UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555-0001

TERRAPOWER, LLC. – DRAFT SAFETY EVALUATION OF NAT-9392, "RADIOLOGICAL SOURCE TERM METHODOLOGY REPORT," REVISION 0 (EPID NO. L-2023-TOP-0046)

SPONSOR AND SUBMITTAL INFORMATION

Sponsor:	TerraPower, LLC (TerraPower)
Sponsor Address:	15800 Northup Way, Bellevue, WA 98008
Project No.:	99902100
Submittal Date:	August 11, 2023, January 16, 2024, and September 13, 2024

Submittal Agencywide Documents Access and Management System (ADAMS) Accession No.: ML23223A234, ML24017A115, and ML24261B944

Brief Description of the Topical Report: On August 11, 2023, TerraPower submitted topical report (TR) number TP-LIC-RPT-0003 (ML23223A234), which provides an overview and description of the model developed to evaluate mechanistic source terms (MSTs) for the proposed Natrium reactor design. On November 15, 2023, the U.S. Nuclear Regulatory Commission (NRC) staff concluded that Revision 0 of the TR was not sufficiently detailed to begin the NRC staff's detailed review. The NRC staff also told TerraPower that it could supplement the submittal with the additional information (ML23292A269). On January 16, 2024, TerraPower supplied the supplemental information by submitting Revision 1 of the TR (ML24017A115) as a replacement to the information contained in Revision 0.

On May 16, 2024, the NRC staff transmitted an audit plan to TerraPower (ML24127A048), and subsequently conducted an audit of materials related to the TR from May 28, 2024, through August 13, 2024. The NRC staff issued the audit summary on January 7, 2025 (ML24232A223). On September 13, 2024, TerraPower submitted a further revision of the radiological source term methodology, which superseded the prior submissions, and renumbered the TR as NAT-9392, Revision 0 (ML24261B944).

For background, TerraPower's overall licensing approach for applications related to the proposed Natrium reactor design follows the Licensing Modernization Project (LMP) methodology described in Nuclear Energy Institute (NEI) 18-04, Revision 1, "Risk-Informed Performance-Based Technology Inclusive Guidance for Non-Light Water Reactor Licensing Basis Development," (ML19241A472). Regulatory Guide (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 (ML20091L698), endorses the LMP methodology described in NEI 18-04. The TR methodology evaluation model (EM) is developed for estimating the radiological source terms (also referred to as source terms) describing potential accidental radiological releases to the environment for use in consequence analyses performed to comply with relevant regulatory requirements in Title 10 of the *Code of Federal Regulations* (10 CFR) Part 50, "Domestic Licensing of Production and Utilization Facilities," including, in part, through the use of the LMP methodology.

REGULATORY EVALUATION

This TR was submitted in support of prospective Natrium reactor construction permit or OL applications under 10 CFR Part 50. Specific regulations relevant to TerraPower's radiological source term methodology include:

- The requirements in Title 10 CFR 50.34(a) with respect to the minimum information to be included in a preliminary safety analysis report submitted as part of a construction permit application, as pertains to the evaluation of events and safety features. Specifically, the following are considered:

  - Title 10 CFR 50.34(a)(1)(ii) requires a description and safety assessment of the site and a safety assessment of the facility. It is expected that reactors will reflect through their design, construction and operation an extremely low probability for accidents that could result in the release of significant quantities of radioactive fission products.

  - Title 10 CFR 50.34(a)(1)(ii)(D) requires the Commission to take into consideration the safety features that are to be engineered into the facility and those barriers that must be breached as a result of an accident before a release of radioactive material to the environment can occur. Special attention must be directed to plant design features intended to mitigate the radiological consequences of accidents. The regulation also requires the applicant to perform an evaluation and analysis of the postulated fission product release (i.e., source term), using the expected demonstrable containment leak rate and any fission product cleanup systems, used together with applicable postulated site parameters, including site meteorology, to evaluate offsite radiological consequences. The safety assessment analyses are intended, in part, to show compliance with the radiological consequence evaluation factors for offsite doses at the exclusion area boundary and outer boundary of the low population zone (LPZ). This evaluation must determine that:

    > "(1): An individual located at any point on the boundary of the exclusion area for any 2 hour period following the onset of the postulated fission product release, would not receive a radiation dose in excess of 25 rem[ ] total effective dose equivalent (TEDE).
    > "(2): An individual located at any point on the outer boundary of the [LPZ], who is exposed to the radioactive cloud resulting from the postulated fission product release (during the entire period of its passage) would not receive a radiation dose in excess of 25 rem [TEDE]."

  - Title 10 CFR 50.34(a)(4) requires a preliminary analysis and evaluation of the design and performance of structures, systems, and components 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 structures, systems, and components provided for the prevention of accidents and the mitigation of the consequences of accidents.

- Title 10 CFR 50.34(a)(3)(i) requires that the preliminary safety analysis report include the principal design criteria (PDC) for the facility. Natrium-specific PDC are provided in approved TerraPower TR NATD-LIC-RPRT-0002-A, "Principal Design Criteria for the Natrium Advanced Reactor," Revision 1 (ML24283A066). Source terms determined by use of the methodology described in this TR are intended to be used in control room (CR) dose consequence analyses to show that the design meets the radiological habitability requirements in Natrium PDC 19, "Control room." In this safety evaluation (SE), the NRC staff is only evaluating the source term EM, not PDC 19 and the corresponding CR dose criterion.

- Title 10 CFR 50.34(b)(3) requires, among other things, that each application for an operating license include a final safety analysis report that includes the kinds and quantities of radioactive materials expected to be produced in the operation of the facility and means for controlling and limiting radioactive effluents and radiation exposures within the limits in 10 CFR Part 20, "Standards for Protection Against Radiation."

- Title 10 CFR 50.33(g)(2)(i) requires non-light-water reactor applicants complying with section 50.160 who apply for a construction permit or an operating license under 10 CFR part 50, to submit as part of the application the analysis used to determine whether the criteria in section 50.33(g)(2)(i)(A) and (B) are met and, if they are met, the size of the plume exposure pathway emergency planning zone. The criteria in 10 CFR 50.33(g)(2)(i)(A) and (B) are:
    - "(A) Public dose, as defined in § 20.1003 ["Definitions"] of this chapter [Chapter I, "Nuclear Regulatory Commission," to Title 10] is projected to exceed 10 mSv (1 rem) [TEDE] over 96 hours from the release of radioactive materials from the facility considering accident likelihood and source term, timing of the accident sequence, and meteorology; and
    - "(B) Pre-determined, prompt protective measures are necessary."

Guidance Documents

Specific guidance documents relevant to TerraPower's radiological release consequences methodology include:

- RG 1.183, "Alternative Radiological Source Terms for Evaluating Design Basis Accidents at Nuclear Power Reactors," Revision 1 (ML23082A305). Specifically, Regulatory Position 2, "Attributes of an Acceptable Accident Source Term," items d and e.
- RG 1.203, "Transient and Accident Analysis Methods," Revision 0 (ML053500170).
    - RG 1.203 provides the EM development and assessment process (EMDAP) as an acceptable framework for developing and assessing the EMs for reactor transient and accident behavior that is within the design basis of a nuclear power plant. RG 1.203 describes an acceptable method for the development of an EM and outlines the four elements of an EMDAP, which is broken into 20 component steps. In the subject TR, TerraPower describes the EM for radiological source term methodology for the proposed Natrium reactor and the assessments that

have been or will be performed in the context of the EMDAP steps. Although it was not written to apply specifically to radiological source terms, the NRC staff considers the guidance in RG 1.203 can be adapted to include development of source terms as an EM.

