



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

November 16, 2025

The Honorable David A. Wright
Chairman
U.S. Nuclear Regulatory Commission
Washington, DC 20555-0001

**SUBJECT: REPORT ON THE SAFETY ASPECTS OF THE CONSTRUCTION PERMIT
APPLICATION FOR A TERRAPOWER NATRIUM REACTOR AT THE
KEMMERER POWER STATION**

Dear Chairman Wright:

During the 730th meeting of the Advisory Committee on Reactor Safeguards, November 5 through 6, 2025, we completed our review of the safety aspects of the construction permit application (CPA) for Unit 1 of the Kemmerer Power Station (KU1) and selected portions of the U.S. Nuclear Regulatory Commission (NRC) staff's associated Safety Evaluation (SE). Our TerraPower Design Center Subcommittee reviewed this matter during subcommittee meetings on October 8 through 9 and October 21 through 23, 2025. During these meetings, we had the benefit of discussions with NRC staff and representatives from TerraPower (the applicant).¹ We also had the benefit of the referenced documents. This report fulfills the requirements of Section 182b of the Atomic Energy Act, as amended.²

CONCLUSIONS AND RECOMMENDATIONS

1. The reactor design for KU1 is a TerraPower Natrium pool-type, metal-fueled, sodium-cooled fast reactor (SFR). This design includes safety enhancements when compared to prior generation SFRs, including two means of passive heat removal, two diverse means of generating scrams, and significant separation between the sodium and steam systems. The design does not credit electrical power or operator intervention to achieve a safe shutdown.
2. The KU1 CPA is the first application for a power reactor to use the Licensing Modernization Project (LMP) methodology that was endorsed by the NRC staff in 2020. This methodology focuses the safety case on those items important to overall risk with increased use of the probabilistic risk assessment (PRA). We consider the applicant's implementation of this

¹ The construction permit application was submitted by TerraPower, LLC, on behalf of US SFR Owner, LLC (USO), a wholly owned subsidiary of TerraPower. For simplicity, this letter report refers to TerraPower as the applicant.

² Section 182b of the Atomic Energy Act (AEA) states, in part, "The Advisory Committee on Reactor Safeguards shall review each application under section 103 or section 104 b. for a construction permit or an operating license for a facility and shall submit a report thereon which shall be made part of the record of the application and available to the public except to the extent that security classification prevents disclosure." The Kemmerer CPA was submitted under section 103 of the AEA.

methodology at this stage of licensing to be acceptable and consistent with Commission policy on risk-informed, performance-based regulation for advanced reactors.

3. As noted in their SE, the staff concludes that the facility can be constructed in accordance with relevant regulations and the design bases outlined in the preliminary safety analysis report (PSAR). Detailed design, analysis, and technology qualification will be completed prior to the operating license (OL) application review. We agree with the NRC staff's assessment.
4. This letter report identifies several areas that warrant special attention during review of the OL application, including implementation of the functional containment approach, the system response to reactivity accidents, validation of the passive cooling design, completion of design features to prevent or mitigate sodium fires, seismic design, integration of the completed PRA and defense-in-depth assessments, evaluation of uncertainties, and quantification of safety margins.
5. Our review supports issuance of the construction permit for KU1.

BACKGROUND

The Kemmerer Power Station consists of one TerraPower-designed Sodium SFR rated to provide 840 megawatts thermal, along with the required power conversion equipment to generate 336 megawatts electrical (MWe) steady-state and 500 MWe peak electrical power. Key features of this plant design include the following:

- A nuclear island that includes the reactor core within a sodium pool and an intermediate heat transfer system that uses liquid sodium to transport heat from the sodium pool to a sodium-salt heat exchanger. The nuclear island also includes structures, systems, and components (SSCs) required to provide the fundamental safety functions of control of heat generation (e.g., reactivity control), control of heat removal (e.g., decay heat removal), and retention of radionuclides (e.g., containment function).
- An energy island that uses molten salt to store and transfer heat for further use, such as steam generation to power a turbine-generator. Because normal operation and fault conditions in the energy island are not expected to affect reactor safety, the applicant has designated all SSCs in the energy island as non-safety.

