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

April 4, 2022

The Honorable Christopher T. Hanson
Chairman
U.S. Nuclear Regulatory Commission
Washington, DC 20555-0001

SUBJECT: INTEGRATION OF SOURCE TERM ACTIVITIES IN SUPPORT OF ADVANCED REACTOR INITIATIVES

Dear Chairman Hanson:

During the 693rd meeting of the Advisory Committee on Reactor Safeguards, March 2-4, 2022, we discussed the staff's integration of source term activities in support of advanced reactor initiatives. Our Regulatory Rulemaking, Policies and Practices: Part 53 Subcommittee (formerly the Future Plant Designs Subcommittee) reviewed this matter on February 17, 2022. During these meetings we had the benefit of discussions with representatives of the NRC staff. We also benefited from the referenced documents.

CONCLUSIONS AND RECOMMENDATIONS

1. The NRC's dedicated web page for source term related documents is commendable and should keep potential applicants up to date on latest developments in this area.

2. The staff should provide an overview on the web page explaining how an applicant can best use the available information in concert with pre-application consultations to be better prepared to develop high quality submittals.

3. NRC staff has expended significant effort related to computer code model development and application for non-light water reactor (non-LWR) technologies. This activity should substantially increase the readiness of the staff and promote expeditious reviews of current and future non-LWR applications.

4. Although design specific evaluations are needed, application of these codes (as part of the NRC staff reference plant evaluations) has identified key phenomena, data gaps, and accident system response features that impact source terms. Staff insights from these evaluations should be documented.

5. Clear and consistent guidance that aligns the use of the terms "maximum hypothetical accident" and "maximum credible accident" should be developed to assist potential applicants that would use this concept in their licensing strategy.

6. Source terms should consider both radioactive and chemically hazardous materials in advanced reactor designs.

BACKGROUND

The staff recently published consolidated Title 10 of the *Code of Federal Regulations* (10 CFR) Part 53 preliminary proposed rule language. The proposed rule language defines a mechanistic source term as the magnitude, mix, and timing of radionuclides that are released into the environment following an unplanned event, after accounting for any retention of radionuclides provided by reactor specific design features. The staff also required that an accident-specific fission product release and physically based models of the facility be used to establish a mechanistic source term in the proposed rule language. In several of our letters we have commented on the need for guidance on non-LWR source terms. Development of a source term that can receive regulatory approval is critical to the success of new reactor design and licensing.

DISCUSSION

REGULATORY BASIS

The regulatory basis for source term is widely dispersed among numerous documents, largely focused on LWRs. The original bounding source term developed within TID-14844 was updated following extensive research performed in the decades following the accident at Three Mile Island (see NUREG-1465 and NUREG-1150). Regulatory Guide (RG) 1.183 developed the significant attributes that define the alternate source term and its application for both pressurized water reactors and boiling water reactors, the basis for which comes from those earlier published NUREGs.

Emergency planning regulations now use source term information from the facility's safety analysis report or probabilistic risk assessment (PRA). Higher-level technology-inclusive guidance for emergency planning source term determination is found in Appendix B of RG 1.242.

With recent policy on functional containment, SECY-16-0012 and SECY-93-092 provide information for calculating a mechanistic source term and its relationship to functional containment, as later described in SECY-18-0096 and its Staff Requirements Memorandum. RGs 1.232 and 1.233 provide additional considerations related to mechanistic source terms as part of establishing the licensing basis for non-LWRs. Finally, NUREG-1537 provides guidance on source term development for a "maximum hypothetical accident" for non-power production and utilization facilities that may be useful for simpler, smaller microreactors.

Recent applications and preapplication discussions between applicants and the staff have demonstrated that there is significant flexibility in how to establish the accident source term for reactor designs under consideration. Approaches can range from performing simple conservative bounding assessments (to support a "maximum hypothetical accident" approach) to more complex detailed analyses that model expected fission product releases across a spectrum of postulated events including the effects of uncertainties. RG 1.183 and Appendix B of RG 1.242 would be good starting points for a non-LWR applicant to develop a mechanistic source term.

The topic of source term is linked strongly to the process of accident identification, the importance of which we have discussed in previous letters. NUREG-1520 provides relevant guidance on a risk matrix to categorize, in a semiquantitative way, the frequency and consequence of postulated off-normal events. The document has been used historically for fuel cycle facilities but may be useful for smaller microreactors beyond the full PRA methodology that underlies RG 1.233. In this regard, clear and consistent guidance that aligns the use of the terms “maximum hypothetical accident” and “maximum credible accident” should be developed to assist potential applicants that would use this concept in their licensing strategy.

