TERRAPOWER, LLC – AUDIT PLAN FOR TOPICAL REPORT "DESIGN BASIS ACCIDENT METHODOLOGY FOR IN-VESSEL EVENTS WITHOUT RADIOLOGICAL RELEASE," REVISION 0 (EPID NO. L-2023-TOP-0050)

Sponsor: TerraPower, LLC

Sponsor Address: 15800 Northup Way, Bellevue, WA 98008

Sponsor Name: Natrium

Project No.: 99902100

Background:

By letter dated September 29, 2023, TerraPower, LLC (TerraPower) submitted topical report (TR) "Design Basis Accident Methodology for In-Vessel Events without Radiological Release," Revision 0 (Agencywide Documents Access and Management System (ADAMS) Accession No.: ML23272A260) to the U.S. Nuclear Regulatory Commission (NRC) staff. The TR summarizes the approach taken to satisfy the guidance outlined in Regulatory Guide (RG) 1.203, "Transient and Accident Analysis Methods," Revision 0 (ML053500170), regarding the Evaluation Model Development and Assessment Process (EMDAP) for in-vessel design basis accident (DBA) events without radiological release in the Natrium reactor. On October 31, 2023, the NRC staff found that the material presented in the TR provides technical information in sufficient detail to enable the NRC staff to conduct a detailed technical review (ML23303A165).

TerraPower has requested the NRC staff's review and approval of the evaluation model (EM) presented in the TR for use by future applications utilizing the Natrium design. The applicant's overall licensing methodology follows the technology-inclusive, risk-informed, and performance-based approach outlined in 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," Revision 0 (ML20091L620).

Purpose:

The purpose of the audit is for the NRC staff to gain a more detailed understanding of TerraPower's EM presented in the TR and to identify any information that will require docketing to support the NRC staff's safety evaluation. The NRC staff will summarize its observations in an audit report to be provided to TerraPower, as discussed below.

Regulatory Audit Basis:

The basis for the audit includes:

- Title 10 of the *Code of Federal Regulations* (10 CFR) 50.34(a)(4) and 10 CFR 50.34(b)(4), which apply to applicants for construction permits and operating licenses, respectively. These sections require analysis and evaluation of the design and

performance of structures, systems, and components (SSCs) of the facility with the objective of assessing the risk to public health and safety resulting from operation of the facility and including determination of the margins of safety during normal operations and transient conditions anticipated during the life of the facility, and the adequacy of SSCs provided for the prevention of accidents and the mitigation of the consequences of accidents.

- Paragraph 50.43(e) of 10 CFR requires that reactor designs that differ significantly from light-water reactor designs licensed before 1997 may only be approved if there has been appropriate demonstration of their safety features. 10 CFR 50.43(e)(1)(i) and (ii) require demonstration of safety feature performance and interdependent effects through analysis, appropriate test programs, experience, or a combination thereof. 10 CFR 50.43(e)(1)(iii) requires that sufficient data exists on the safety features to assess the analytical tools for safety analysis over a sufficient range of plant conditions.

Regulatory Audit Methodology:

The audit will follow the guidance in NRC Office of Nuclear Reactor Regulation (NRR) Office Instruction LIC-111 “Regulatory Audits,” Revision 1 (ML19226A274), and focus on information provided by TerraPower in an electronic reading room.

Information and Other Material Necessary for the Regulatory Audit:

The NRC staff requests TerraPower to make available the information and subject matter experts necessary to respond to the audit inquiries included in the enclosure. These inquiries fall into the general categories of:

- Additional detail on the phenomena and identification and ranking table (PIRT) exercises conducted to support this TR
- Additional detail regarding the legacy experiments being considered for inclusion in the EM
- Additional detail on the SAS4A/SASSYS-1 (SAS) code and its implementation in the EM
- Additional detail on changes made to SAS for the EM
- General clarification of various subjects included in the TR

Team Assignments

Reed Anzalone	Senior Nuclear Engineer, Audit Lead
Deion Atkinson	Project Manager, Natrium
Roel Brusselmans	Project Manager, Natrium
Stephanie Devlin-Gill	Senior Project Manager, Natrium
Zachary Gran	Reactor Engineer
Michelle Hart	Senior Reactor Engineer
Alec Neller	Reactor Systems Engineer

Logistics

Entrance Meeting	March 25, 10:30 A.M.
Exit Meeting	April 26, 2:00 P.M.