- 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.
- RG 1.247 (For Trial Use), "Acceptability of Probabilistic Risk Assessment Results for Non-Light-Water Reactor Risk-Informed Activities" (ML21235A008).
    - NEI 18-04 references the American Society of Mechanical Engineers (ASME)/American Nuclear Society (ANS) probabilistic risk assessment (PRA) standard, RA-S-1.4-2021, which is endorsed with exceptions by RG 1.247. The NRC staff's review was informed, in part, by guidance on the elements of an MST analysis contained in RG 1.247 and ASME/ANS RA-S-1.4-2021.

Policy Considerations

TerraPower's proposed Natrium reactor design would be a non-light-water reactor (non-LWR). In the NRC staff requirements memorandum (SRM) to SECY-93-092, "Issues Pertaining to the Advanced Reactor (PRISM, MHTGR, and PIUS) and CANDU 3 Designs and Their Relationship to Current Regulatory Requirements," (ML040210725 (SECY), ML003760774 (SRM)), the Commission approved the NRC staff's recommendation that source terms for non-LWRs be based upon a mechanistic analysis and that the acceptability of an applicant's analysis will rely on the NRC staff's assurance that the following items are met:

- The performance of the reactor and fuel under normal and off-normal conditions is sufficiently well understood to permit a mechanistic analysis. Sufficient data should exist on the reactor and fuel performance through the research, development, and testing programs to provide adequate confidence in the mechanistic approach.

- The transport of fission products can be adequately modeled for all barriers and pathways to the environs, including the specific consideration of containment design. The calculations should be as realistic as possible so that the values and limitations of any mechanism or barrier are not obscured.

- The events considered in the analyses to develop the set of source terms for each design are selected to bound severe accidents and design-dependent uncertainties.

SECY-93-092 also states that the design-specific source terms for each accident category would constitute one component for evaluating the acceptability of the design.

As discussed in SECY-93-092, an MST is the result of an analysis of fission product release based on the amount of cladding damage, fuel damage, and core damage resulting from the specific accident sequences being evaluated. It is developed using best-estimate phenomenological models of the transport of the fission products from the fuel through the reactor coolant system, through all holdup volumes and barriers, taking into account mitigation features, and finally, into the environs.

In SECY-16-0012, "Accident Source Terms and Siting for Small Modular Reactors and Non-Light Water Reactors," (ML15309A319), the NRC staff informed the Commission of the status of staff activities related to accident source terms for small modular reactors and non-LWRs. The NRC staff stated that non-LWR applicants can use modern analysis tools to demonstrate quantitatively the safety features of those designs.

In SECY-18-0096, "Functional Containment Performance Criteria for Non-Light Water Reactors," (ML18114A546), the NRC staff stated that differences between non-LWRs and LWRs has led to different approaches to limiting release of radioactive materials, including describing a functional containment concept as "a barrier, or a set of barriers taken together, that effectively limits the physical transport of radioactive material to the environment." The staff also proposed a methodology for non-LWR functional containment performance criteria. In SRM-SECY-18-0096, "Staff Requirements – SECY-18-0096 - Functional Containment Performance Criteria for Non-Light-Water-Reactors," (ML18338A502), the Commission approved the NRC staff's proposed methodology for establishing functional containment performance criteria for non-LWRs.

TECHNICAL EVALUATION

1.0 INTRODUCTION

1.1 Topical Report Overview

The TR provides information on the Natrium radiological source term EM that TerraPower developed using the four-element EMDAP described in RG 1.203 as a guideline. The EMDAP consists of four main elements, including determining the requirements of the EM, developing an assessment base, developing the EM, and assessing EM adequacy. Each element is also broken into component steps. As stated in TR section 1.2, TerraPower considered the EMDAP guidance as industry best practice in methods development, but TerraPower does not intend for the source term EM to meet verbatim conformance with RG 1.203.

All elements and steps of the EMDAP are explicitly discussed in the TR, though TerraPower notes that certain steps are ongoing. For the purposes of developing this SE, the NRC staff reviewed each of TerraPower's EMDAP elements and steps against the applicable step of RG 1.203. The technical evaluation section is generally organized by the EMDAP element, with each section discussing the guidance of RG 1.203 and other guidance as stated in the SE regulatory evaluation above, the relevant information from the TR, and the NRC staff's evaluation.

TerraPower intends to complete activities that are relevant to certain EMDAP steps as described in the TR. The NRC staff imposes limitations and conditions, provided at the end of the SE, to address these activities.

The TR methodology includes the evaluation of source terms for normal operation, system leakage scenarios, plausible accident scenarios, and to aid in the determination of the plume exposure pathway emergency planning zone. The methodology also includes evaluation of source terms for effluents, radwaste system design, shielding design, and equipment qualification. Source terms for specific events are outside the scope of the TR and will be reviewed as part of licensing applications implementing the TR methodology.

TR section 1, "Introduction," provides background information on the objective and scope of the TR, relevant regulatory requirements and guidance, a high-level description of the proposed Natrium reactor design, and event types addressed by the source term EM. TR section 2, "Evaluation Model Capability Requirements," discusses EM capability requirements to address RG 1.203, EMDAP Element 1, "Establish Requirements for Evaluation Model Capability." TR section 3, "Evaluation Model Assessment Base Development," describes the development of the EM assessment base and aspects described in RG 1.203, EMDAP Element 2, "Develop Assessment Base." TR section 4, "Evaluation Model Development," discusses the source term EM development, including the associated plan to follow the guidance contained in RG 1.203, to address RG 1.203, EMDAP Element 3, "Develop Evaluation Model." TR section 5, "Evaluation Model Adequacy Assessment," discusses the source term EM adequacy assessment to address RG 1.203, EMDAP Element 4, "Assess Evaluation Model Adequacy." TR section 6, "Natrium Sample Analysis Results," describes sample analyses that will be performed to demonstrate how the methodology can develop a source term and how entities adopting the TR will use the various computer codes (components) of the EM, with the examples being provided in appendix A. TR section 7, "Adequacy Decision," discusses the overarching EM adequacy decision. TR section 8, "Conclusions and Limitations" addresses the limitations on the source term EM identified by TerraPower.

