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

March 1, 2021

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

SUBJECT: REVIEW OF ADVANCED REACTOR COMPUTER CODE EVALUATIONS

Dear Chairman Hanson:

During the 682nd meeting of the Advisory Committee on Reactor Safeguards, February 3-5, 2021, we reviewed the final two volumes of the staff evaluations of computer codes to be used for analyses of advanced non-light water (non-LWR) reactors: Volume 4 – "Licensing and Siting Dose Assessment Codes" and Volume 5 – "Radionuclide Characterization, Criticality, Shielding, and Transport in the Nuclear Fuel Cycle." Our Future Plant Designs Subcommittee also reviewed these reports during meetings on September 22 and December 1, 2020, respectively. During these meetings we had the benefit of discussions with representatives of the NRC staff. We also had the benefit of the referenced documents.

CONCLUSIONS AND RECOMMENDATIONS

1. The five volumes of the Strategy 2 report supporting the Vision and Strategy document describe the staff's approach for identifying and assessing non-LWR computer codes and data that may be used to support licensing reviews of non-LWR submittals. The staff has met its primary goal in this work to ensure readiness to review submittals for many different types of non-LWR designs.

2. Volume 4 provides descriptions and evaluations of computer codes the NRC staff uses for radiation protection and dose assessment. It describes knowledge gaps and code development needs for non-LWRs and, given the large number of codes to be improved and consolidated, the approach proposed by the staff is comprehensive and workable.

3. Volume 5 considers the computer codes NRC staff uses for radionuclide characterization, criticality, shielding, and transport throughout the fuel cycle. It is a plan for preparing a series of subsequent reports evaluating computer code development needs and identifying knowledge gaps that need to be closed for a range of non-LWR designs and fuel cycles. It represents a flexible and workable strategy for continuing development of the regulatory review process for new designs.

4. We urge the staff to keep in mind the four principles elucidated in our letter report of November 4, 2019: simplicity, completeness, working the problem backwards, and scaling down the level of effort of licensing review proportionately as the hazard decreases.

BACKGROUND

The subject of our current review is part of a continuing effort that is designed to implement the "*NRC Vision and Strategy: Safely Achieving Effective and Efficient Non-Light Water Mission Readiness.*" Over the past five years, we have provided letter reports on the vision and strategy as well as a number of products of its Implementation Action Plans including non-LWR design criteria, functional containment performance criteria, the licensing modernization project (LMP, now called the "Technology-Inclusive, Risk-Informed, and Performance-Based Approach to Inform the Content of Applications for Licenses, Certifications, and Approvals for Non-Light-Water Reactors), and siting for advanced reactors. Strategy 2, Computer Codes, of the vision and strategy is addressed in a series of draft documents prepared by the staff that evaluate computer codes needed to conduct confirmatory analyses of non-LWR nuclear power plants. The main goal of Strategy 2 is to identify and develop the tools and databases that will optimize regulatory readiness and assist the NRC staff in performing its safety reviews of non-LWR license applications.

Our letter report of November 4, 2019, provided our review of four documents produced by the staff evaluating computer codes to be used for analyses of advanced non-LWR reactors: an overview report — "Code Assessment Plans for NRC's Regulatory Oversight of Non-Light Water Reactors," Volume 1 – "Computer Code Suite for Non-LWR Design Basis Event Analysis," Volume 2 – "Fuel Performance Analysis for Non-LWRs," and Volume 3 – "Computer Code Development Plans for Severe Accident Progression, Source Term, and Consequence Analysis."

DISCUSSION

The staff has completed a set of reports addressing Strategy 2, Computer Codes. The two draft documents they shared with us complete their near-term action plan for identifying and assessing the available computer codes and databases.

<u>VOLUME 4 — Licensing and Siting Dose Assessment Codes</u>

Volume 4 describes the staff's approach to identify and assess computer codes and data used for licensing and siting dose assessment. Dose assessment codes have three major components: (1) source term input, in-plant transport, and release to the environment; (2) atmospheric transport and diffusion models and environmental pathways models; and (3) a dose consequence model. The report identifies and describes the computer codes the staff uses for (1) licensing reviews for design basis accidents, control room habitability, atmospheric concentration in building wake, and ground level concentrations for accident releases; (2) siting codes used in environmental reviews for the routine effluent source term and routine effluent dose assessment; (3) emergency response assessments; (4) decommissioning termination surveys; and (5) other purposes such as environmental dosimetry and severe accident consequences.

