



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

April 21, 2025

Dr. Mirela Gavrilas
Executive Director for Operations
U.S. Nuclear Regulatory Commission
Washington, DC 20555-0001

**SUBJECT: TERRESTRIAL ENERGY'S PRINCIPAL DESIGN CRITERIA FOR THE
INTEGRAL MOLTEN SALT REACTOR**

Dear Dr. Gavrilas:

During the 724th meeting of the Advisory Committee on Reactor Safeguards, April 2 through 3, 2025, we completed our review of the Principal Design Criteria (PDC) for Integral Molten Salt Reactor (IMSR) Structures, Systems and Components Topical Report, Revision C, and the associated draft safety evaluation (SE). Our Terrestrial Energy Subcommittee also reviewed this matter on March 20, 2025. During these meetings, we had the benefit of discussions with the Nuclear Regulatory Commission (NRC) staff, and Terrestrial Energy USA, Inc. (TEUSA). We also had the benefit of the referenced documents.

CONCLUSIONS AND RECOMMENDATIONS

1. The PDC proposed by TEUSA for the IMSR reactor have been developed by adapting Advanced (Non-Light Water) Reactor design criteria from NRC guidance; design criteria from draft guidance in the American National Standards Institute (ANSI)/American Nuclear Society (ANS) ANSI/ANS-20.2-2023, "Nuclear Safety Design Criteria and Functional Performance Requirements for Liquid-Fuel Molten Salt Reactor (MSR) Nuclear Power Plants"; and consideration of the unique design features of the IMSR.
2. The use of a negative fuel salt temperature coefficient as the sole means of placing and maintaining the reactor in a "safe state" has not yet been demonstrated for this design. Additionally, the use of a "safe state" as equivalent to "safe shutdown," with long-term criticality as an acceptable post-accident state, is a significant departure from accepted nuclear safety practices. The following have not been justified for this first-of-a-kind reactor:
 - a. Absence of an automatic reactor protection system to ensure that the reactor can always be placed in a safe condition.
 - b. Lack of a shutdown system with appropriate margin for malfunctions to ensure, that post accident, the reactor can be maintained in a subcritical state, not just a "safe state." This position is consistent with the ANSI/ANS MSR Standard Criteria 20, "Protection System Functions," and 26, "Reactivity Control and Redundancy."

3. The PDC proposed by TEUSA remove the requirement for a containment cleanup system as found in Criterion 41, "Containment Atmosphere Cleanup," of the draft ANSI/ANS standard. The Committee considers this premature given that the final design is not complete.
4. The PDC are foundational to the overall safe design of the reactor. Therefore, they should be available in a non-proprietary format to provide transparency to the public.
5. The staff should consider these comments prior to issuing the final SE.

BACKGROUND

The General Design Criteria (GDC) for Nuclear Power Plants, Appendix A, "General Design Criteria for Nuclear Power Plants," to Title 10 of the *Code of Federal Regulations* (10 CFR) Part 50, are the minimum design requirements for light-water reactors (LWRs) 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 safety and design issues and improve the predictability and efficiency of NRC reviews of licensing applications. They provide assurance that structures, systems, and components important to safety will remain functional during and following identified design basis events. These criteria also provide a basis for the staff review.

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 amongst NRC, the Department of Energy, and experts in the nuclear community in each of the technologies. Regulatory Guide 1.232 notes that applicants may need to develop entirely new PDC to address unique design features. Early engagement and agreement between the applicant and staff on plant-specific PDC facilitate a more effective design development and regulatory review.

Terrestrial Energy USA, Inc. is developing the IMSR. The IMSR nuclear power plant site consists of two Reactor Auxiliary Buildings (RAB) and a single Control Building. Each RAB has a single operating IMSR Core unit. Each Core unit consists of a 442-Megawatt thermal (MWt) liquid-fuel MSR.

The current RG 1.232 does not include technology specific design criteria for MSRs, so TEUSA has developed the IMSR PDC by adapting the design criteria from other PDC listed in RG 1.232 for advanced technologies. TEUSA has also considered draft guidance from the development of the draft ANSI/ANS standard for MSRs. However, the draft ANSI/ANS MSR design standard is based on a functional containment, while the IMSR has a traditional containment. These factors lead to the TEUSA IMSR having a unique set of PDC. The NRC staff is in the process of reviewing ANSI/ANS-20.2-2023 for possible endorsement.

DISCUSSION

Molten salt reactors are Generation IV reactor concepts that have several potential advantages over current LWRs in terms of safety and economics. However, the operating experience of

MSRs is limited and based mostly on the Molten Salt Reactor Experiment (MSRE) that operated at Oak Ridge National Laboratory in the 1960s at a power level of 7.4 MWt thermal. The MSRE used a different fuel salt than proposed for the IMSR. These and other important design differences between the MSRE and the IMSR suggest retaining many of the traditional requirements in the PDC that the applicant proposed deleting or scaling back.

The proposed PDC for reactivity control in the IMSR are novel and do not conform to PDC used in existing LWRs and proposed in other advanced non-LWRs.

