Spent Fuel Project Office
Draft Interim Staff Guidance - 21
USE OF COMPUTATIONAL MODELING SOFTWARE

Issue

Given the growing need for the industry to store spent reactor fuel of higher heat loads in dry storage casks, and to eventually transport that same spent fuel in transportation packages, analyzing the performance of casks, as well as other radioactive material packages, has become an increasing challenge. Due to the impracticalities and cost considerations involved in physical testing of spent nuclear fuel storage and transportation casks and some radioactive material transportation packages, Finite Element, Finite Difference, and Finite Volume analysis computer codes, defined here as Computational Modeling Software (CMS), are tools used by many licensees to analyze cask and package performance in the structural and thermal disciplines. CMS can be used to determine structural stresses, dynamic impact or drop performance, and thermal performance of cask designs. In NUREG-1536, "Standard Review Plan for Dry Cask Storage Systems," NUREG-1567, "Standard Review Plan for Spent Fuel Dry Storage Facilities," NUREG-1609, "Standard Review Plan for Transportation Packages for Radioactive Materials," and NUREG-1617, "Standard Review Plan for Transportation Packages for Spent Nuclear Fuel," the staff has not been provided with specific guidance on what information safety analysis reports (SARs) should include with respect to analyses completed using CMS, in order for the staff to adequately review an application that utilizes CMS for structural and thermal evaluations.

Licensees can use computer codes to analyze cask, or package, criticality and shielding performance. These codes may also be defined as CMS. In addition to the NUREGs cited above, NUREG/CR-5661, "Recommendations for Preparing the Criticality Safety Evaluation of Transportation Packages," and NUREG/CR-6802, "Recommendations for Shielding Evaluations for Transport and Storage Packages," collectively provide the guidance on the information necessary to appear in SARs for performing a review of analyses that rely upon CMS in these disciplines.

Introduction:

This interim staff guidance (ISG) provides the staff's position on what an acceptable analysis using CMS should include, and what information should be reviewed by the staff when considering a submittal from an applicant using CMS in the design review of a storage cask or transportation package. This ISG applies to both thermal and structural analyses utilizing CMS. However, application of this ISG does not extend to shielding and criticality analyses that rely on CMS since present guidance sufficiently addresses current issues in these areas.

Discussion:

As the industry redesigns its casks/canisters to accommodate spent fuel with higher burnups and higher heat loads, reliance on complex computer simulation increases. The current standard review plans (SRPs) do not provide sufficient detail on what information the staff

should review in a SAR and what supporting documentation is needed to adequately describe the specifics of computer modeling of cask or package performance. In order for the staff to efficiently review cask and package analyses, sufficient detail is necessary for the staff to perform confirmatory analyses. Because cask and package analyses contain many parameters that can change the results of the analyses if treated inappropriately, situations may exist where the staff may want to verify the validity of an applicant's analysis model, the methodology used to create the model, and perform confirmatory analyses. This ISG will delineate the specific areas that will be addressed by the staff when reviewing cask analyses using CMS, including performing confirmatory analyses. The staff encourages applicants to submit full documentation and validation of analytic methods used. This documentation will enhance the efficiency of staff review, minimize the need for additional questions, and provide for a shorter overall review time.

Regulatory Basis:

10 CFR 72.24 defines the technical information to be contained in an application for spent fuel storage (site specific license). Specifically applicable to this ISG, but not necessarily all inclusive, are 72.24(b), (c)(1), (2), and (3), and (d)(1) and (2).

10 CFR 72.230, subparts (a) and (b), and 72.236 subparts (a), (b), (d), (e), (f), (g), and (l) define the design requirements that provide the regulatory basis for spent fuel storage cask submittals and the specific requirements to be satisfied for spent fuel storage cask design approval and fabrication (Certificate of Compliance). This ISG delineates CMS information to be submitted that can substantiate the cask design bases per the above regulatory requirements.

10 CFR 71.31(a)(2) and (b) define the technical information that provide the regulatory basis for this ISG to be contained in an application for radioactive material packaging and transportation.

10 CFR 71.35(a) provides the regulatory basis for this ISG which defines the requirements for the content of an application and provides reference to the applicable Sections (subparts E and F of 10 CFR Part 71), where specific regulatory standards on demonstrating compliance are delineated for spent fuel transportation.

Technical Review Guidance:

<u>Computational Modeling Software Application</u>

The staff does not endorse the use of any specific version of CMS. Any CMS application could be used for analyses of cask or package components, however, for any CMS used as the basis for demonstrating the cask design satisfies regulatory requirements, adequate validation of that CMS must be demonstrated by the applicant.

The reviewer should verify that the following information is provided in the SAR or related documentation:

(1) details of the methodology and the theoretical basis of the program;

(2) a description of benchmarking against other codes or validation of the CMS against applicable published data;
(3) standardized verification problems analyzed using the CMS, including comparison of the theoretical predicted results with the results of the CMS; and

(4) release version and applicable platforms.