The PSAR, provided to support the CPA, was prepared using the LMP methodology.³ The LMP approach to safety justification is based primarily on a PRA, supported by a hazards analysis and supplemented by explicit assessment of safety margins and defense-in-depth. This CPA is the first application to be submitted to the NRC using the LMP methodology.

³ The LMP approach is described in Nuclear Energy Institute (NEI) Report NEI 18-04, "Risk-Informed Performance-Based Technology-Inclusive Guidance for Non-Light Water Reactor Licensing Basis Development," Revision 1, and was endorsed by 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.

DISCUSSION

Approach to Review: Our review of the safety aspects of the Kemmerer CPA was focused on areas that we identified as potentially unique, novel, and/or noteworthy in the application. These are summarized as follows:

- Implementation of Fundamental Safety Functions:
 - Control of Heat Generation: How does KU1 address the unique reactivity characteristics of SFRs, such as the potential for an increase in reactivity on core geometry changes, and what design features are included to mitigate them?
 - Control of Heat Removal: How are the different passive means of decay heat removal and their assumed reliability validated?
 - Retention of Radionuclides: The KU1 reactor is the first SFR to use a functional containment approach. What departures are made relative to the historical approach to SFR containment, and how are they justified?
- Adequacy of the overall safety case: Does this first use of the LMP methodology provide sufficient justification to issue a Construction Permit?

Control of Heat Generation:

The KU1 design uses active, passive, and inherent means of reactivity control to limit heat generation. When required by upset conditions such as plant transients, control rods can be inserted into the reactor core. The control rod drive system uses passive and active means to insert two control rod banks of diverse geometrical design into the core:

- The scram function results in passive gravity insertion of control rods into the reactor core to control heat generation. A gravity insertion will occur when reactor trip circuit breakers (RTBs) open via either of two diverse systems: (1) the reactor protection system (RPS), which removes power to the RTB undervoltage trip circuits based on any of several plant parameter sensors; or (2) as described by the applicant, the “alternative shunt trip” system that is not detailed in the PSAR, which will use parameter sensors and interfacing circuitry that are diverse from the RPS to trip the RTBs using their active shunt trip circuits. In either case, the RTBs remove power from scram system solenoid valves that then open to vent scram pistons, de-latching the control rods and allowing them to drop due to gravity.
- The driveline scram follow function results in active motor-driven insertion of the control rods when the RPS or alternative shunt trip system generates a scram signal. This feature provides defense in depth in case control rods fail to de-latch.

Inherent reactivity feedback characteristics of the reactor core also substantially contribute to the control of heat generation. As fuel and coolant temperatures rise, the combined effects of various feedback mechanisms result in net negative reactivity feedback within the core that reduces power. Their combined effect is a safe and stable power level at which heat production and heat removal are in balance and, importantly, provides a strong inherent response to counteract any unanticipated reactivity excursions.

Past SFR designs considered the possibility that common cause failures could result in loss of the active, passive, and inherent features that act to control heat generation. Specifically, they included consideration of a “hypothetical core disruptive accident (HCDA),” where an accident, caused by failure of the active and passive features, was postulated to relocate fissile material into a more reactive configuration and thereby perturb the inherent reactivity control features. An HCDA could potentially lead to an energetic transient with consequences such as pressure-driven leakage of sodium coolant from the reactor vessel into containment.⁴ TerraPower explained that HCDAs will be shown to be incredible events as part of the OL application, and their consequences will not be specifically considered as part of plant design and safety analysis. The safety case is expected to include: (1) design features that make accidents that lead to the potential for melting/relocation of fuel extremely unlikely; and (2) characteristics of metal fuel that make energetic reactivity transients unlikely even if fuel melting and relocation were to occur, particularly when compared to other SFR designs that use oxide fuel. The Appendix to this letter report summarizes the information provided by the applicant on this issue. We plan to further evaluate the justification when we review the OL application.

Safety analyses for reactivity addition and loss of flow transients assume certain bounds on the severity of the transients; specifically, only one control rod is assumed to withdraw, and the loss of flow is assumed to be caused by loss of power to primary sodium pumps whose rotors then coast down. More severe transients than those described above can be postulated, including: 1) withdrawal of more than one rod, which is precluded by a non-safety rod withdrawal interlock; and 2) pump failures that cause a pump locked rotor condition without a coastdown, which will be mitigated by a pump design that allows enough bypass flow to establish natural circulation and prevent fuel melt. TerraPower intends to review the safety classification of preventive controls such as the rod withdrawal interlock prior to submitting an OL application. We agree that this review is warranted and consider that the evaluation of a dual locked-rotor scenario, to provide defense-in-depth for such an unlikely transient, will be an important detail for the OL application.

