Additionally, Limitation and Condition No. 2 in the draft SER states that approval of the TR is based on use of the RG 1.233 licensing process (and development of complementary design criteria as discussed in RG 1.253), which should ensure that any user of the TR will include consideration of plant-specific PDC beyond those specified in RG 1.232.

Functional Containment

The technical justification to base Natrium functional containment on the RG 1.232 MHTGR-DC did not address the differences between the SFR-DC and MHTGR-DC. The SFR and modular high temperature gas-cooled reactor containment design criteria captured in RG 1.232 resulted from development of the functional containment concept for each of these advanced reactor types. For SFRs, these evaluations concluded that a separate containment structure should be

utilized.[2] Neither the TR nor the staff draft SER address this divergence from the technical bases that were developed to support the SFR functional containment design criteria.

Consequently, in our Committee meeting on June 5, 2024, TerraPower identified five key Natrium design features that they consider support deletion of the containment-related SFR-DC. The first four of these apply also to the prior-generation SFRs and hence are not new to Natrium:

1. The low pressure of the reactor system provides little driving force for movement of fission products through the barriers;

2. The use of a fully metal core in sodium coolant that enables retention of some fission products in the fuel matrix and others in the sodium;

3. The use of a sodium pool within an integrated reactor vessel, results in a design with significant thermal inertia and a large margin to sodium boiling;

4. Structures such as a guard vessel and reactor head access area enclosure provide secondary barriers around all sodium piping, significantly reducing the likelihood of large energy releases to the environment associated with air-sodium fires; and

5. No interface between sodium and water due to moving the steam generation function to a downstream salt system that is outside the functional containment boundary. This reduces the risk relative to prior designs that used a sodium-water steam generator.

The above key design features support application of the functional containment concept to Natrium.

As discussed in 4 above, the Natrium design includes a guard vessel and a head access area enclosure, which were the major components of the containment design for prior SFR designs.[3] These barriers are an important part of the intended functional containment concept, and they serve a comparable function as their predecessor containment systems. Staff review of this set of barriers at the construction permit application stage will include assessment of performance requirements that may be informed by the existing containment design criteria for SFRs.

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[2] From the “rationale” for SFR-DC Number 16 in RG 1.232: “Furthermore, all past, and current, SFR designs use a low-leakage, pressure-retaining containment concept, which aims to provide a barrier to contain the fission products and other substances and to control the release of radioactivity to the environment. Reactions of sodium with air or water, sodium fires, and hypothetical reactivity accidents caused by sodium voiding or boiling could release significant energy inside the reactor containment structure. Therefore, a low-leakage, pressure-retaining structure surrounding the reactor and its primary cooling system is required. Note that a design could have a low design pressure for the containment.”

[3] Section 6.1.6 of “Guidance for Developing Principal Design Criteria for Advanced (Non-Light Water) Reactors”, dated December 2014 (INL/EXT-14-31179 Revision 1, ADAMS Accession No. ML14353A224), describes the containment of the S-PRISM advanced SFR design, which it characterizes as a representative SFR containment architecture. The SFR-DC in RG 1.232 are based on this containment architecture, which uses a guard vessel as the lower half of containment and the head area access enclosure as the upper half of containment.

SUMMARY

The Principal Design Criteria proposed by TerraPower adapt the advanced reactor design criteria provided in NRC guidance to the Natrium plant design. Additionally, TerraPower stated they continue to assess the potential for additional PDC as part of the licensing process. As we stated in 2018, we support application of the functional containment concept to advanced reactors like Natrium and note that establishing the details of a functional containment can be complex. TerraPower has not yet fully developed the Natrium functional containment design, and the concept described by TerraPower results in a set of barriers that share many similarities with previous SFR designs. Therefore, the functional containment approach is expected to maintain significant defense-in-depth capability comparable to prior SFRs. The SER should be issued.

We are not requesting a response to this letter.

Sincerely,

Walter L Kirchner Signed by Kirchner, Walter on 06/28/24

Walter L. Kirchner
Chair

REFERENCES:

1. U. S. Nuclear Regulatory Commission, “TerraPower, LLC – Draft Safety Evaluation of Topical Report NATD-LICRPRT- 0002, ‘Principal Design Criteria For The Natrium Advanced Reactor,’ Revision 1 (EPID L-2021-TOP-0020),” April 10, 2024 (Agencywide Documents Access and Management System (ADAMS) Accession No. ML24103A212).

2. U. S. Nuclear Regulatory Commission, “Regulatory Audit Summary Report TerraPower, LLC Topical Report ‘Principal Design Criteria for The Natrium Advanced Reactor,’ Revision 0, Project no. 99902100,” January 30, 2024 (ADAMS Accession No. ML24051A030).

3. TerraPower, LLC., “Submittal of TerraPower Topical Report, ‘Principal Design Criteria for the Natrium Advanced Reactor,’ Revision 1,” April 10, 2024 (ADAMS Accession No. ML24101A362).

4. The General Design Criteria for Nuclear Power Plants, Appendix A to Title 10 of the *Code of Federal Regulations* Part 50 - Domestic Licensing of Production and Utilization Facilities.

5. U.S. Nuclear Regulatory Commission, Regulatory Guide 1.232, “Guidance for Developing Principal Design Criteria for Non-Light-Water Reactors,” Revision 0, April 2018 (ADAMS Accession No. ML17325A611).

6. U.S. Nuclear Regulatory Commission, Regulatory Guide 1.233, “Guidance for a Technology-Inclusive, Risk-Informed, and Performance-Based Methodology to Inform the Licensing Basis and Content of Applications for Licenses, Certifications, and Approvals for Non-Light Water Reactors,” Revision 0, June 2020 (ADAMS Accession No. ML20091L698).

7. U.S. Nuclear Regulatory Commission, Regulatory Guide 1.253, “Guidance for a Technology-Inclusive Content of Application Methodology to Inform the Licensing Basis and Content of Applications for Licenses, Certifications, and Approvals for Non-Light-Water Reactors,” Revision 0, March 2024 (ADAMS Accession No. ML23269A222).

8. Advisory Committee on Reactor Safeguards, “Draft SECY Paper, ‘Functional Containment Performance Criteria for Non-Light Water Reactor Designs’,” May 10, 2018 (ADAMS Accession No. ML18108A404).

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