Modeling techniques and practices used by applicants need to be verified to demonstrate adequacy of the model.

- The reviewer should verify that the CMS and the options used by the applicant are appropriate for adequately capturing the behavior of a cask, package, or any components.

  Relevant input and results files should be submitted with the original application. Files should be submitted in an electronic format that would most easily allow them to be run by the staff, should the staff desire to do so. In-depth review of CMS models is most easily done with input files that contain individual commands used to develop the model and apply the various boundary conditions. Therefore a text input file format (versus database format) is preferred. Input files should be thoroughly annotated to demonstrate the process behind building and solving models developed using CMS. A well annotated input file will expedite staff review and preclude the need for further clarification questions by the staff. DVD, CDROM, ZIPdisk, or 3 ½" diskettes are appropriate for case and support files.

Computer Model Development

- The reviewer should verify that the computer model used for the analysis is adequately described, is geometrically accurate, has addressed material and manufacturing uncertainties, and has no significant analysis errors.

- The reviewer should verify that the SAR, calculation notes, or other documents submitted by an applicant include a clear description of the computer model including a listing of the types of elements used and any applicable options for element behavior. Note that this information can often be retrieved from a detailed analysis input file.

- Boundary conditions placed on the model should also be clearly defined. Although the submittal of electronic files that contain actual model data may provide relevant specific information, textual description of the specifics of the model should be included in the SAR or related documents.

- The reviewer should verify that the description includes the basis for choosing each of the parameters and components of the model, as applicable, for use in each model application (e.g., why was a particular type of element chosen for each application).

- The reviewer should verify that models are not over-simplified and are representative of cask or package geometry. Models created with CMS are often simplified in order to reduce computer processing time. Models can often omit geometric details or use

homogenized or smeared material properties to represent complex geometry or material combinations and still retain analytic accuracy. Each incremental time step should be converged to a reasonable engineering tolerance.

- The reviewer should verify that the model accurately predicts the behavior of the cask or package. Tolerances and contact resistance should be accounted for in cask or package models.

- The reviewer should verify that if credit is taken for conservatism in the analysis, the applicant justifies and quantifies the applicability of the assumed conservatism to the analytical model. If a particular assumption is accounted for through the application of added conservatism, the assumption must be addressed through validation of the model. For example, without specialized CMS codes and extended compute times, current models cannot directly account for certain conditions that occur in the hypothetical accident condition (HAC) fire, such as combustion of materials, the random behavior of a pool fire, material anomalies that may manifest themselves in a fire, and seal to surface interactions. CMS used to model these types of conditions should be validated using empirical data and it should be demonstrated as applicable to the design configuration modeled.

- The reviewer should determine whether the applicant provided a clear discussion of how validation of the CMS illustrates the conservatism in the analysis.

- The reviewer should verify that the applicant has provided a discussion of how error, warning, or advisory messages affect the analysis result. When processing a computer model developed using CMS, the software frequently provides error, warning, or advisory messages indicating a possible problem with the model that may or may not be sufficient to terminate processing. If the error/warning function has been disabled during processing, an explanation of why this is appropriate should be provided.

- The reviewer should verify that any model validation done with applicable experiments is properly documented.

Justification of Bounding Conditions/Scenario for Model Analysis

Title 10 of the Code of Federal Regulations, Parts 71 and 72, do not provide a specific definition of most damaging orientation and worst case conditions for analysis of transportation packages or dry cask storage system designs. The regulations place the responsibility on the applicant to make the determination of the most damaging orientation and worst case conditions for a given design and document how the analytic model was configured for the scenario.

- The reviewer should verify that the applicant provided sufficient justification for selecting the most damaging orientation and worst case conditions .

Description of All Boundary Conditions and Assumptions

- The reviewer should verify, as necessary, that boundary conditions and assumptions regarding the boundary conditions are addressed in the textual description included in

the SAR or other documents (e.g., emmissivity values, absorptivity values, convective coefficients, and radiation view factors). This information should be presented in either tabular form or in a complete textual manner. Justifications and bases for such items should also be included in the textual description. Values or quantities indicating performance enhancements, i.e., increasing material conductivity values to mimic internal convection or substantially reduced design load factors (DLF's) reflecting an unusually high degree of impact damping, should be accompanied with credible justifications and should be closely reviewed and independently verified, if needed, by staff.

Documentation of All Material Properties

As needed, the reviewer should assess that;

(1) the consistency of units for material properties throughout the SAR,

(2) all material properties for all temperature ranges are included, and

(3) references to specific materials used by the CMS application in the form of material numbers in the models and specific material properties based on geometry (i.e., conductivity in the X, Y and Z directions), are listed in the SAR in tabular format.

In addition the reviewer should verify that types of elements used in the model are listed in relation to materials or components used in the model. Computer code/input validation with appropriate geometries and conditions could serve to validate input parameters.

Description of Model Assembly

- The reviewer should verify that the applicant has described all elements that are present in the computer model and has provided an explanation as to why they are used.