OBSERVATIONS ON SOURCE TERM DEVELOPMENT

Establishing a source term requires an integrated understanding of the physics and chemistry associated with fission product release and transport, coupled with the reactor system accident response. To assure there are no gaps in the technical basis for the source term that can impact an expeditious licensing review, we emphasize the following elements for consideration by the staff:

- Source terms should consider both radioactive and chemically hazardous materials as well as releases due to interactions between these materials. Because some advanced reactors use hazardous materials in their designs, the chemical source term from the facility will need to be evaluated for both workers and the public.

- Source term estimates should be based on actual experimental data considering the following important effects: time at temperature, volatility of specific fission products, chemical environment effects and important fuel characteristics (e.g., burnup). When data are sparse, conservative bounding estimates may be necessary.

- Understanding the relevant physics and chemistry is critical to accurate modeling of the physical form of the fission products. Aerosols can be important in many advanced reactor designs (e.g., fires associated with alkali metal coolants, aerosolization of non-water liquid coolants, and dust in some gas reactor designs). In some cases where there is a lack of external aerosol sources, assuming all fission products are vapors may be more appropriate.

- The necessary level of sophistication in modeling the transport of fission products through multiple barriers using a functional containment approach is strongly dependent on design details and can vary. Sometimes complex modeling using a fluid dynamics code that can capture the behavior of vapors and aerosols during transport is required. In other cases, simpler transport modeling such as a lumped parameter model can be effective. The optimal approach depends on the technology (fuel, coolant, moderator), the design of the reactor and surrounding enclosures/buildings, and the nature and progression of the postulated accident(s). But in all cases, a conservative approach to confinement barrier retention should be assumed based on the influence of relevant service conditions and accident environment on barrier effectiveness.

- The U.S. Department of Energy Handbook 3010-94 provides useful information for a wide range of potential source term constituents that could be applied to advanced reactors.

RECENT NRC FOCUS

NRC has devoted significant effort to being ready to evaluate applications across a range of reactor technologies (e.g., gas, sodium, salt, and heat pipe reactors). They have adapted their computer models (e.g., MELCOR, and SCALE) and then applied them in the non-LWR demonstration project to idealized designs available in the open literature to understand the system response to accidents and the relevant physics and chemistry associated with the source term. Particularly notable is the work on analysis of accident progression in a heat pipe reactor, a concept that has not received as much attention as the other technologies under consideration. Although design-specific evaluations are needed, these reference plant evaluations have identified key phenomena, data gaps, and accident system response features that impact source terms. Staff insights from these evaluations should be documented. These insights can help inform designers and regulators where the uncertainties in source term determination are the greatest and where other aspects of the source term have less impact, focusing attention where data may be required. This activity should substantially increase the readiness of the staff and promote expeditious reviews of current and future non-LWR applications.

The NRC has proposed risk-informed performance-based approaches to establishing a source term for a non-LWR (across the major technologies: gas, liquid metal, and salt), but how this can best be accomplished has not been finalized. The fuel qualification framework for advanced reactors (NUREG-2246) also discusses the need to establish a source term for non-LWR fuels to demonstrate the facility can meet accident-related regulatory limits. The Mechanistic Source Term Analysis element in the non-LWR PRA Standard (ASME/ANS RA-S-1.4-2021) also provides useful information on what to do to develop mechanistic source terms.

The staff presentation on source term contained a wealth of information (both in depth and breadth) that can serve as a starting point for potential applicants going forward. The use of a web page as a “one stop shop” is a good way to capture this information and keep potential applicants up to date on the latest work and progress in this area. Given the rapidly evolving nature of this topic, the use of a web page to capture relevant information is preferable to formal documented guidance at this point in time. The staff should provide an overview on the web page explaining how an applicant can best use the available information in concert with pre-application consultations to be better prepared to develop high quality submittals. Non-LWR applicants could also benefit from consolidated guidance on the “acceptable” attributes of the source term. We expect this need will be substantiated by staff interactions with advanced reactor stakeholders.

We look forward to additional meetings with the staff to review their continued improvement in guidance to define the radiological source term and its applications.

SUMMARY

Development of a source term that can receive regulatory approval is critical to the success of new reactor design and licensing. The use of a web page as a “one stop shop” is a very good way to capture source term related information and keep potential applicants up to date on latest efforts in this area. NRC staff has expended significant effort related to computer code development and application for non-LWR technologies. Both NRC efforts should allow expedited staff reviews.

We do not expect a response to this letter. Instead, staff should address this topic in our future 10 CFR Part 53 interactions when appropriate.

Sincerely,

Signed by Rempe, Joy
on 04/04/22

Joy L. Rempe
Chairman

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Accession No: ML22069A083 **Publicly Available (Y/N):** Y **Sensitive (Y/N):** N
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