Control of Heat Removal:

The KU1 design uses active and passive means to control heat removal. Two diverse residual heat removal systems, the intermediate air cooling (IAC) system and reactor air cooling (RAC) system, perform these functions. The IAC system provides means that are active or passive, while the RAC system provides passive means of removing decay heat.

Both the IAC and RAC systems rely on natural circulation of sodium coolant and air to passively remove decay heat. The OL application is expected to have more information to confirm effective natural circulation flow and heat transfer from sodium systems to air. For example, models of natural circulation flow will need to be validated, as well as heat transfer from the core to the ultimate heat sink through various interfaces such as the gap between the reactor vessel and guard vessel. Additionally, both the IAC and RAC systems rely on air flow through long passages that could be blocked as a consequence of external events. A means to reliably keep such air passages open will need to be demonstrated.

⁴ As an example, a 2022 study included an assumption of 350 kilograms of sodium forced into the containment volume due to a postulated HCDA; see International Atomic Energy Agency (IAEA), “Modelling and Simulation of the Source Term for a Sodium Cooled Fast Reactor Under Hypothetical Severe Accident Conditions,” IAEA TECDOC-2006, <https://www-pub.iaea.org/MTCD/Publications/PDF/TE-2006web.pdf>.

Retention of Radionuclides:

The KU1 design performs the fundamental safety function of retaining radionuclides using a functional containment strategy that employs diverse passive barriers to ensure regulatory dose criteria and Quantitative Health Objectives are met. These barriers begin at a radionuclide source and include all SSCs between that source and the environment. The functional containment system consists of: (1) the safety-related primary functional containment boundary, defined as the minimum set of barriers encompassing the core and primary system that prevent a release of radionuclides from exceeding regulatory limits; and (2) enveloping barriers, defined as either non-safety-related or non-safety-related with special treatment SSCs that each provide a backup radionuclide retention function to the primary functional containment boundary it envelopes. Under LMP, the safety classifications for the primary and enveloping boundaries are established through their relative safety significance.

In addition to the physical barriers, an important inherent plant design feature supporting the functional containment strategy is the high boiling point of sodium (relative to operational coolant and fuel temperatures). This ensures that the reactor core remains covered by subcooled sodium at near atmospheric pressure during licensing basis events (LBEs). The low operating pressure of the primary system, including the sodium cover gas, ensures there is no significant driving force to energetically transport radionuclides away from the reactor.

The KU1 reactor is the first SFR design to use a functional containment strategy. TerraPower stated that the functional containment barriers described in the PSAR were selected to meet radiological dose criteria for the mechanistic source term associated with the range of accident scenarios considered for the CPA under LMP. This includes an assessment of the most limiting design basis accident (DBA) to support regulatory requirements in Title 10 of the *Code of Federal Regulations* (10 CFR) Part 50.⁵ Accident analyses to be performed in support of the OL application are expected to confirm adequacy of the selected barriers.

The radionuclide barriers that were selected to meet the LMP frequency/consequence guidelines share many similarities with prior SFR containment designs, such as credited physical barriers with leak-rate limits and planned testing through plant life to confirm those limits continue to be met. The principal differences when using the KU1 functional containment approach are higher leak rate limits than prior designs and non-safety designations for certain components of the enveloping barriers. When compared to prior SFR designs, the KU1 reactor has several safety enhancements as described in the Appendix, resulting in what is expected to be a net reduction in risk despite these changes in containment design. Therefore, it is reasonable to expect that the functional containment approach can be fully justified during the OL phase, pending completion of design. We expect to further review the functional containment approach at the OL stage, with continued focus on the adequacy of the supporting

⁵ 10 CFR 50.34(a)(1) states in part, "In performing this assessment, an applicant shall assume a fission product release³ from the core into the containment assuming that the facility is operated at the ultimate power level contemplated." The cited footnote 3 states, "The fission product release assumed for this evaluation should be based upon a major accident, hypothesized for purposes of site analysis or postulated from considerations of possible accidental events. Such accidents have generally been assumed to result in substantial meltdown of the core with subsequent release into the containment of appreciable quantities of fission products." Per option 1 of Regulatory Position C.3.b in Regulatory Guide 1.253, the staff will accept the DBA dose consequence results from an LMP-based approach to meet this regulatory requirement.

accident analyses and the design and testing approaches as they compare to traditional containment designs.