No new codes are identified, but the staff proposes to consolidate and modernize many of the existing codes. Their pedigrees and practical use vary widely, and many are rigid in their application with built-in assumptions that would be difficult to manipulate for new non-LWR designs. The consolidated code package is to be modular, flexible, efficient, and user-friendly. This will permit modification for each non-LWR application. The staff envisions that code modules can be developed as the need is forecast, allowing flexibility consistent with the uncertainties associated with anticipated applications and available new data. The report

describes the many existing computer codes and how they would be applied and consolidated for the non-LWR design types. It also summarizes the tasks needed to update their capability to model and simulate those designs.

An additional consideration for the staff is that there is a broad user base for these codes, within the NRC and beyond. Consistency in how the codes and their output appear to the users will be important for their general acceptance. Given the large number of separate codes to be improved or consolidated, the approach proposed by the staff is comprehensive and workable.

The staff concluded by noting that this plan identifies many, but not all, of the gaps in code development and assessment for non-LWR designs. The staff is currently prioritizing these gaps and revisions for the consolidated code package. We suggest that the most important modifications might be associated with the ability to calculate dose consequences for small emergency planning zones that some non-LWRs are expected to propose. The staff is using their best judgment on expected submittals to ensure they have the necessary confirmatory tools. We expect that staff priorities will change often over the next few years.

VOLUME 5 — Radionuclide Characterization, Criticality, Shielding, and Transport in the Nuclear Fuel Cycle

Volume 5 describes the staff's plan to assess changes to the existing fuel cycle analyses for non-LWR designs. It focuses on the staff's ability to (1) perform independent fuel cycle safety analyses and consequence assessments; (2) identify gaps in knowledge and in computer codes; and (3) assess readiness. These are the essential elements required to ensure that they can effectively review non-LWR applications.

The existing NRC computer codes (such as SCALE, MELCOR, and consequence tools) are examined to establish NRC non-LWR fuel cycle safety analysis capabilities and development needs. The use and augmentation of current safety analysis tools rather than the development of new computer codes makes sense and is consistent with past practice for earlier non-LWR-related activities. We find the approach to be logical, well organized, and structured to allow flexibility in setting priorities among the many necessary tasks. It will also allow the staff to adjust their priorities in line with their expectations for industry submissions.

This report has a strong focus on the technical gaps – analytical capability gaps, modeling capability gaps, analytical modeling gaps, nuclear data gaps, and validation gaps — that need to be identified and closed before the staff will be ready to review submissions for each non-LWR type. It will be important for the staff to include chemical toxicity and flammability for relevant non-LWR fuel cycles.

The report is less an evaluation of codes and development needs and more a strategy or plan for developing a series of evaluation reports covering the span of anticipated non-LWR designs. Currently, ten reports are planned — five non-LWR reference designs that were defined in Volume 3 and five "front-end" fuel cycle reports. The five reference design reports will demonstrate that the staff has an understanding of the relevant non-LWR issues for five general design types and should identify related knowledge gaps to be resolved for each. It is expected that specific submittals may require specialization of these reports:

1. Fluoride-salt-cooled High Temperature Reactor Fuel Cycle Analysis

2. Heat Pipe Reactor Fuel Cycle Analysis

3. Sodium Fast Reactor Fuel Cycle Analysis

4. High Temperature Gas Reactor Fuel Cycle Analysis

5. Molten Salt Reactor Fuel Cycle Analysis

The five front end reports appear to reorganize current knowledge into a logical order to help identify gaps:

6. Enrichment and UF6 Handling up to 20 wt% (high assay low enriched uranium — HALEU — common to all reference designs)

7. TRI-structural ISOtropic Particle Fuel (TRISO) Kernel Fabrication

8. Uranium Metallic Fuel Fabrication

9. Fast Reactor Fuel Fabrication

10. Pebble TRISO Fuel Fabrication

Each fuel cycle report will describe scenarios, identify strategies to close capability gaps, and demonstrate through analysis the readiness of the NRC to review non-LWR fuel cycle activities. The staff acknowledge that their work is progressing before expected information will be developed and provided by the U.S. Department of Energy (DOE) and industry, because there is no other choice, if regulatory delays are to be controlled. The staff faces a difficult task of anticipating the specific designs that are likely to be submitted and when new information will become available. We expect priorities to shift as data and designs are developed. Aggressive management and close interaction among the staff, DOE, and developers (potential applicants) will be essential to optimize regulatory readiness.

The staff should summarize the analysis approach that will find gaps and assess capability. They have laid out a fuel cycle flow diagram based on the LWR fuel cycle. When applied to each non-LWR fuel cycle, this process comparison is expected to provide a logical framework to help the staff identify the differences in each process and thereby focus the examinations on possible gaps.