Audit meetings will take place in a virtual format, using Microsoft Teams or another similar platform. Audit meetings will be scheduled on an as-needed basis after the entrance meeting and once the NRC staff has had the opportunity to review any documents placed in the online reference portal. The audit will begin on March 25, 2024, and continue as necessary, with activities occurring intermittently during the audit period. The audit period may be reduced or extended, depending on the progress made by the NRC staff and TerraPower in addressing audit questions.

Special Requests

The NRC staff requests that TerraPower ensure that their technical staff are available to answer questions during the audit. The NRC staff also requests that TerraPower provide access to supporting documents via an electronic reading room.

Deliverables

At the completion of the audit, the audit team will issue an audit summary within 90 days after the exit meeting but will strive for a shorter duration. The audit summary will be declared and entered as an official agency record in ADAMS and be made available for public viewing through the publicly available records component of ADAMS.

If you have questions about this audit, please contact me at 301-415-0829 or via email at Roel.Brusselmans@nrc.gov.

Sincerely,

/RA/

Roel Brusselmans, Project Manager
Advanced Reactors Licensing Branch 1
Division of Advanced Reactors and Non-Power
Production and Utilization Facilities
Office of Nuclear Reactor Regulation

Project No.: 99902100

Enclosure:
As stated

cc: TerraPower Natrium
via GovDelivery

SUBJECT: TERRAPOWER, LLC – AUDIT PLAN FOR TOPICAL REPORT "DESIGN BASIS ACCIDENT METHODOLOGY FOR IN-VESSEL EVENTS WITHOUT RADIOLOGICAL RELEASE," REVISION 0 (EPID NO. L-2023-TOP-0050) DATED: MARCH 5, 2024

DISTRIBUTION:
PUBLIC
RidsNrrDanu Resource
RidsNrrDanuUal1 Resource
RidsNrrDanuUtb2 Resource
SDevlin-Gill, NRR
DGreene, NRR
DAtkinson, NRR
RBrusselmans, NRR
MSutton, NRR
WJessup, NRR
RAnzalone, NRR
CdeMessieres, NRR
ANeller, NRR

ADAMS Package No: ML24064A176
ADAMS Audit Plan (Public) No: ML24064A195
ADAMS Audit Plan (Non-public) No: ML24064A178 **NRR-106**

OFFICE	NRR/DANU/UTB2	NRR/DANU/UTB2:BC	NRR/DANU/UAL1:LA
NAME	RAnzalone	CdeMessieres	DGreene
DATE	2/22/2024	2/22/2024	3/4/2024
OFFICE	NRR/DANU/UAL1:BC	NRR/DANU/UAL1:PM	NRR/DANU/UAL1:PM
NAME	WJessup (SDevlin-Gill for)	RBrusselmans	DWilliams
DATE	3/4/2024	3/4/2024	3/5/2024

OFFICIAL RECORD COPY

Audit questions related to TP-LIC-RPT-0004 Revision 0,
"Design Basis Accident Methodology for In-Vessel Events without Radiological Release"

1. In TR Section 2.2, "Figures-of-Merit: EMDAP Step 2," fuel centerline temperature is selected as a figure-of-merit. Is there potential for another portion of the fuel to be hotter than the centerline due to fuel composition changes from uranium and zirconium migration? If so, how will this temperature deviation be accounted for?

2. TR Section 2.3, "Systems, Components, Phases, Geometries, Fields, and Processes Modeled: EMDAP Step 3," provides a hierarchical system decomposition of items that need to be modeled in the EM. Are there any transient scenarios which could require the flow of both sodium and argon in a pipe to be modeled?