One of the primary goals of the containment system for an SFR is to contain the effects of a fire caused by chemical interaction of sodium with air. TerraPower stated they will optimize locations in the KU1 design where two barriers are provided between the sodium coolant and air to minimize risk. For example, a guard vessel surrounds the reactor vessel to provide two barriers for sodium in the core. However, given the difficulty in fighting sodium fires, more details about mitigating barriers, sodium fire progression models, and the fire protection program are needed to support the fire risk assessment that will be performed as part of the OL application review.

Radionuclide retention during accident conditions will also depend upon the sodium-salt heat exchanger being a reliable pressure boundary. The sodium-salt heat exchanger couples the nuclear and energy islands. Ongoing research and development programs by TerraPower are addressing materials compatibility, reaction energetics, and leak detection and isolation methods. The heat exchanger design concept is innovative but remains one of the least mature elements of the plant, and continued progress in these areas will be important to the safety case at the OL stage.

Adequacy of the overall safety case:

Application of Licensing Modernization Project

Implementation of the LMP approach is an important element of the safety case. The LMP methodology is centered around use of a PRA to select LBEs, determine appropriate safety classification of SSCs, assign associated risk-informed special treatments, and determine adequacy of defense in depth. As the PRA evolves from the CP stage, the above attributes may be revised accordingly. This iterative process, as conceived in Regulatory Guide (RG) 1.233 and RG 1.253, will provide valuable information when evaluating advantages and shortcomings of an application that is based on LMP. The NRC staff stated they are evaluating this CPA for lessons learned and potential clarifications to associated NRC guidance.

TerraPower's approach to implementing the LMP guidance for defense in depth was notable. They used a methodical "defense line" approach, where every group of LBEs is assessed against the LMP five-layer defense-in-depth model to assure appropriate independence and diversity in system design and operation. TerraPower stated that the linkage between these defense lines, principal design criteria, key safety functions, and quantifiable performance measures will continue to progress through final design and the OL application. We encourage the NRC staff to further develop guidance for such approaches as they have the potential to apply the principle of defense in depth in a straightforward manner.

The LMP methodology uses a frequency-consequence curve that specifies acceptable dose consequence limits that get larger as the event frequency gets smaller. For event sequences with frequency less than a 5×10^{-7} per year cutoff, LMP does not specify a dose limit but requires consideration of these very low frequency sequences to assess for cliff-edge effects and to assure adequacy of defense in depth. The Kemmerer CPA uses the term "other quantified events," or OQE, to refer to such events. However, the PSAR is not clear on cliff-edge effects or what acceptance criteria are used when assessing OQE. The intent of evaluating OQEs is to determine if any low frequency events are sufficiently consequential to consider additional mitigation. To address cliff-edge effects and defense-in-depth adequacy, TerraPower stated

they will evaluate all scenarios that meet either of two conditions: (1) the scenario has an estimated frequency of occurrence of 1.0×10^{-7} per year or greater with a 95% confidence level; or (2) any scenario, regardless of frequency, that has a consequence of greater than 1000 rem Total Effective Dose Equivalent over 30 days at the exclusion area boundary. They also stated that they had not yet encountered a scenario with a dose level high enough to warrant this further evaluation, even considering event types such as unprotected reactivity addition and unprotected loss of flow. We expect to review these conclusions at the OL stage.

We consider the applicant's implementation of the LMP methodology at this stage of licensing to be acceptable and consistent with Commission policy on risk-informed, performance-based regulation for advanced reactors.

Seismic Isolation System

One specific design feature considered to be novel is the use of a seismic isolation system (SIS) for the reactor enclosure system. The design approach is to embed in the reactor building substructure an SIS to support the reactor and enhance protection against seismic events. TerraPower is following the general lead of the GE PRISM™ design of the 1980s, which envisioned using steel/rubber isolation devices to support the reactor and provide seismic protection. Special attention will be required to address the relative deflections between SSCs supported by the seismic isolation system and those outside the system, such as connections to intermediate heat transfer system piping. Additionally, phenomena such as reactivity response to seismic forces may be relatively new for an SFR design and warrant additional attention during the OL stage.