The staff has provided a schedule that seems reasonable at this time, if somewhat aggressive. They also provided a detailed summary of current capabilities from NUREG/CR-6410, “Nuclear Fuel Cycle Facility Accident Analysis Handbook.”

SUMMARY

The staff has completed a workable set of draft reports on NRC Vision and Strategy, Strategy 2, Computer Codes. Substantial development work on specific codes remains. Reiterating our thoughts from our earlier letter, four principles suggest the way to judiciously move forward: simplicity, completeness, working the problem backwards, and a graded, risk-informed licensing review. The analysis approach should be to start simple and only get detailed as needed. The

staff should find a way to make the licensing effort commensurate with the associated risk. Something akin to the approach used for research reactors could be considered for small simpler designs, which would likely simplify the required analyses.

We look forward to continued interactions with the staff.

Sincerely,

Matthew W. Sunseri Digitally signed by Matthew W. Sunseri
Date: 2021.03.01 18:09:39 -05'00'

Matthew W. Sunseri
Chairman

REFERENCES

1. Draft NRC Document, “NRC Non-Light Water Reactor (Non-LWR) Vision and Strategy, Volume 4 – Licensing and Siting Dose Assessment Codes,” August 2020 (ML20028F255).
2. Draft NRC Document, “NRC Non-Light Water Reactor (Non-LWR) Vision and Strategy, Volume 5 – Radionuclide Characterization, Criticality, Shielding, and Transport in the Nuclear Fuel Cycle,” November 3, 2020 (ML20308A744).
3. U.S. Nuclear Regulatory Commission, “NRC Vision and Strategy: Safely Achieving Effective and Efficient Non-Light Water Reactor Mission Readiness,” December 21, 2016 (ML16356A670).
4. Advisory Committee on Reactor Safeguards, “Review of Advanced Reactor Computer Code Evaluations,” November 4, 2019 (ML19302F015).
5. U.S. Nuclear Regulatory Commission, “NRC Non-Light Water Reactor (Non-LWR) Vision and Strategy Staff Report: Near-Term Implementation Action Plans: Volume 2 – Detailed Information,” July 2017 (ML17165A069).
6. Advisory Committee on Reactor Safeguards, “NRC Non-Light Water Reactor Vision & Strategy – Near-Term Implementation Action Plans and Advanced Reactor Design Criteria,” March 21, 2017 (ML17079A100).
7. Advisory Committee on Reactor Safeguards, “Draft Final Regulatory Guide 1.232, ‘Guidance for Developing Principal Design Criteria for Non-Light Water Reactors’,” March 26, 2018 (ML18081A306).
8. Advisory Committee on Reactor Safeguards, “Draft SECY Paper, ‘Functional Containment Performance Criteria for Non-Light Water Reactor Designs’,” May 10, 2018 (ML18108A404).

9. Advisory Committee on Reactor Safeguards, “Draft SECY Paper and Guidance Documents to Implement a Technology-Inclusive, Risk-Informed, and Performance-Based Approach to Inform the Content of Applications for Licenses, Certifications, and Approvals for Non-Light-Water Reactors,” March 19, 2019 (ML19078A240).

10. Advisory Committee on Reactor Safeguards, “Draft Proposed Rule, ‘Emergency Preparedness for Small Modular Reactors and other New Technologies’,” October 19, 2018 (ML18291B248).

11. Advisory Committee on Reactor Safeguards, “Review of Draft SECY Paper,” “Population-Related Siting Considerations for Advanced Reactors,” October 7, 2019 (ML19277H031).

12. Draft NRC Document, “Code Assessment Plans for NRC’s Regulatory Oversight of Non-Light Water Reactors,” April 1, 2019 (ML19093B266).

13. Draft NRC Document, “NRC Non-Light Water Reactor (Non-LWR) Vision and Strategy, Volume 1 – Computer Code Suite for Non-LWR Design Basis Event Analysis,” April 1, 2019 (ML19093B322).

14. Draft NRC Document, “NRC Non-Light Water Reactor (Non-LWR) Vision and Strategy, Volume 2 – Fuel Performance Analysis for Non-LWRs,” August 21, 2019 (ML19246C319).

15. Draft NRC Document, “NRC Non-Light Water Reactor (Non-LWR) Vision and Strategy, Volume 3 – Computer Code Development Plans for Severe Accident Progression, Source Term, and Consequence Analysis,” April 1, 2019 (ML19093B404).

16. U.S. Nuclear Regulatory Commission, “Nuclear Fuel Cycle Facility Accident Analysis Handbook,” NUREG/CR-6410, March 1998 (ML072000468).

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