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

November 4, 2019

The Honorable Kristine L. Svinicki
Chairman
U.S. Nuclear Regulatory Commission
Washington, DC 20555-0001

SUBJECT: REVIEW OF ADVANCED REACTOR COMPUTER CODE EVALUATIONS

Dear Chairman Svinicki:

During the 667th meeting of the Advisory Committee on Reactor Safeguards, October 2-4, 2019, we reviewed the staff's evaluations of computer codes to be used for analyses of advanced non-light water reactors (non-LWRs). Our Future Plant Designs Subcommittee also reviewed this matter during meetings on May 1 and September 17, 2019. Previously we were briefed by the U.S. Department of Energy (DOE) concerning the capabilities of their computer codes on August 21 and November 16, 2018. 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

The four draft documents on Strategy 2 of the Vision and Strategy document provide an evolving exposition of the staff's approach for the identification and assessment of non-LWR computer codes and data that may be used to support licensing reviews of non-LWR submittals.

1. The approach taken by the staff supports their readiness to review submittals for non-LWR designs of many different types. This approach can also help the staff understand the new reactor designs and associated phenomena.

2. Ideally, the tools for staff confirmatory analysis should be as independent as practical, validated, understood by the staff, and usable on the staff's computer resources.

3. The staff also needs to become sufficiently familiar with applicant codes to support timely reviews of submitted analyses.

4. The overview report should be revised to better explain how this approach integrates the evaluations discussed in Volumes 1-3 and to present a coherent strategy for evaluations. Four principles should underlie the strategy: simplicity, completeness, working the problem backwards starting with the source term, and scaling down the level of effort of licensing review proportionately as the hazard decreases.

5. The staff should perform pilot studies using relatively mature designs to illustrate how the analysis should proceed. They should consider a case using the licensing modernization project (LMP) and one that uses an alternative approach. This would increase confidence in the overall approach being pursued by staff and flush out any needed refinements.

BACKGROUND

The NRC staff developed a report in 2016, "NRC Vision and Strategy: Safely Achieving Effective and Efficient Non-Light Water Mission Readiness," as the staff contemplated how to review and regulate a new generation of non-LWRs including their associated fuel cycles and waste forms. The report lays out six strategies to accomplish its goals and provides a set of Implementation Action Plans that identify specific, actionable tasks that can fulfill the strategies. Over the intervening years, we have provided letter reports on the vision and strategy document as well as several products of the Implementation Action Plans—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.

The subject of our current review is a series of draft documents prepared by the staff on evaluating computer codes needed to conduct confirmatory analyses of non-LWR nuclear power plants. The draft documents reviewed are entitled, "Code Assessment Plans for NRC's Regulatory Oversight of Non-Light Water Reactors," "NRC Non-Light Water Reactor (Non-LWR) Vision and Strategy, Volume 1 - Computer Code Suite for Non-LWR Design Basis Event Analysis," "NRC Non-Light Water Reactor (Non-LWR) Vision and Strategy, Volume 2 – Fuel Performance Analysis for Non-LWRs," and "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."

The draft documents were prepared under Strategy 2 of the Vision and Strategy document. 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. Central to Strategy 2 are the selection and development of computer codes to be used for confirmatory analyses of non-LWR designs.

DISCUSSION

The staff has completed a major step in addressing Strategy 2: Computer Codes. The four draft documents they shared with us complete a major portion of their near-term action plan by identifying and assessing the available computer codes and databases. This activity is helping the staff develop their understanding of the technologies involved and the associated phenomena that will be encountered in reviewing non-LWR designs. Two final documents, Volume 4 on licensing and siting dose assessment codes and Volume 5 on fuel cycle topics, have not been completed. The gap analyses associated with Volumes 1-3 consider both knowledge gaps (fundamental physics and chemistry) and computer code gaps. Staff stated that most of the knowledge gaps are in the area of severe accidents. They have been comprehensive in identifying potential gaps, consistent with Phenomena Identification and Ranking Tables (PIRTs) that have been performed in recent years. Knowledge gaps will need to be addressed by experiment and operating history, perhaps as interpreted by expert elicitation. Computer code gaps have been addressed in the current drafts. The staff's contractor developed a predictive capability maturity model (PCMM) to characterize the state of readiness of the computer codes. It generates maturity level scores over a set of six fundamental modeling and simulation elements for each reactor type. It has been useful for evaluating the level of effort expected to complete development of the computer codes for use in staff reviews.

The staff evaluated computer codes from four sources—NRC codes, DOE advanced multi-physics codes, commercial codes, and international codes. During the period of our review, the staff was rapidly developing its evaluation, drafting the four reports, and conducting preliminary testing. As part of their approach, the staff has assembled a suite of primarily NRC and DOE codes they call BlueCRAB as a comprehensive reactor analysis bundle. The set includes a commercial computational fluid dynamics (CFD) code and one international code for nuclear cross-sections, as well as NRC and DOE codes for cross-sections, system and core thermal hydraulics, CFD, neutronics, thermal hydraulics and fuel performance. Almost all have now been coupled primarily through the DOE MOOSE (multiphysics object-oriented simulation environment) platform, a fully coupled, fully implicit solver that allows independent codes to be coupled and exchange information. BlueCRAB includes no codes for source term evaluation; the staff will rely on their own code MELCOR.