1.2 Relationship to Other TerraPower TRs

The source term methodology TR is related to several other TerraPower methodology TRs that collectively provide a strategy for evaluating the consequences of potential accidental radiological releases for the proposed Natrium reactor design. The output of the source term methodology is radiological releases to the atmosphere (source terms) which are input to the radiological consequence EMs described in TerraPower report NAT-9391, "Radiological Release Consequences Methodology Topical Report," (ML24208A180).[1]

The source term methodology does not determine the licensing basis events (LBEs), design basis accidents (DBAs), or other quantified event scenarios that result in radiological source terms. LBEs, DBAs, and other quantified events are selected using the LMP process described in NEI 18-04. DBA analysis methodologies are provided in TerraPower TRs NAT-9390, "Design Basis Accident Methodology for In-Vessel Events without Radiological Release," Revision 2, (ML24295A202) and TP-LIC-RPT-0007, "Design Basis Accident Methodology for Events with Radiological Release," Revision 0 (ML24082A262). Additional event scenarios for which source term analyses are needed are defined in NAT-3056, "Plume Exposure Pathway Emergency Planning Zone (EPZ) Sizing Methodology," Revision 3 (ML24304B034).[2]

TR section 8.2, "Limitations," Limitation 5 identifies the output of the radiological source term methodology (i.e., radionuclide inventory up to the last barrier prior to the environment) and the

---

[1] TR NAT-9391 is undergoing separate NRC staff review. The NRC approval of TR NAT-9392, if appropriate, does not affect the NRC staff approval or denial of TR NAT-9391.
[2] TRs NAT-9390, TP-LIC-RPT-0007, and NAT-3056 are undergoing separate NRC staff review. The NRC approval of TR NAT-9392, if appropriate, does not affect the NRC staff approval or denial of TRs NAT-9390, TP-LIC-RPT-0007, and NAT-3056.

relationship of the radiological source term methodology to the radiological release consequences methodology. The NRC staff determined that this limitation accurately characterizes the scope and relationship of the two TerraPower methodologies; however, the staff concluded that it is not necessary to impose this as a limitation and condition because the radiological source term methodology and radiological release consequence methodology TRs are independent methodologies.

1.3 Review Approach

Scenario-specific source terms developed from physically based modeling of accident progression and radionuclide transport phenomena are also known as MSTs. There is limited specific guidance on non-LWR MST development. However, the NRC staff has used the principles described in SECY-93-092 and RG 1.183 Regulatory Position 2, with additional consideration of the SECY-18-0096 description of functional containment, to aid in its review of the technical aspects of the MST.

As discussed in TR section 1.2, “Regulatory Requirements and Guidance,” the TR considers the elements of an EMDAP described in RG 1.203 as industry best practice but does not attempt to verbatim conform with RG 1.203. The NRC staff’s review of the TR methodology considered the guidance on EMDAP, with a focus on the modeling of radionuclide transport and retention phenomena to provide MSTs for use in license applications, the reasons why this is acceptable are discussed below.

TR section 1.2 also identifies the high-level requirements for MST analysis as one of the PRA elements in the ASME/ANS Advanced Non-LWR PRA Standard (ASME-RA-S-1.4 2021). The objectives and characteristics of the non-LWR PRA MST analysis can also be found in RG 1.247, which endorses ASME-RA-S-1.4 2021 for trial use with no objections with respect to the MST analysis element. Considering that the LMP process described in NEI 18-04 is based on the use of PRA, the NRC staff used the information in the non-LWR PRA standard’s MST analysis element as an aid in its assessment of the considerations pertaining to source term phenomena within the TR source term EM. The NRC staff did not evaluate the acceptability of the Natrium PRA as part of its review of this TR.

2.0 STAFF EVALUATION

2.1 Use of EMDAP for Determination of MST

RG 1.203 provides principles for EM development and assessment through four EMDAP elements followed by an adequacy decision by the EM developer. Following the EMDAP provides confidence that the EM, including calculational devices, is validated for the key phenomena identified for specified events and can appropriately evaluate event behavior relative to figures of merit for the license application. Though RG 1.203 addresses transient and accident analysis methods which evaluate plant events, such as a LWR loss-of-coolant accident (LOCA) EM, many EMDAP concepts are generically applicable.

TR section 1, “Introduction,” notes that although not all aspects of the RG 1.203 EMDAP are directly applicable to the determination of radiological source terms, the TR methodology radiological source term EM generally adheres to the guidance of RG 1.203. Information summarizing the EMDAP elements and their relationship to the TR methodology is given in TR section 1. Based on the TR description on the use of RG 1.203 EMDAP to guide EM development and assessment for the radiological source term methodology, the NRC staff determined that the TR use of EMDAP guidance in RG 1.203 is appropriate for describing the framework of a source term methodology because it allows the NRC staff to understand the use of analytical tools in determining the radiological source term, the methodology assessment of the EM, and how the upstream and downstream processes relate to this specific methodology.

2.2 Source Term EM Capability

The first element of the EMDAP is to establish requirements for the EM capability, which frames and focuses the process. Within EMDAP Element 1 entities developing an EM identify the mathematical modeling methods, components, phenomena, physical processes, and parameters needed to evaluate event behavior relative to the chosen figures of merit (FOMs). Following EMDAP Element 1 ensures that the EM can appropriately analyze the source terms for the selected events and that the validation process addresses the key phenomena for those events. TR section 2 summarizes the four steps of Element 1 taken to describe the capabilities of the source term methodology. The TR steps are consistent with the first four RG 1.203 EMDAP steps which comprise Element 1, "Establish Requirements for Evaluation Model Capability."

As stated in TR section 2, the steps are the following:

- TR section 2.1, "Analysis Purpose, Transient Class, and Power Plant Class," addresses EMDAP Step 1.
- TR section 2.2, "Figures of Merit," addresses EMDAP Step 2.
- TR section 2.3, "Systems, Components, Phases, Geometries, Fields and Processes," addresses EMDAP Step 3.
- TR section 2.4, "Identification and Ranking of Phenomena and Processes," addresses EMDAP Step 4.

TR section 2.1 provides information on LBE definitions to align with the Anticipated Operational Occurrences (AOO), Design Basis Events (DBE), Beyond Design Basis Events (BDBE), and DBA definitions that are found within NEI 18-04. The TR further states that the types of events with potential for radionuclide releases are from significant reductions in flow, localized high power-to-flow conditions, physical damage to fuel, and reactivity insertion.

The source term EM outputs are MSTs intended for use in LMP-based license applications or other best-estimate plus uncertainty analyses. If an applicant chooses to implement the TR methodology in license applications that do not use the LMP (e.g., conservative deterministic licensing analysis using a postulated maximum hypothetical accident), the applicant must justify use of TR methodology. Therefore, the staff imposes Limitation and Condition 7.

TR section 2.2 defines the FOMs as quantitative standards of acceptance that are used to define acceptable answers for a safety analysis. The purpose of the EM is to generate source terms that are intended to be used in consequence analyses which are used to show compliance, in part, with the safety analysis requirements in 10 CFR 50.34 including the offsite dose criteria in 10 CFR 50.34(a)(1)(ii)(D) and conformance with the dose-based evaluation in LMP. Based on this, the TR identified FOMs based on the dose to an individual. The two FOMs described in the TR pertaining to the source term are the inhalation dose potential and the submersion dose potential, as associated with a release scenario or final radiological consequence. The TR uses the FOMs in a phenomena identification and ranking table (PIRT) process to evaluate the source term phenomena. As stated in TR section 2.2, the dose potential is used instead of actual dose results for each scenario to compare the relative importance of each source term-related phenomenon. The TR further clarifies that in the context of the PIRT, the use of the word “potential” was used to guide the PIRT participants in ranking phenomena by recognizing that the release scenarios associated with LBEs and operational events may involve different dominant isotopes from each other. The NRC staff acknowledges that the applicant’s stated description of the source term PIRT FOMs as dose “potential” is to be understood as potential consequences developed for comparison to the range of events evaluated because source term is an input into the radiological consequence evaluation model that determines the actual calculated dose.

