

Modeling and Testing in the Reactor Design and Licensing Process

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Introduction

- This presentation will focus on NRC requirements, guidelines and expectations for the review and licensing of new designs, and in particular what those mean for analytical codes used in safety analysis.
- Modeling and Simulation (M&S) of accidents along with testing are critical to a successful design & licensing effort.
- The regulatory requirements and guidance are to ensure public safety, however proper development of modeling capability and testing also enables the reactor developer to optimize the design.

Regulatory Requirements

- Modeling and Testing Requirements
 - 10 CFR 50.439(e): Provides guidance on design certification applications with regards to demonstration of safety system performance, data sufficiency for assessment analytical tools.
 - 10 CFR 50.46 & Appendix K: LOCA and LWR – centric. However, defines “Evaluation Model,” and provides staff expectations on supporting data, documentation, etc.
- Advanced Reactor Design Criteria (ARDC) are intended to provide guidance for non-LWRs, and contain expectations specific to each design.

10 CFR 50.43(e) Requirements

- The performance of each safety feature must be demonstrated through either analysis, test programs, experience, or combination thereof.
 - Interdependent effects of safety features must be demonstrated.
 - Sufficient data must exist to assess analytical tools for safety analysis.

OR

- There has been acceptable testing of a prototype over normal operating conditions.

10 CFR 50.46 & Appendix K Guidance

- Evaluation Model (EM): The calculational framework for evaluating the behavior of the reactor system. Includes one or more computer programs . . . “mathematical models used” ... “assumptions” ... treatment of “input and output”.
- “The evaluation model must include sufficient information must include sufficient supporting justification to show that the analytical technique realistically describes the behavior of the reactor system . . .”
- “Comparisons to applicable experimental data must be made . . .”
- Errors in the EM must be reported.

Analysis Tool Review “Expectations”

- While the NRC defines regulatory criteria for advanced reactors, several basic principles will be expected with respect to modeling and testing in support of analysis tools:
 - Evaluation Model description & documentation
 - Identify models, correlations, assumptions, scenarios.
 - The applicant owns it.
 - Code Assessment = V&V
 - Verification (possibly more difficult for “multi-physics”)
 - Validation

Validation

- Validation is the critical component of a successful Evaluation Model approval. Two elements to address:
 - Separate Effects Tests: Demonstrate adequacy of models & correlations for a particular phenomena (convective heat transfer, condensation, break flow, etc.)
 - Integral Effects Tests: Demonstrate adequacy of safety systems, ECCS performance, and assess code(s) for ability to simulate system interactions.

Modeling and Testing Challenges

- Separate Effects Tests
 - Range of Conditions: Models and Correlations often developed at one set of conditions and then “extrapolated” to prototypical conditions
 - Geometry dependence
- Integral Effects Tests
 - Availability of facilities
 - Scaling

Recommendations for Pre-Applicants

- Development of a test & analysis plan
 - Model development, experimental needs
 - EMDAP and CSAU provide guidance
- Early engagement with the NRC
 - Identify code(s) for LBE
 - Identify potential technical issues
- Early engagement with ACRS
 - Provides an independent assessment of technical issues and NRC review