The primary goal of Strategy 2, and indeed of the entire vision and strategy process, is readiness. The staff needs to be ready to review non-LWR submittals and to perform confirmatory analyses. This implies that they must have an in-depth understanding of how each design works. The staff sees the need to be prepared for a range of review strategies and regulatory concerns. The specific approach will depend on applicant submittals.

Staff considers its readiness highest for high-temperature, gas-cooled reactors and sodium fast reactors. For gas-cooled fast reactors, heat pipe based microreactors, molten salt reactors, and molten salt-fueled reactors substantial development will be required. For the more exotic of these technologies, the staff anticipates substantial savings if DOE codes are selected for confirmatory analysis. Some of our members are not so sanguine.

The staff readiness goals suggest that all designs should be considered equally likely for submittal. However, it is clear that such an approach is neither practical nor possible. The time to make necessary improvements to the codes and ensure staff competence in their use cannot be reconciled with such an egalitarian point of view. Near-term submittals are expected, and the staff must set priorities based on best judgment. The staff is holding discussions with DOE to identify data gaps and set high-priority needs for obtaining such data.

Because this work is of high priority and time is believed to be short, many tasks are being performed in parallel. In the rush to complete, it is not surprising to find some inconsistencies.

The technical volumes of the draft report identify key issues of readiness for three types of analysis and the associated computer codes:

- Volume 1 considers codes for non-LWR design basis event analysis—systems analysis—evaluating how each machine works, whether the safety functions and systems are acceptable, and if the operating limits are met. Volume 1 presents the comparative maturity evaluations for each reactor type but draws no conclusions about which codes should be used. The variety of detailed computational tools in BlueCRAB may be needed to verify that some advanced reactor safety functional and operational limits are met.

- Volume 2 considers fuel performance codes for non-LWRs by performing a comparison of current fuel performance codes, NRC's FAST and DOE's BISON. They have chosen FAST for their confirmatory analysis tool for fuel performance. They used the PCMM model this time to plan necessary development activities throughout the next two and a half years.

- Volume 3 considers non-LWR code development for severe accident progression, source term, and consequence analysis, evaluating what is the fission product inventory, its transport, and the resulting source term. Volume 3 lays out the regulatory needs, the required development activities for each reactor type, and a development plan for that work over the next two and a half years. Staff identified their systems analysis code, MELCOR, that can perform reactor severe accident progression and source term analysis.

Early on, we had a sense that the staff might be force-fitting some of the detailed DOE codes to meet their need for confirmatory analysis. Our members offered many comments suggesting that we may not need all the detail in the DOE codes for deciding safety issues. The staff should decide where the current codes are good enough for safety findings and where the new codes could become necessary or advantageous. Over the four months between our subcommittee meetings, the staff's view of the best path forward appeared to evolve and coalesce. Staff agrees that DOE codes provide exceptional detail and acknowledge that such details might be very essential for a core designer who wants to minimize the number of feed assemblies or to optimize performance. However, as they are evaluating margins to various safety limits, they generally will not need that detail.

The staff considers that they need two sets of tools—one for adequacy of safety functions and operational limits and another for source term. Ideally, the tools for staff confirmatory analysis should be as independent as practical, validated, understood by the staff, and usable on the staff's computer resources. The staff also need to become sufficiently familiar with applicant codes to support timely reviews of submitted analyses.

We and the staff concur that expanding the overview report to clarify the staff's strategy on selecting computer codes for confirmatory analysis would be helpful, as would explaining why different criteria might apply for different applications. Four principles suggest the way to judiciously move forward: simplicity, completeness, working the problem backwards, and a graded, risk-informed licensing review.

The philosophy should be to start simple and only get detailed as needed. If the margins for the new reactors are substantial, simple analyses can confirm that safety is maintained. With some of the new designs and an expected lack of data, a judicious consideration of uncertainty in the associated calculations will be important. An example of an area that affects the complexity of analysis and code use is the issue of design basis accidents (DBAs) and beyond design basis accidents (BDBAs). The continued separation of DBA and BDBA codes may not be necessary for some non-LWRs. Modeling of accident phenomena that occur in LWRs changes significantly from DBA to BDBA regime because of rod ballooning, loss of geometry, oxidation, and meltdown. Some of the advanced reactors may have a much more graceful change in accident space and this should allow one toolset to do all the calculations. This characteristic should enable a great simplification of the analysis.

Completeness is essential to ensure we have identified the most risk-significant scenarios. The process described in the LMP provides a systematic way to identify initiating events and scenarios that can lead to release. Any alternative must use a systematic search and not rely on past experience with LWRs.

The best way to approach the stepwise application of increasing detail could be to work the problem backwards. By that we mean start with the source term. Depending on its associated hazard and the ability to mobilize it, a simple bounding analysis could show that safety criteria are met. If not, then stepwise increase the detail and realism of the analysis.

The final principle relates to scaling down the level of effort of licensing review proportionately as the hazard decreases. 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, which would greatly simplify the analyses.

Finally, we recommend pilot studies to illustrate how the analysis should proceed using relatively mature designs. Such studies can provide insights about the required level of detail, the importance of modeling parameters, and prioritization of data needs. These pilots are an important step for increasing confidence in the overall approach being pursued by staff for identifying any needed refinements. The staff should consider a case using LMP and one that uses an alternative approach.

SUMMARY

The staff has made significant progress in the challenging area of Strategy 2 for developing staff readiness to review non-LWR submittals. However, there is much more to accomplish in a relatively short time. We look forward to continued interactions with the staff.

Sincerely,

/RA/

Peter C. Riccardella
Chairman

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