TR section 2.3 addresses the identification of design information for proposed Natrium systems pertinent to source term evaluation, including the reactor core and fuel, systems which support core cooling and heat transport, decontamination systems, and functional containment. TR section 2.3 also addresses the elemental phases of released radionuclides and the media through which radionuclides are transported, the processes to transport radionuclides, and the functional containment barriers to release of radionuclides credited for each event.

Specifically, TR section 2.3.1.1, “Reactor Core System,” and TR section 1.3, “Plant Description,” state that metal fuel with a sodium bond has been selected for the proposed Natrium reactor design, which is a pool-type sodium fast reactor (SFR) design. The reactor is designed to accommodate both Type 1 and Type 1B fuel designs. The TR source term methodology is specific to these fuel designs, which is identified by limitations in TR section 8.2. TR Limitation 1 states that the methodology is limited to a proposed Natrium reactor design that has a pool-type, SFR design with metal fuel and sodium bond as described in TR sections 1.3 and 2.3.1. TR Limitation 1 also states that changes from these design features will be identified and justified in safety analysis reports of Natrium license applications. TR Limitation 2 states that the fuel failure fractions during normal operation and transient conditions are subject to the qualification of Type 1 fuel. TR Limitation 3 states that if bonded sodium is not utilized in subsequent fuel designs, additional information shall be provided to justify the fission product release behavior from metal fuel to the gas plenum.

Additionally, TR section 2.3.5, “Functional Containment,” provides information on functional containment for the TerraPower proposed Natrium reactor design. The TR adopts the high-level definition of functional containment from SECY-18-0096 which states that it is a barrier, or set of barriers taken together, that effectively limits the physical transport of radioactive material to the environment. For the TR methodology the functional containment barriers are defined as physical system boundaries or structures for which leakage performance can be specified in design and verified by testing or associated analyses. Other radionuclide removal mechanisms such as aerosol scrubbing in the liquid sodium and aerosol deposition are considered phenomena of the MST analysis and not barriers of functional containment. The NRC staff’s evaluation of the source term EM modeling of the functional containment with respect to radionuclide transport and retention is discussed below in SE section 2.4.2.3.

TR section 2.4 discusses the use of a PIRT. The PIRT process described in the TR was done for three postulated events: Fuel Handling Accidents (FHA), Sodium Processing System (SPS) Leak, and an Unprotected Loss of Flow with Degraded Pump Coastdown (ULOP+). TR tables 2-4, “PIRT for FHA,” table 2-5, “PIRT for SPS Leak,” and table 2-6, “PIRT for ULOF+,” provide the results for each of the three events. TR table 2-7, “Summary of Higher Risk Phenomena,” identifies phenomena for which knowledge may not be sufficiently developed given their importance. The TR states that TR table 2-7 will be used as a basis for further tasks within the EMDAP to address the knowledge level in support of the source term EM development and assessment.

Based on the information in TR section 2, NRC staff understands the process for identification of phenomena and barriers important to the development of MSTs for the proposed Natrium reactor design and finds that it is consistent with the RG 1.203 guidance on EMDAP Element 1. The NRC staff determined that the PIRT process is acceptable because it follows the guidance in RG 1.203, and that the PIRT phenomena and ranking are appropriate for the scenarios considered in the EM because they are consistent with the proposed Natrium design and past SFR operating experience. Therefore, the PIRT is acceptable for the methodology scope defined in EMDAP Element 1.

Based on its review of the TR description of the radiological source term methodology EM capability requirements, the NRC staff determined that the TR section 2 methodology acceptably considered design features, dose metrics of interest, and important phenomena and processes for MST development in the source term EM, consistent with the approach in RG 1.203 EMDAP Element 1. In addition, the NRC staff determined that TR Limitations 1, 2 and 3 (reproduced as Limitation and Conditions 1, 2, and 3 in this SE) are acceptable because they identify the source term methodology reliance on design information as described in the TR.

2.3 Source Term EM Assessment Base

The second element of EMDAP as discussed in RG 1.203 is to develop an assessment base consistent with information determined in EMDAP Element 1. This assessment base is used to validate calculational devices or codes used as part of the EM and may consist of a combination of legacy experiments and new experiments. TR section 3 address EMDAP Element 2 which includes Steps 5 through 9. These steps pertain to the gathering of source term-related data, assessment of the data, and the determination of testing needs.

- TR section 3.1, “Assessment Base Objectives,” addresses EMDAP Step 5.
- TR section 3.2, “Scaling Analysis and Similarity Criteria,” addresses EMDAP Step 6.
- TR section 3.3, “Existing Data Needed to Complete the EM Validation Database,” addresses EMDAP Step 7.
- TR section 3.4, “Evaluation of [Integral Effects Test] Distortions and SET Scaleup Capability,” addresses EMDAP Step 8.
- TR section 3.5, Experimental Uncertainties Determination,” addresses EMDAP Step 9.

TR section 3.1 provides information on the ranking of the phenomena identified in TR section 2.4 with a summary in TR table 3-1, “Phenomena/Processes with High Importance Ranking.” TR section 3.2 provides information on the source term phenomena of interest based on the information developed in EMDAP Element 1, to ensure that the data and models will be applicable to the source term methodology. TR section 3.2 also notes that the identification and pedigree evaluation of legacy tests and in-house test plans will be discussed as part of a future revision to the TR.

TR section 3.3 assesses the availability of legacy experimental data, assesses the pedigree of the available data, and states that an alternative is to use a conservative approach to address concerns with uncertainty. If TerraPower determines new experiments are needed, the TR states that TerraPower will provide the information in an operating license (OL) application. table 3-2, “Phenomena/Process with High and Medium Important Ranking Conservative Approaches,” shows how the methodology could describe the approach to using conservative information when the PIRT determines a medium or low level of knowledge about a phenomenon or process. TR section 3.3 also states that it is not expected that a new experiment will be required to support the submittal of the preliminary safety analysis report of the proposed Natrium reactor design. However, depending on the source term PIRT and the final design of the facility, additional experiments may be necessary to complete the EM assessment database. TR section 3.3 states that ongoing work is planned to be completed prior to submittal of an OL application, and relevant information included in a future licensing submittal.

TR section 3.4 addresses the effects of distortion and states that this will be addressed in a future submittal. TR section 3.5 addresses experimental uncertainty, and states that this information will also be addressed in a future submittal.

Because the TR states that identification and pedigree evaluation of legacy tests and in-house test plans will be discussed as part of a future revision to the TR and there is ongoing work related to experimental data for which results will be provided in OL applications implementing the TR methodology, the NRC staff imposes Limitation and Condition 8 to ensure that the stated information is provided for NRC staff review.