Treatment of Safety Analysis Uncertainties and Margins

Some of the calculations required to support the safety case are much more involved and complex than for other reactor technologies, and the PSAR does not include discussion of the uncertainties or available margins. These analyses will be refined as the design proceeds from the CP stage to the OL stage. It will be important to establish the margin to figures of merits that are used to assess whether principal design criteria are met. While in the end there may be sufficient margin, the uncertainties associated with those calculations need to be established and assessed for acceptability at the OL stage. Examples that should be addressed and explicitly documented in the Final Safety Analysis Report include:

- Reactivity feedback coefficients depend on complex calculations of the deformation of the fuel rods as restrained by the core restraint system, including the effect of the lower grid plate. Moreover, point kinetics may not capture the three-dimensional (3-D) nature of the response of the core and 3-D kinetics may be necessary. The uncertainties associated with those calculations and the margin to avoiding a net positive reactivity coefficient should be quantified.
- Calculations related to confirmation of acceptable fuel integrity and safety-related structural materials, in general, depend on detailed thermomechanical analysis and the uncertainty in the predicted response (stress, strain, creep rupture, etc.) that are not discussed in the PSAR or referenced topical reports. In particular, analysis of the margin to eutectic melt, a key metric for fuel failure, is needed. These uncertainties and margins are expected to be quantified.

SUMMARY

TerraPower has sufficiently completed the early phases of a risk-informed safety case, using the LMP approach, to justify approval of their construction permit application for a Sodium SFR at a site in Kemmerer, Wyoming. This application is supported by safety enhancements associated with the KU1 reactor design that are significant when compared to prior SFR designs. These enhancements can be leveraged to support simplifications (such as use of a functional containment approach) in design and analysis. We look forward to reviewing the final safety case when it is submitted with an application for an operating license.

Our review supports issuance of the construction permit for KU1.

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

Sincerely,



Signed by Kirchner, Walter
on 11/16/25

Walter L. Kirchner
Chairman

Enclosures:

1. Appendix: Safety Enhancements of the Sodium Reactor Design Relative to Prior Sodium-Cooled Fast Reactors (SFRs)
2. List of Acronyms

REFERENCES

1. TerraPower, LLC, "Submittal of the Construction Permit Application for the Natrium Reactor Plant, Kemmerer Power Station, Unit 1," March 28, 2024 (Agencywide Documents Access and Management System (ADAMS) Package No. [ML24088A059](#))
2. TerraPower, LLC, "Submittal of Revisions to the Construction Permit Application for the Natrium Reactor Plant, Kemmerer Power Station Unit 1," October 3, 2025 (ADAMS Package No. [ML25276A289](#))
3. TerraPower, LLC, "Preventative Measures Classification Methodology and Preliminary Results," September 10, 2025 (ADAMS Package No. [ML25253A385](#))
4. TerraPower, LLC, "Transmittal of TerraPower, LLC, 'Natrium Demonstration DID Evaluation Report,' NAT-4770 Revision 1," July 23, 2025 (ADAMS Package No. [ML25205A086](#) (public), Accession No. [ML25205A088](#) (non-public))
5. TerraPower, LLC, "Research and Development Supplemental Information," October 1, 2025 (ADAMS Package No. [ML25274A123](#) (public), Accession No. [ML25274A125](#) (non-public))
6. U.S. Nuclear Regulatory Commission, "Draft Safety Evaluations for the Kemmerer Power Station Unit 1 Construction Permit Application to Support the ACRS Full Committee," November 6, 2025 (ADAMS Package No. [ML25303A295](#))
7. U.S. Nuclear Regulatory Commission, ACRS Letter Report, "Draft Safety Evaluation Of TerraPower's Natrium Topical Report On Fuel And Control Assembly Qualification," June 27, 2024 (ADAMS Accession No. [ML24172A046](#))
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9. U.S. Nuclear Regulatory Commission, ACRS Letter Report, "Draft Safety Evaluation of the TerraPower Topical Report, 'Plume Exposure Pathway Emergency Planning Zone Methodology,' Revision 3," November 26, 2024 (ADAMS Accession No. [ML24324A305](#))
10. U.S. Nuclear Regulatory Commission, ACRS Letter Report, "Natrium Topical Report, 'Radiological Source Term Methodology Report,' (NAT-9392 Revision 0)," June 9, 2025 (ADAMS Accession No. [ML25140A136](#))
11. Nuclear Energy Institute, Report NEI 18-04, "Risk-Informed Performance-Based Technology-Inclusive Guidance for Non-Light Water Reactor Licensing Basis Development," Revision 1, August 2019 (ADAMS Accession No. [ML19241A472](#))
12. 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](#))
13. 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](#))