3. In Section 2.3 of the TR, the sodium-salt heat exchangers are included in the hierarchical decomposition. Given the SAS code appears unable to model salt in a loop attached to an intermediate loop, provide a description of how the salt side of the heat exchanger will be modeled.

4. TR Section 2.4, "Identification and Ranking of Phenomena and Processes: EMDAP Step 4," discusses the performance of five PIRTs, three by external experts and two by internal TerraPower experts. Provide more details regarding the performance of the PIRTs. The two internal PIRT scenarios were not discussed in the TR; therefore, include information regarding what scenarios were considered by the internal panel.

5. In TR Section 2.5, "Preliminary Evaluation of Highly-Ranked Phenomena," eight highly-ranked phenomena will be "quantified using sensitivity studies that envelope the range of interest via input to the EM." Provide additional information on how this will be performed in SAS.

6. Provide more information on the role computational fluid dynamics (CFD) calculations plays for analysis of in-vessel DBAs without radiological release. Section 3.4.2, "Top-down Description of PHT [Primary Heat Transfer System] Loop Flow Dynamics," states that "the one-dimensional characterization of the large pool sections needs to be reevaluated via CFD calculations to represent multi-dimensional effects in the flow/temperature distribution." **[[**

]].

7. Section 3.5.1 of the TR discusses the scaled IET, identifying seven highly-ranked phenomena that will be assessed based on data from the IET. The Preliminary Natrium Code Assessment Matrix (table 3-5) **[[**

]]. Clarify which phenomena will be assessed with data from the IET.

ENCLOSURE

8. Based on TR Section 3.5.1.1, **[[**

]]

9. TR Section 3.5.1.2, **[[**

]]

10. **[[**

]] TR Section 3.5.1.3, **[[**

]]

11. **[[**

]]

12. In TR Section 3.3, "Assessment Base Objectives: EMDAP Step 5," a complete assessment base is described as having "[e]xperimental data from at least one Category 1 IET and the supporting Category 1 SETs deemed necessary are available to support assessment of all the highly-ranked phenomena identified in Element 1." Are any IETs being considered for the **[[ ]]** phenomena related to the RAC system to meet this objective?

13. **[[**

]] Based on the NRC staff review, it appears that the tests discussed in TR Sections 3.5.2, "EBR-II Tests: SHRT-17, SHRT-45R, and balance of plant (BOP)," 3.5.3, "FFTF Tests: LOFWOS Test #10-12," and 3.5.4, "Phenix Tests: Natural Circulation Tests," **[[**

]]

14. TR Section 3.5.4 states that tabular data for the Phenix experiment is available in reference 18. Reference 18 of the TR is a technical report documenting Toshiba electromagnetic pump development (as referenced in TR Section 3.5.7, "Toshiba 4S Test Facility Tests"). It does not seem to contain any relevant data on the Phenix natural circulation test. Is there a different document this section should be referencing?

15. TR table 3-5 lists the **[[**

]] According to Section 3.3 of the TR, to meet Category 1 requirements, "the physical geometry of the experimental facility used to generate data relevant to the Natrium design, including unique features, is assessed considering both the design of the system components and the comparison to experimental facility similarity criteria." How was **[[**

]]?

16. **[[**

]]?

17. TR Section 3.5.10, "PCN 37-Pin Bundle Experiments," does not seem to fully capture the two different experimental rigs used (CCTL-CFR and PLANDTL-DHX) which are discussed in TR Reference 37, instead listing the objectives of the CCTL-CFR experiment as objectives of the PLANDTL-DHX experiment. Additionally, TR table 3-5 states that **[[**

]]. These phenomena do not appear to be related to the objectives of either the CCTL-CFR or PLANDTL-DHX experiments.

    a. How will PLANDTL-DHX data be used to assess the reactivity feedback phenomena listed in table 3-5?
    b. For the reactivity feedback phenomena, how was it determined that the PLANDTL-DHX facility met Category 1 scaling requirements for the Natrium design?
    c. Currently, PLANDTL-DHX is the only listed experiment for the three reactivity feedback phenomena. Are any other experiments or legacy datasets being considered for these phenomena?