Based on its review of TR section 3, the NRC staff determined that the methodology provided in this TR section is consistent with guidance for RG 1.203 EMDAP Element 2. Specifically, the NRC staff determined based on its engineering judgment that TR section 3 appropriately describes the process for determining the phenomena of interest and describes the process for obtaining existing experimental data or using conservative approaches to address concerns with uncertainty for phenomena relevant to MST in a manner that is consistent with the guidance in RG 1.203. The NRC staff determined that the use of conservative approaches as described in TR section 3 can address the uncertainty due to lack of experimental data. However, the NRC staff did not make a final determination of the acceptability of the approaches. The NRC staff will review the implementation of the source term EM, including the treatment of uncertainty through use of conservative approaches, in the review of analyses supporting future license applications.

2.4 Source Term Evaluation Model

The third element of the EMDAP involves selecting or developing the calculational devices needed to analyze source term in accordance with the information determined in EMDAP Element 1. The EM is the calculational framework for evaluating the source term. The EM may include one or more computer programs, special models, and all other information needed to apply the calculational framework to source term development. TerraPower states that TR section 4, “Evaluation Model Development,” addresses EMDAP Element 3, which includes Steps 10 through 12.

- TR section 4.1, “Evaluation Model Development Plan,” addresses EMDAP Step 10.

- TR section 4.2, "Evaluation Model Structure," addresses EMDAP Step 11.
- TR section 4.3, "Closure Models," addresses EMDAP Step 12.

TR section 4.1 establishes an EM development plan requiring the same information cited in RG 1.203 appendix B, section 1.3.1, "Step 10. Establish an Evaluation Model Development Plan," for every computer code used in this methodology (i.e., TR sections 4.1.1 – 4.1.4: "[RADionuclide Transport, Removal And Dose Estimation code (RADTRAD)]," **[[** **]]** respectively). TR section 4.1.5, "Computer Codes Used Upstream of Source Term EM," provides a list of computer codes that are used to generate inputs into the source term methodology. For example, TR section 4.1.5 lists computer codes to determine **[[** **]]** which are input to the source term methodology EM. The determination of these inputs to the source term EM is outside the scope of the subject TR and will be assessed in the NRC staff's review of a license application that references this TR.

TR section 4.1.6, "Code Capability Gaps," identifies the important source term phenomena from the PIRT that are not covered by the computer codes used in the source term EM. The TR states that these gaps will be addressed by "using conservative assumptions, analysis defense-in-depth, and/or experimental results."

TR section 4.2 describes the structure of each individual calculational device (i.e., computer code), and how the overall EM structure combines these devices to work together through input and output interfaces between each calculational device to analyze events. The discussions provided in the TR are consistent with the information contained in RG 1.203, section C.1.3.2, with respect to use of codes. More specifically, the TR discusses the use of RADTRAD, **[[** **]]** as computer codes used by the source term EM. TR sections 4.2.1 through 4.2.4 establish the EM structure by ensuring systems and components, constituents and phases, field equations, closure relations, numerics, and additional features of each code are considered.

TR sections 4.2.5 through 4.2.14 address the types of radionuclide inputs associated with different events for which the user may need to calculate a source term. These TR sections also discuss the development of source terms for normal operations, sodium processing system leaks, LBEs, DBAs, FHA, plume exposure pathway for EPZ sizing, and equipment qualifications that will be used as input into the EM. The NRC staff is not reviewing specific inputs into the source term methodology and will evaluate the source terms when reviewing subsequent license applications referring to this TR.

TR section 4.2.15, "Handoff to Downstream EM," states that the outputs generated by the source term EM will be utilized by the downstream radiological release consequence EM. These include the outputs discussed in TR section 4.2.15.1, "Radionuclide Inventory," and TR section 4.2.15.2, "Release Characterization."

The NRC staff audited documentation for each computer code cited as generating input to and used in this source term EM to generate output to enhance its understanding of the information provided in TR sections 4.1 and 4.2 regarding the methods and models being employed by each computer code. The NRC staff verified the types of information that would be provided as inputs into this source term methodology, and how the computer codes that make up this methodology would account for the phenomena identified in TR section 3. The NRC staff determined, based on engineering judgment, that TR section 4.1.5 and 4.2.15 clearly describe the input interfaces that will be used for the source term EM and output interfaces that will be utilized by the downstream radiological consequences EM, respectively. The NRC staff review determined that the process delineated in TR section 4.1 and 4.2 is acceptable because it provides sufficient information to understand the computer codes and computer code capabilities, including how the EM addresses code gaps consistent with the Steps 10 through 12 in the RG 1.203 process.

The subsections below address key aspects of developing radiological source term as described in TR section 4's implementation of EMDAP Step 12. The NRC staff considered RG 1.247 guidance when reviewing the TR methodologies to address the MST characterization of radiological releases to the environment from each event sequence leading to a release.

2.4.1 Source Term Characterization

The TR states that the source term EM is intended to be used in the LMP methodology by the applicant referencing the TR. As described in NEI 18-04, the LMP methodology uses information from a facility-specific PRA, including MSTs. As described in RG 1.247, section C.1.3.16, the objective of the MST analysis PRA element is to characterize the radiological release to the environment resulting from each event sequence leading to a release. The characterization includes:

- an identification of risk-significant isotopes to be included in the consequence assessment and data needed to characterize release locations;
- the physical and chemical form of released radioisotopes;
- the time-dependent isotopic release rates to the atmosphere;
- heat content (or energy) of the carrier fluid; and
- the data needed to estimate plume buoyance.

TR section 4.2.5, "Radionuclide Inventory Selection," states that information from one Argonne National Laboratory report, ANL-ART-49, "Regulatory Technology Development Plan Sodium Fast Reactor," and two Sandia National Laboratory reports, SAND2021-11703, "Preliminary Radioisotope Screening for Off-site Consequence Assessment of Advanced Non-LWR Systems," and SAND2022-12018, "Quantitative Assessment for Advanced Reactor Radioisotope Screening Utilizing a Heat Pipe Reactor Inventory," were used to identify risk-significant radionuclides. The methods described by TR section 4.2.5 state that **[[ ]]** will be used to generate core inventory, and that, based on preliminary reviews, 20 different radionuclides account for more than 99.9 % of the TEDE dose. TR section 4.2.15.1, states that the output of the source term EM is time-dependent matrices of radionuclides released to the environment for each event analyzed. The release characterization also includes information on the physical aspects of the release, such as release location and leakage or flow rates.

The NRC staff determined that the information contained in TR section 4.2.5, and the referenced documents, justifies the method of identifying risk-significant radionuclides because the referenced national laboratory reports are relevant to SFR designs and, based on the NRC staff's engineering judgment, the NRC staff determined that these reports are useful in identifying radionuclides of interest for fast spectrum metallic fuel systems. Using the preliminary design information in the TR captured by Limitation and Conditions 1, 2, and 3, TerraPower states that the TR demonstrates that the method ensures that radionuclide isotopes which contribute to 99.9 % of the TEDE dose will be included in the analysis. The NRC staff is not reviewing the screening of specific radionuclides used in the source term methodology and will evaluate the radionuclide screening methods when reviewing subsequent license applications referring to this TR.