- We acknowledge the strong negative temperature coefficient associated with the design; however, it is not unique to this design, as other reactors also have this characteristic.
- Because of the complexities, uncertainties, and time constants associated with the underlying phenomena, inherent negative reactivity feedback has historically been demonstrated in test reactors and prototypes prior to taking credit for this characteristic in large-scale power reactors. Examples include: negative feedback from rod bowing and growth in fast reactor metallic fuel assemblies in the Experimental Breeder Reactor-II (EBR-II) and the Fast Flux Test Facility (FFTF); demonstration of the High-Temperature Gas-Cooled Reactor (HTGR) negative temperature coefficient in the German pebble-bed reactor prototype known as the AVR, the High-Temperature Engineering Test Reactor (HTTR) and the 10 MWt High Temperature Gas-cooled Test Reactor (HTR-10); and confirmation in the Chinese commercial High Temperature Gas-Cooled Reactor - Pebble-bed Module (HTR-PM). No such testing exists for this technology as applied in the IMSR.
- While the use of liquid fuel enhances the negative reactivity coefficient, this is offset by uncertainties associated with the first-of-a-kind nature of the facility and unique geometry.

Therefore, we deem it essential to have an automatic reactor protection system to execute the safety function of reactivity control in a reliable manner until sufficient operating experience is gained with this first-of-a-kind IMSR.

The proposed PDC on reactor shutdown included in Criterion TEUSA-26 is also novel due to the definition of "safe state." One of the fundamental safety functions is to control the fission process, which has traditionally been interpreted as always being able to place the reactor in a subcritical state. Changing this requirement to only require the reactor to be in a "safe state" (and not subcritical) depends on the definition of a "safe state" and the ability to demonstrate by analytical means that a safe state can be achieved. The ability to demonstrate this is contingent on validation of the computer codes used in such a calculation, uncertainties in cross sections, and the movement of delayed neutrons associated with the dissolved fuel out of the core used in the feedback analysis. In addition, due to the first-of-a-kind nature of this design, there may be unknown scenarios where the "safe state" may not be obtained. It is therefore necessary to include the traditional requirement that a shutdown system with appropriate margin for malfunctions be available to ensure that the reactor can always be brought to a subcritical state, not just a "safe state." The requirement to be able to place the reactor in a subcritical state is consistent with the concept of "safe shutdown" used in Criterion 26 of the draft ANSI/ANS MSR standard.

One feature of molten salt reactors is that gaseous fission products are continuously released from the reactor core and are not contained in fuel rods. In the preliminary IMSR design, the fission product gas may be contained in a gas holding tank for the entire life of the IMSR. The

source term in this gas holding tank will be significant. The final design should consider the consequences of leaks when handling compressed fission product gas. It is premature to conclude that a containment atmosphere cleanup system is not necessary until the final design of this system and consequences of leakages and accidental releases have been analyzed and determined. This is consistent with Criterion 41 of the draft ANSI/ANS MSR standard.

Finally, TEUSA's treatment of the IMSR PDC as proprietary is a significant departure from common practice. The PDC are foundational to the overall safe design of the reactor. Therefore, they should be available in a non-proprietary format to provide transparency to the public.

SUMMARY

The PDC proposed by TEUSA for the IMSR reactor have been developed by adapting Advanced (Non-Light Water) Reactor design criteria from NRC guidance, design criteria from a draft ANSI/ANS standard for MSRs, and consideration of the unique design features of the IMSR.

The use of a negative fuel salt temperature coefficient as the sole means of placing and maintaining the reactor in a "safe state" has not yet been demonstrated for this design. Additionally, the use of a "safe state" as equivalent to "safe shutdown," with long-term criticality as an acceptable post-accident state, is a significant departure from accepted nuclear safety practices. The following have not been justified for this first-of-a-kind reactor: absence of an automatic reactor protection system to ensure that the reactor can always be placed in a safe condition; and, lack of a shutdown system with appropriate margin for malfunctions to ensure, that post accident, the reactor can be maintained in a subcritical state, not just a "safe state." This position is consistent with the draft ANSI/ANS MSR Standard Criteria 20 and 26.

The PDC proposed by TEUSA remove the requirement for a containment cleanup system as found in Criterion 41 of the draft ANSI/ANS MSR standard. The Committee considers this premature given that the final design is not complete.

The PDC are foundational to the overall safe design of the reactor. Therefore, they should be available in a non-proprietary format to provide transparency to the public.

We request a response from the staff prior to issuance of the SE.

Sincerely,



Signed by Kirchner, Walter
on 04/21/25

Walter L. Kirchner
Chairman

REFERENCES

1. U.S. NRC, Draft of the Safety Evaluation Regarding the Principal Design Criteria for Integral Molten Salt Reactor Structures, Systems and Components Topical Report, Revision C, February 24, 2025 (Agencywide Documents Access and Management System (ADAMS) Accession No. [ML24339A109](#) (Proprietary, Non-Public) and [ML24339A121](#) (Public)).
2. Terrestrial Energy, Principal Design Criteria for IMSR Structures, Systems, and Components Topical Report, Revision C, July 19, 2024 (ADAMS Accession Package No. [ML24204A092](#)).
3. U.S. NRC, Regulatory Guide 1.232, "Guidance for Developing Principal Design Criteria for Non-Light Water Reactors," Revision 0, March 27, 2018 (ADAMS Accession No. [ML18058B961](#)).
4. American Nuclear Society (ANS) ANSI/ANS-20.2-2023, "Nuclear Safety Design Criteria and Functional Performance Requirements for Liquid-Fuel Molten Salt Reactor Nuclear Power Plants," January 4, 2024 (www.ans.org).
5. ANSI/ANS 20.2, "Nuclear Safety Design Criteria and Functional Performance Requirements for Liquid-Fuel Molten Salt Reactor Nuclear Power Plants" (DRAFT) (www.ans.org).
6. The General Design Criteria for Nuclear Power Plants, Appendix A to Title 10 of the *Code of Federal Regulations* [Part 50](#).

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