18. TR Section 3.5.12, "UIUC [University of Illinois Urbana-Champaign] Natural Circulation Tests," discusses **[[**

]]?

19. Provide more information on the functional, performance, and validation requirements of the EM development plan as outlined in TR Section 4.1, "EM Development Plan: EMDAP Step 10." **[[**

]]

20. **[[**

]].

21. Table 4-2, “Applicable SAS4A/SASSYS-1 Modules and Phenomenological Models,” lists applicable SAS modules and models that will be used for analyzing in-vessel DBAs without radiological release:

    a. Beyond this list, what other modules will be used for analyzing in-vessel DBAs without radiological release (e.g., SSTHRM, TSTHRM, MFUEL)? Based on the NRC staff evaluation of the SAS user manual, table 4-2 appears to be missing key modules required for transient analysis.
    b. How will the **[[ ]]** module be employed? The NRC staff reviewed **[[ ]]** of the SAS user manual and it appears that the **[[ ]]** module is focused on modeling **[[ ]]** .

22. Provide additional information on how TerraPower intends to model the sodium-salt heat exchanger and the sodium-air heat exchanger. The SAS user manual indicates only four heat exchangers can be modeled in a design and assumes a sodium-water heat exchanger in the intermediate loop.

23. Section 5.4.7, “RVACS/RACS Models,” of the SAS user manual outlines three different models available for reactor vessel auxiliary cooling and RAC systems. Which model is TerraPower planning on implementing for analyzing in-vessel DBAs without radiological release?

24. TR Sections 4.2.1.2.d, “Closure Relations,” and 4.3, “Closure Models and Conservativisms – EMDAP Step 12,” state closure relationships are discussed in the SAS user manual, providing context only on three new correlations being added to SAS. The NRC staff reviewed the user manual and did not find concise discussions on what correlations or closure relationships are being used. Provide additional information on what correlations are being used in SAS for your analysis.

25. Section 4.3 of the TR discusses three correlations which are being added to SAS for the EM. How will this be implemented in SAS (i.e., what correlations will they be replacing)? Provide context for these changes.

26. In TR Section 4.3.1.3, “Wire-wrapped Pin-Bundle Pressure Drop,” **[[**

]]

27. Has commercial grade dedication (CGD) been completed for SAS? Section 5.5, "Integrated EM – Top-down: Assess Applicability of EM to Simulate System and Global Capability: EMDAP Steps 17 and 18," states both "the final summary and conclusion of CGD is documented in the SAS4A/SASSYS-1 Software Dedication Report [52]" and "[t]he CGD will be performed if a version of the code is adopted for the application."

28. TR Section 4.3.2, "Conservativisms, Biases, and Hot Channel Factors," discusses applying safety hot channel factors to the temperature rise across the coolant, film, clad, gap, and fuel layers. Will a corrosion layer form on the clad? If so, has TerraPower considered the temperature rise across this layer?

29. Provide clarification for the following:

    a. Table 3-5 appears to **[[**

       ]].
    b. In TR Section 5.2, "Closure Relations (Bottom-up: Model Fidelity and Accuracy): EMDAP Step 14," two references to past chapters appear to be misnumbered (i.e., experiments are described in chapter 4 (vice actually being in chapter 3) as well as describing Steps 10 and 12 in chapter 5 (vice these steps actually being detailed in chapter 4).
    c. In TR Sections 3.3 and 5.4, "Integrated EM - Top-down: Field Equations/Numeric Solutions Capabilities - EMDAP Step 16," Category 2 is described as "[t]he physical properties (e.g., the thermodynamic state and a similar working fluid), and." Is this the complete definition? The NRC staff notes that descriptions for Categories 1 and 3 are complete sentences.