TR section 4.3.4.2, "Radionuclide Mitigation Phenomena," describes that the radionuclide transport modeling strategy is predicated upon understanding the mitigation phenomena provided by each compartment that radionuclides are contained within and transferred between, including the physical and chemical forms of radionuclides.

TR section 4.3.4.3, "Radionuclide Groups," describes the methods to group radionuclides based on chemical and physical characteristics. **[[ ]]**.

To describe how the source term methodology handles the physical and chemical forms of radionuclides identified by their assessment of risk-significant radionuclides, TR section 4.2.2, **[[ ]]** provides information on the **[[ ]]** computer code, with further discussion of use of the code in subsections of TR section 4.2. The **[[ ]]** computer code used by this TR methodology assesses the physical and chemical characteristics of radionuclides released for the SFR designs in general.

To verify the information being credited by the **[[ ]]** computer code the NRC staff reviewed the user manual to obtain details on the ability of this computer code to assess the physical and chemical characteristics of release radionuclides. In the audit summary report, the NRC staff discusses the results of their review of the referenced computer code. Based on those results, the NRC staff determined that the description of the source term models contained within the computer code are as described in the TR. The NRC staff determined that those models in the computer code and the TR discussion of the use of the code, including parameter selection, reflect the physical and chemical forms of released radionuclides from an SFR design in general.

To assess how this methodology addresses time-dependent isotopic release rates to the atmosphere, the NRC staff conducted an audit to obtain information on this topic. During the audit, as documented by the audit summary report, TerraPower clarified that the selection of time step size is not predetermined by the TR methodology, and therefore is outside the scope of this review. The user of the methodology will determine the time step size at the time of the analysis and the NRC staff will review this when reviewing license applications referencing this TR. TR section 4.2.1, "Calculational Device - RADTRAD," states that a time step size sensitivity study will be performed as part of an analysis implementing the methodology. Time step sensitivity studies would also be done for other calculational methods including **[[ ]]** as discussed in TR section 4.2.2.5, "Numerics," and **[[ ]]** as discussed in TR section 4.2.3.5, "Numerics."

Through audit, the NRC staff confirmed that the TR information does not characterize heat content of the radiological release carrier fluid. Specifically, TerraPower clarified that heat content of the carrier fluid is not considered in this methodology and that the data needed to estimate plume buoyancy is addressed by the TerraPower Radiological Release Consequences

Methodology TR (NAT-9391). The assumptions on the heat content and modeling of plume buoyancy of the radiological release for a specific event will be documented in the consequence analysis which will be available to the NRC staff during review of a license application which implements the methodology unless otherwise justified in the license application.

Based on its review of the TR, the NRC staff determined that the TR description of the radiological source term characterization provides information that

- could be used as input to a radiological release consequences analysis, and
- is consistent with:
    - the descriptions of source term characterization in RG 1.247, section C.1.3.16 for MST analysis for non-LWR PRA for use in risk-informed activities, and
    - the general aspects of source term characterization in RG 1.183.

2.4.2 Source Term EM Closure Models

TerraPower modeled radionuclide transport and retention phenomena in the source term EM either by models built into the computer codes used or by user-defined assumptions. TR section 4.2 includes an overview of the closure relationships and phenomenological models for each of the computer codes used in the source term EM. TR section 4.3 states that closure relationships or closure models describe a specific process during a plant transient that can be developed and/or incorporated in the principal analytical computer code, if needed. TerraPower mostly developed closure models based on the results of tests related to SFR plant response in general, and source term phenomena. TerraPower incorporated the developed models into the main analytical computer codes. The closure models contained in TR section 4.3 include pool scrubbing, aerosol radionuclide natural deposition, functional containment modeling, and radionuclide transport. The NRC staff's review of these closure models is provided below.

2.4.2.1 Pool Scrubbing

TR section 4.3.1, "Pool Scrubbing," describes the method for addressing the scrubbing of radionuclides after release from the fuel as they travel from the fuel through the sodium pool to the cover gas region. The TR states that **[[**

]]. TR Limitation 4 states that the sodium pool scrubbing and associated radionuclide retention within the primary sodium coolant is limited to where the bulk sodium is in subcooled conditions.

To assess if this methodology addresses the data needed to inform parameter selection for pool scrubbing, the NRC staff requested access to information through audit on the computer code **[[ ]]**. This allowed the NRC staff to understand the models for pool scrubbing in the computer code that may be selected for use in the source term EM as described in TR section

4.3.1. As documented in the audit report, the NRC staff obtained clarification on computer code capabilities and necessary user inputs for the **[[ ]]** computer code by examination of the code user manual. The NRC staff agrees that the models detailed in the TR assume a subcooled sodium pool and therefore the models only apply to this subcooled condition. TR Limitation 4 (reproduced as Limitation and Condition 4 in this SE) ensures that the models are only used under the appropriate conditions. The NRC staff determined that the TR methodology, as subject to SE Limitation and Condition 4, appropriately accounts for radionuclide removal through aerosol scrubbing in the subcooled sodium pool because the computer code model and user inputs are chosen to be conservatively bounding for DFs based on references which are relevant to radionuclide transport phenomena in a sodium pool for sodium-cooled SFR designs, in general. The NRC staff review also determined that the TR methodology assumption of a bounding DF for aerosol scrubbing in the spent fuel pool water is acceptable because it is reasonable, as subject to **[[ ]]** and evaluation in the subsequent analyses which implement the TR methodology.

2.4.2.2 Aerosol Radionuclide Natural Deposition

TR section 4.3.2, "Aerosol Radionuclide Natural Deposition," describes the methods to model natural deposition of aerosols for this methodology. The methodology states that generally, natural deposition is only credited in the cover gas region for DBAs. The methodology also states that for methods using RADTRAD, Henry's correlation may be used to calculate the natural deposition of radionuclides in aerosol form. This is a feature built into RADTRAD and details for this correlation are provided in NUREG/CR-6604 (ML15092A284). **[[ ]]**.

To assess if the methodology addresses the data needed to address aerosol radionuclide natural deposition, the NRC staff evaluated the use of the selected methods by reviewing the cited reports for aerosol deposition rates which include the correlation included in NUREG/CR-6604 (ML15092A284) and **[[ ]]**. The NRC staff determined use of the Henry's correlation implemented in RADTRAD as a model for aerosol gravitational settling in the methodology is acceptable because the correlation is based on aerosol removal experiments using sodium oxide aerosols, which are similar in size distribution to the potential aerosol releases from a sodium pool that can be applied to the anticipated Natrium DBAs. The NRC staff concluded that the implementation of the Henry correlation in RADTRAD is conservative because RADTRAD only accounts for radioactive aerosols in determining the aerosol density within the volume, whereas the presence of non-radioactive aerosols would increase the aerosol density and subsequently increase the aerosol settling rate. The NRC staff confirmed that **[[** the **]]**. **[[ ]]** which the NRC staff determined is based on an acceptable reference. Therefore, based on the TR methodology's conservatively biased inputs to the Henry's correlation in the computer codes, the NRC staff finds the TR modeling of aerosol transport and retention in the functional containment to be acceptable.