- The reviewer should verify that a sufficient explanation of the logic behind the creation of each specific computer model is provided, in order for effective confirmatory calculations to be performed. Aspects of the computer model that are notable during its construction may become blurred or transparent in the model as presented in its final form.

- The reviewer should verify that the applicant has provided annotated input files as appendices to the SAR or in the calculation notes, that explain the various steps in building the computer models submitted. If the input files provided do not adequately describe model assembly, the applicant should provide an adequate explanation of how computer models were assembled using the CMS in the appropriate SAR chapters.

Loads and Time Steps

- The reviewer should verify that loads, load combinations, and, if used by the analytical code, the load steps utilized in the computer model are clearly explained by the applicant. The staff should evaluate all loads, how they are placed on the computer models, load combinations, and if used, the time steps applied in the analysis.

- The reviewer should verify that time steps are sufficiently small to capture the behavior of the computer model and that each subset is adequately converged.

Sensitivity Studies

- The reviewer should verify that the applicant has completed sensitivity studies for relevant CMS modeling parameters. This includes mesh type and density, load step size, interfacing gaps or contact friction, material models and model parameters selection, and property interpolation, if applicable. For example, a mesh sensitivity study should be conducted not only for mesh density but also for mesh density/refinement in areas of thermal or structural concern or where performance of the material is crucial, such as seal areas, bolts, etc.

- The reviewer should verify that the results of all sensitivity studies performed are clearly described in the SAR or related documentation and may be independently verified, if necessary.

- The reviewer should verify that the applicant's documentation includes model variations used in their mesh sensitivity. The discussion of sensitivity studies should be included in the general model discussion noted above with relevant references to examples included in the SAR or in any appendices.

Results of the Analysis

- The reviewer should verify that the SAR, or related document(s), include all relevant results (tabular and computer plots) for applicable load cases and load combinations evaluated for design code compliance, and that all governing results (stresses/deformation) are clearly identified in the tables and on plots.

- The reviewer should verify that results are consistent throughout the SAR, and that the correct results are used in calculations of other cask or package performance parameters (e.g., calculated temperatures used in the internal pressure calculation should be verified).

Recommendation: Revise NUREGs as follows:

NUREG-1536, "Standard Review Plan for Dry Cask Storage Systems"

Revise, as follows:

1. Insert the following at the end of the Chapter 3.0 Structural Evaluation, Section V.d.ii(1), Finite-Element Analyses:

   Verify that the applicant has provided the information details as described in Appendix A to this Chapter.

2. Insert the following at the end of the Chapter 4.0 Thermal Evaluation, Section V.5.a.

   Verify that the applicant has provided the information details, relevant to thermal analyses, as described in Appendix A to Chapter 3.

3. Insert the Technical Guidance section of this ISG in Chapter 3.0 as Appendix A.

NUREG-1567, "Standard Review Plan for Spent Fuel Dry Storage Facilities"

Revise, as follows:

1. Insert the following new section in Chapter 5.0 Installation and Structural Evaluation:

   5.5.6 Finite Element Analyses: Verify that the applicant has provided the information details as described in Appendix A to this Chapter.

2. Insert the following at the end of the Chapter 6.0 Thermal Evaluation, Section 6.4.4.

   Verify that the applicant has provided the information details, relevant to thermal analyses, as described in Appendix A to Chapter 5.

3. Insert the Technical Guidance section of this ISG in Chapter 5.0 as Appendix A.

NUREG-1609, "Standard Review Plan for Transportation Packages for Radioactive Material"

Revise, as follows:

A. Renumber Section 2.5.8 Appendix, to be 2.5.9.

B. Insert the following new section in Chapter 2.0, Structural Evaluation:

   2.5.8 Finite Element Analyses: Verify that the applicant has provided the information details as described in Appendix A to this Chapter.

C Renumber Section 3.5.6, Appendix, to be 3.5.7. with commensurate renumbering of each subsection.

D. Insert the following at the end of the Chapter 3.0 Thermal Evaluation:

3.5.6 Finite Element Analysis: Verify that the applicant has provided the information details, relevant to thermal analyses, as described in Appendix A to Chapter 2.

E. Insert the Technical Guidance section of this ISG in Chapter 2.0 as Appendix A.

NUREG-1617, "Standard Review Plan for Transportation Packages for Spent Nuclear Fuel"

Revise, as follows:

1. Insert the following at the end of the Chapter 2.0 Structural Review, Section 2.5.4.1, Evaluation by Analysis:

   Verify that the applicant has provided the information details as described in Appendix A to this Chapter.

2. Insert the following at the end of Chapter 3.0 Thermal Review, Section 3.5.3.1, Evaluation by Analysis.

   Verify that the applicant has provided the information details, relevant to thermal analyses, as described in Appendix A to Chapter 2.

3. Insert the Technical Guidance section of this ISG in Chapter 2.0 as Appendix A.

Approved:_____ Date:_____
SFPO DIRECTOR