14. International Atomic Energy Agency, "Modelling and Simulation of the Source Term for a Sodium Cooled Fast Reactor Under Hypothetical Severe Accident Conditions," IAEA TECDOC-2006, 2022 (<https://www-pub.iaea.org/MTCD/Publications/PDF/TE-2006web.pdf>)
15. R. Wigeland and J. Cahalan, "Fast Reactor Fuel Type and Reactor Safety Performance," INL/CON-09-15241 for Proceedings of Global 2009 Paris, France, September 6-11, 2009 (<https://www.osti.gov/servlets/purl/968659-cAosXU/>)
16. T. Sofu, "A Review of Inherent Safety Characteristics of Metal Alloy Sodium-Cooled Fast Reactor Fuel Against Postulated Accidents," Nuclear Engineering and Technology, Volume 47, Issue 3, April 2015, Pages 227-239 (<https://www.sciencedirect.com/science/article/pii/S1738573315000753>)
17. U.S. Nuclear Regulatory Commission, "Staff Requirements – SECY-19-0117 – 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," May 26, 2020 ([ML20147A504](#))

November 16, 2025

SUBJECT: REPORT ON THE SAFETY ASPECTS OF THE REAUTHORIZATION OF
POWER OPERATIONS FOR THE PALISADES NUCLEAR PLANT

Accession No: ML25311A150 Publicly Available (Y/N): Y Sensitive (Y/N): N
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APPENDIX

SAFETY ENHANCEMENTS OF THE NATRIUM REACTOR DESIGN RELATIVE TO PRIOR SODIUM-COOLED FAST REACTORS (SFRs)

Purpose: This appendix enumerates some of the safety enhancements in the Natrium design as described by TerraPower. Their implementation of the Licensing Modernization Project (LMP) methodology takes credit for such safety enhancements to address the potential for a hypothetical core disruptive accident (HCDA) and the adequacy of the functional containment design strategy in the safety basis for Kemmerer Unit 1 (KU1).

Background: As a risk-informed methodology, LMP focuses on accident scenarios determined via a probabilistic risk assessment (PRA) and mechanistic source terms instead of postulated events that are deterministically judged to be bounding. Use of a risk informed approach can lead to differences in safety design and analysis compared to the use of deterministic methods. For KU1, this approach resulted in two significant changes relative to earlier SFR designs:

1. Prior SFR designs considered the potential for an HCDA, which is a hypothetical severe event in a SFR characterized by a rapid, uncontrolled increase in reactor power and subsequent rearrangement of fuel into a more reactive configuration. This could lead to a power excursion and energy release that might challenge the reactor's containment. Such accidents may be triggered by a loss of coolant flow, or a transient overpower event, especially if the reactor fails to shut down automatically (known as "unprotected" events). For KU1, TerraPower does not include an HCDA in their safety basis since it is not deemed to be credible per the LMP risk-informed process.
2. Prior SFR designs included a containment structure (or set of structures) with characteristics specified by principal design criteria that define low leakage barriers and safety classifications. For KU1, TerraPower employs a functional containment design strategy that identifies the radionuclide retention barriers and their performance characteristics shown to be needed by a mechanistic source term analysis.