2.4.2.3 Functional Containment Modeling

TR section 4.3.3, "Functional Containment Modeling Strategy," describes the methodology users would employ to develop modeling of functional containment barriers for the development of event-specific source terms. The methodology states that it directs the development and evolution of the functional containment modeling to address specific issues, risks, and information gaps for each release event category (i.e., DBA, AOO, DBE, and BDBE).

TR section 4.3.3.1, "Event Categorization," provides the high-level categories of events for which containment performance analysis is needed to evaluate the potential releases to the environment. These event categories are releases from in-vessel events, releases from ex-vessel events, releases from sodium chemical reactions, and normal operation releases and effluents.

TR section 4.3.3.3, "Modeling Development / Evolution," describes the methods that will be used to identify and model phenomena that are important to the performance of the functional containment during events. This section also states that potential leakage rates from within the functional containments are not defined or readily represented by simple assumptions. To address this lack of information, the modeling strategy is to start with basic modeling to investigate the response of containment compartments under accident conditions and then identify the phenomena and parameters important to the mixing and leakage behavior during each event. The TR specifies the expectation of repeating this feedback loop until an acceptable model is developed. Modeling of the thermal-hydraulic conditions for each event are calculated using **[[**

]].

Once the thermal-hydraulic conditions in the functional containment for each event are determined, the TR methodology uses this information to model radionuclide transport **[[**

]].

TR section 4.3.3.3.3, "Sodium Fire Modeling," describes the methodology for modeling events with potential for sodium fires. The methodology identifies that **[[**

]].

The TR functional containment modeling strategy also includes performance of sensitivity studies and refinement of the functional containment model, as described in TR section 4.3.3.3.5, "Model Evolution."

Based on its review of the information in TR section 4.3.3 and subsections, the NRC staff determined that the TR methodology strategy for modeling of functional containment is acceptable because it provides a structured evaluation of the barriers to radionuclide release for each event, assesses the sensitivity of final dose results to the functional containment modeling assumptions, and provides a process for refining the model as needed. The NRC staff also determined that the **[[** **]]** thermal-hydraulic

conditions for input to the source term EM is appropriate because it is consistent with the code purpose. In addition, the NRC staff determined that the TR methodology's handling of potential sodium fires is adequate because it **[[**
]].

2.4.2.4 Radionuclide Transport

TR section 4.3.4, "Radionuclide Transport Modeling Strategy," provides information on the strategy used to determine radionuclide transport for each radionuclide release event. TR section 4.3.4.2 describes the strategy that is used to understand the mitigation phenomena for each compartment that makes up the functional containment being evaluated for each event. TR section 4.3.4.2 provides information on the radionuclide mitigation phenomena and barriers reviewed for the analysis. The NRC staff notes that the assumptions and methods to model the listed radionuclide mitigation phenomena are described in more detail in conjunction with the models in the computer codes in TR sections 4.1 and 4.2, which are evaluated above in SE section 2.4.

TR section 4.3.4.3 discusses the grouping of radionuclides that are important to release and transport based upon the similarities in chemical and physical characteristics. **[[**

]].

TR section 4.3.4.4, "Radionuclide Transport Strategy," discusses the computer codes used in the EM to assess radionuclide transport for the methodology. It discusses the modeling needs to have a quantitative assessment of radionuclides as they are transported between barriers accounting for the effectiveness of radionuclide mitigation phenomena. This TR section then provides a listing of the codes that the proposed Natrium reactor design will use in assessing transport of the radionuclides. The NRC staff notes that these computer codes are discussed in more detail, including their interactions, as part of the EM structure in TR sections 4.1 and 4.2, which are evaluated above in SE section 2.4.

Based on its review, the NRC staff determined that the radionuclide mitigation phenomena listed in TR section 4.3.4.2 are consistent with the discussion of potential radionuclide transport mechanisms in the non-LWR PRA standard MST analysis element as endorsed by RG 1.247. Because the specific details on how the computer codes model radionuclide transport phenomena are provided only by reference, the NRC staff requested access to information on the computer codes user manuals, through audit. The NRC staff confirmed that the TR radionuclide transport and retention models are based on first principles or are empirically derived, are models that are consistent with the technology-inclusive phenomena models used in the NRC-developed version of the RADTRAD code, and use conservatively biased user inputs as stated in the TR.

Based on its review of the information in TR section 4.3.4 and subsections, the NRC staff determined that the TR methodology strategy for modeling of radionuclide transport is acceptable because it provides a structured evaluation of the radionuclide release from fuel and models the transport and retention phenomena within the barriers to radionuclide release for each event.

2.4.3 Uncertainties in the Mechanistic Source Term and Transport Phenomena

TR section 4.4, "General Conservative Methods," discusses the methodology's identified uses of conservativisms. This section provides information on the strategy for selection of conservative input parameters when information becomes available as the design is further developed, as well as information on addressing uncertainty with important phenomena as identified by the PIRT. This TR section also provides insights to inform the use of conservative inputs when information is not well known about a phenomena or process. Because the analytical tools used in the EM require user input (e.g., parameter values) the NRC staff imposes Limitation and Condition 6 to ensure that the user inputs for which specified values are not provided in the TR are documented and justified.

The NRC staff reviewed how the TR addressed uncertainties in the MST analysis and determined that the methodology accounts for uncertainties in the modeling of source term phenomena by recommending the use of conservative approaches, subject to Limitation and Condition 6. The NRC staff also determined that the discussion of uncertainty is consistent with the characteristics and attributes to achieve the objectives of an MST for a non-LWR risk informed submittal as listed in RG 1.247, section C.1.3.16.

2.4.4 Source Term Evaluation Model Conclusions

The NRC staff reviewed TR section 4 and determined that it is consistent with RG 1.203 guidance on EMDAP Element 3. The NRC staff determined that TR section 4 appropriately establishes a source term EM development plan, describes the structure of the EM, and describes the closure models or relationships for radionuclide release, transport and retention phenomena relevant to MST as well as their bases and justification.

2.5 EM Adequacy Assessment

Element 4 of the EMDAP revolves around evaluating the adequacy of the EM. It consists of two parts: a bottom-up evaluation of the closure relationships used and then a top-down evaluation of the governing equations, numerics, and integrated performance of the EM. After these two parts are completed, the biases and uncertainties of the EM can be determined. A key feature of this adequacy assessment is the ability of the EM to predict appropriate experimental behavior for source term phenomena. TR section 5 is stated to address EMDAP Element 4 which includes EMDAP Steps 13 through 20.

- TR section 5.1.1, "Determine Closure Model Pedigree and Applicability," addresses EMDAP Step 13.
- TR section 5.1.2, "Prepare Input and Perform Calculations to Assess Model Fidelity and/or Accuracy," addresses EMDAP Step 14.
- TR section 5.1.3, "Assess Scalability of Models," addresses EMDAP Step 15.
- TR section 5.2.1, "Determine Capability of Field Equations and Numeric Solutions to Represent Processes and Phenomena," addresses EMDAP Step 16.

- TR section 5.2.2, "Determine Applicability of Evaluation Model to Simulate System Components," addresses EMDAP Step 17.
- TR section 5.2.3, "Prepare Input and Perform Calculations to Assess System Interactions and Global Capability," addresses EMDAP Step 18.
- TR section 5.2.4, "Assess Scalability of Integrated Calculations and Data for Distortions," addresses EMDAP Step 19.
- TR section 5.3, "Determine Evaluation Model Biases and Uncertainties," addresses EMDAP Step 20.

TR section 5 describes the assessment of the adequacy of the source term EM, including a comparison to the attributes of an accident source term described in RG 1.183, Regulatory Position 2 and a general assessment of the EM adequacy in evaluating sodium chemical reactions, radionuclide release and transport, and functional containment analysis. The TR does not provide a final EM adequacy assessment or explicit details of calculated accuracies at this stage of development.

The TR indicates that work supporting EMDAP Element 4 is ongoing and that the work will be completed prior to the submittal of an OL application implementing the methodology. The NRC staff reviewed TR section 5 and determined that the amount of information that was submitted is appropriate for the current stage of the design because additional details will be provided in a future submittal.

TR Limitation 6 states that adequate verification and validation assessment information should be made available to the NRC staff as part of future submittals supporting the codes that make up the EM. This verification and validation information should be justified to reasonably bound the operational envelope for the design for any applicant referencing the source term EM methodology.

The NRC staff determined that TR Limitation 6 (reproduced as Limitation and Condition 5 in this SE) is appropriate to ensure that future submittals referencing this TR provide the verification and validation assessments not completed by this TR. Although the EM adequacy assessment is not complete at this time, the NRC staff determined that the discussion of the ongoing work and future plans, subject to SE Limitation and Condition 5, is sufficient for the methodology development stage given the relevance of the methodology at the construction permit stage.

2.6 Natrium Sample Analysis Results

TR section 6 "Natrium Sample Analysis Results," provides a discussion of sample analyses. The NRC staff found the information contained in TR section 6 helpful in understanding the source term EM. However, the NRC staff did not make a finding on these analyses because they are examples.

2.7 EM Adequacy Decision

TR section 7 “Adequacy Decision,” describes the last step in the EM adequacy demonstration process and states that this task has not been performed and will be provided in a future licensing submittal. The NRC staff finds that this information is sufficient for the methodology development stage given the relevance of the methodology at the construction permit stage.

2.8 Limitation and Condition 8

The TR identifies throughout information and activities that are required to complete the execution of the EMDAP. The NRC staff imposes Limitation and Condition 8 to ensure that an applicant or licensee referencing the methodology developed in this TR submits documentation and justifies that the identified activities have been completed to a state that is appropriate for the intended licensing application and that the identified information has been provided. Limitation and Condition 8 applies to all information and activities the TR identifies as missing regardless of whether this SE identifies this specific information as missing.

LIMITATIONS AND CONDITIONS

The NRC staff identified the following limitations and conditions, applicable to any licensee or applicant referencing this TR.

1. The methodology is limited to a Natrium design that has a pool-type, SFR design with metal fuel and sodium bond as described in TR sections 1.3 and 2.3.1. Changes from these design features will be identified and justified in Safety Analysis Reports of Natrium license applications.
2. The fuel failure fractions during normal operation and transient conditions are subject to the qualification of Type 1 fuel.
3. If bonded sodium is not utilized in subsequent fuel designs, additional information shall be provided to justify the fission product release behavior from metal fuel to the gas plenum.
4. The sodium pool scrubbing and associated radionuclide (RN) retention within the primary sodium coolant is limited to where the bulk sodium is in subcooled conditions.
5. Adequate verification and validation assessment information should be made available to the NRC staff as part of future submittals supporting the codes that make up the EM. This verification and validation information should be justified to reasonably bound the operational envelope for the design for any applicant referencing the source term EM methodology.
6. User inputs to analytical tools used in the source term EM (e.g., parameter values) for which specified values are not provided in this TR should be documented and justified in the analysis supporting a license application referencing this TR methodology.
7. The source term EM described in this methodology results in MSTs intended for use in LMP-based license applications or other best-estimate plus uncertainty analyses. For applications using another process (e.g., conservative deterministic licensing analysis using postulated maximum hypothetical accident), the user must demonstrate that the TR methodology is applicable to that other process.
8. The TR documents that certain activities related to the development of the source term EM have not been completed. These activities are relevant to Steps 6, 7, 8, 9, 12, 13, 14, 15, 16, 17, 18, 19, and 20 of the EMDAP. This also includes ongoing work related to

experimental data to justify the source term phenomena closure models as described in TR section 3. An applicant or licensee referencing the methodology developed in this TR must submit documentation and justify that the identified activities have been completed to a state that is appropriate for the intended licensing application and that the identified information has been provided.

CONCLUSION

Based on its evaluation, the NRC staff determined that NAT-9392, Revision 0, subject to the limitations and conditions discussed above, provides an acceptable approach for developing MSTs for determining site-specific radiological release consequences for the proposed Natrium reactor design. Accordingly, the NRC staff concludes that the subject TerraPower TR can be used in developing MSTs for DBAs, LBEs, and normal operation to support analyses to show compliance with the regulatory requirements in 10 CFR 50.34(a)(1) and (4), 10 CFR 50.34(b)(3), to assess CR radiological habitability PDC in accordance with the regulatory requirements in 10 CFR 50.34(a)(3)(i), and to support plume exposure pathway EPZ sizing analysis in accordance with the regulatory requirements in 10 CFR 50.33(g)(2), for prospective Natrium reactor construction permit or OL applications under 10 CFR Part 50.

Principal Contributors: Z. Gran, NRR
M. Hart, NRR
R. Anzalone, NRR

SUBJECT: TERRAPOWER, LLC. – DRAFT SAFETY EVALUATION OF NAT-9392, "RADIOLOGICAL SOURCE TERM METHODOLOGY REPORT," REVISION 0 (EPID NO. L-2023-TOP-0046) DATED: FEBRUARY 20, 2025

DISTRIBUTION:
Public
RidsNrrDanu Resource
RidsNrrDanuUal1 Resource
RidsOgcMailCenter Resource
RBrusselmans, NRR
SDevlin-Gill, NRR
MSutton, NRR
DAtkinson, NRR
ZGran, NRR
JBorromeo, NRR
DGreene, NRR
CdeMessieres, NRR
MHart, NRR
RAnzalone, NRR

ADAMS Accession Nos.:
Pkg: ML25024A106
Public Enclosure: ML25024A141
Non-Public Enclosure: ML25023A138

OFFICE	NRR/DANU/UAL1:PM	NRR/DANU/UAL1:LA	NRR/DANU/UTB2:BC
NAME	SDevlin-Gill	DGreene	CdeMessieres
DATE	01/17/2025	02/06/2025	01/16/2025
OFFICE	OGC – NLO	NRR/DANU/UAL1:BC	
NAME	NMertz	JBorromeo	
DATE	02/04/2025	02/20/2025	

OFFICIAL RECORD COPY