Discussion: The Natrium reactor design incorporates several important features that support the LMP-based design decisions discussed above:

- A large sodium pool with a high degree of thermal inertia. The primary sodium, except for a small amount that is sent to the sodium processing system, remains in the reactor vessel. All penetrations are above the top of the primary sodium pool.
- Metal fuel, which significantly reduces the amount of stored energy available for interaction between the fuel and the coolant when compared to oxide fuels used in other SFR designs.
- No addition of plutonium in fuel, which reduces the magnitude of the void reactivity worth compared to other SFR fuel systems.
- Two independent and diverse shutdown mechanisms (gravity scram and motor-driven driveline scram follow), each controlled by independent and diverse trip systems (reactor protection system and alternative shunt trip system). Each of these shutdown mechanisms inserts two diversely designed sets of control rods.

- Two independent, decay heat removal systems. The reactor air cooling (RAC) system is passive and is always on, and the intermediate air cooling (IAC) system can operate in active and passive modes.
- Two primary mechanical sodium pumps whose design enables the transition from forced to natural circulation of sodium.
- Functional containment as supported by improved understanding of fission product release from metallic fuel and its subsequent transport in sodium and the cover gas.
- Separation of the energy island from the nuclear island, which essentially eliminates the potential for sodium-water interaction. There is potential for sodium-salt interaction at the sodium-salt heat exchanger, but TerraPower plans to prevent or mitigate this interaction as described in Chapter 13 of the preliminary safety analysis report.
- Acceptable reactor performance for many unprotected scenarios. Preliminary analyses done by TerraPower indicated that while fuel rod failure (releasing the contents of the fuel rod plenum) could be expected in severe low frequency unprotected events such as unintended withdrawal of one control rod or a loss of flow caused by loss of power to the primary sodium pumps, inherent reactivity feedback features (doppler, fuel axial expansion, grid plate radial expansion) should preclude sodium boiling or fuel melt.
- Additional preventive features. Unprotected transients complicated by failures such as unintended withdrawal of multiple control rods or locked rotor failures of both primary sodium pumps could potentially lead to fuel melt or boiling of sodium. The applicant intends to include defense-in-depth features, such as rod withdrawal interlocks and bypass flow in the sodium pumps to mitigate locked rotor conditions, to further lower the likelihood of such outcomes.
- Reduced potential for a severe accident to lead to an energetic reactivity transient. Specifically, as discussed in referenced National Laboratory documents, certain thermal and physical properties of metal fuel make it unlikely that fuel melt would lead to a reactivity addition, particularly when compared to designs that use oxide fuel.^{1, 2}

Conclusion: These features result in a robust implementation of the key safety functions in the Natrium design. They demonstrably influence plant safety by either reducing the frequency of postulated events or reducing the associated consequences. Thus, a significant reduction in the overall risk profile of the plant is expected when compared to other SFR designs. It is reasonable to expect that these safety enhancements can be leveraged in an operating license application to fully justify the TerraPower conclusions that an HCDA is not credible and that a functional containment strategy driven by a robust mechanistic source term analysis is technically sound.

¹ R. Wigeland and J. Cahalan, "Fast Reactor Fuel Type and Reactor Safety Performance", INL/CON-09-15241 for Proceedings of Global 2009 Paris, France, September 6-11, 2009.

² T. Sofu, "A Review of Inherent Safety Characteristics of Metal Alloy Sodium-Cooled Fast Reactor Fuel Against Postulated Accidents," Nuclear Engineering and Technology, Volume 47, Issue 3, April 2015, Pages 227-239.

LIST OF ACRONYMS

10 CFR	Title 10 of the <i>Code of Federal Regulations</i>
3-D	Three Dimensional
AEA	Atomic Energy Act
CPA	Construction Permit Application
DBA	Design Basis Accident
HCDA	Hypothetical Core Disruptive Accident
IAEA	International Atomic Energy Agency
IAC	Intermediate Air Cooling
KU1	Kemmerer Power Station, Unit 1
LBE	Licensing Basis Events
LMP	Licensing Modernization Project
MW _e	Megawatts Electric
NEI	Nuclear Energy Institute
NRC	Nuclear Regulatory Commission
OL	Operating License
OQE	Other Quantified Events
PRA	Probabilistic Risk Assessment
PSAR	Preliminary Safety Analysis Report
RAC	Reactor Air Cooling
RG	Regulatory Guide
RPS	Reactor Protection System
RTBs	Reactor Trip Breakers
SE	Safety Evaluation
SFR	Sodium Fast Reactor
SIS	Seismic Isolation System
SSCs	Structures, Systems and Components
USO	US SFR Owner, LLC