APPENDIX 4A COMPUTATIONAL MODELING SOFTWARE TECHNICAL REVIEW GUIDANCE

4A.1 Computational Modeling Software Application

The staff does not endorse the use of any specific type or code vendor of computational modeling software (CMS). Any appropriate CMS application could be used for analyses of cask or package components; however, for any CMS to demonstrate that a particular cask design satisfies regulatory requirements, the applicant should demonstrate adequate validation of that CMS. Descriptions of CMS validations can be contained within a given application or incorporated by reference.

Verify that the SAR or related documentation (such as proprietary calculation packages or benchmark reports) provides the following information:

- details of the methodology used to assemble the computational models and the theoretical basis of the program used
- a description of benchmarking against other codes or validation of the CMS against applicable published data or other technically qualified and relevant data that are appropriately documented
- standardized verification problems analyzed using the CMS, including comparison of theoretically predicted results with the results of the CMS
- release version and applicable platforms

Once the information described above has been docketed, it need not be submitted with each subsequent application but can be referred to in subsequent safety analysis reports (SARs) or related documents. If an applicant changes its analysis methodology or changes the type or vendor of the CMS used, the applicant should submit either a revision of previously submitted information or include a clear explanation of the methodology changes, and their effects on the analysis in question, in subsequent SAR submittals.

4A.2 Modeling Techniques and Practices

The staff may need to verify the modeling techniques and practices the applicants used to demonstrate adequacy of the model.

Verify that the CMS and the options the applicant used are appropriate for adequately capturing the behavior of a cask, package, or any components.

The original application should include relevant input and results files or an equivalent detailed model description and output.

4A.3 Computer Model Development

Verify that the computer model used for the analysis is adequately described, either in the SAR or in other documentation; is geometrically representative of the cask design being analyzed; has

addressed how material and manufacturing uncertainties might affect the analysis; has appropriate boundary conditions; and has no significant analysis errors.

Verify that the model description includes an adequate basis for the selection of parameters and components, as appropriate, used in the analysis model (e.g., the reason a particular element type was applied in the analysis model).

Verify that the models sufficiently represent cask or package geometry and that adequate justification is provided for simplifications used. Models created with CMS are often simplified 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. If smeared or homogenized properties are used, verify that the applicant has provided adequate justification for this approach, as the response of the problem can be dramatically altered.

Verify that the applicant has discussed how manufacturing or assembly tolerances and contact resistances will affect the analyses that have been conducted, if at all, in both the structural and thermal disciplines. Verify that the applicant has described how tolerances or contact resistances are accounted for, if applicable, in the cask or package analysis models that are submitted for review.

Verify that the applicant has provided a general discussion of how error, warning, or advisory messages generated by the software affect the analysis result (if applicable). When processing a computer model developed using CMS, the software will frequently provide 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 or warning function has been disabled during processing, ensure the applicant provides an explanation of why this is appropriate.

Verify that, within the specific disciplines, the dimensions and physical units used in the models developed are clearly labeled and mutually consistent. The fundamental units of time, mass, and length should be clearly identified. All other physical units derived should be consistent with the basic units adopted. For example, if the unit of length is the millimeter, time in milliseconds, and mass in gram, then the mechanical force should have units of Newton, energy in millijoule, and stress in megapascal. Verify that the input parameters are expressed in the units as assigned. If an applicant chooses not to adopt this uniformity of units, the appropriate conversion should be applied before processing input into CMS. Similar assurances should be provided for the output for the analysis solution.

4A.4 Computer Model Validation

Verify that model validation done with applicable experiments or testing is properly documented and appropriate references are provided. For example, an analytical model's ability to capture relevant model output such as g-loads, and plastic deformations could be demonstrated by comparing the physical test data of a similar package that was instead drop tested.

The test data used to validate or benchmark the analytical model should be similar in regard to the expected package behavior of interest. For instance, a package with impact limiters should be used to benchmark a package that also has impact limiters. Plastic strain data used for validation, for instance, should come from areas of the package where such data are crucial or relaxant to the performance of the package such as the containment boundary. Other details to consider when benchmarking and validating physical data include whether the package is bolted or

welded, and whether the response will be dominated primarily by a quasi-static, wave or impulse-type response. The data source should be readily available or included, as appropriate, in the application and should describe all the assumptions and simplifications made during physical testing so that staff can weigh its relevance to the design of interest.

4A.5 Justification of Bounding Conditions and Scenario for Model Analysis

Ensure the applicant determines the most damaging orientation and worst-case conditions for a given design and document how the analytic model was configured for the scenario. Verify that the applicant provided sufficient justification for selecting the most damaging orientation and worst-case conditions.

4A.6 Description of Boundary Conditions and Assumptions

Verify, as necessary, that the textual description included in the SAR or other documents address boundary conditions such as an unyielding surface in a drop scenario. The textual description should also include justifications and bases for such items. Confirm that the application reflects appropriate material (temperature dependent) properties.

4A.7 Description of Model Assembly

Verify that the SAR lists the types of elements used in the model along with the corresponding materials or components in which they are used in the analysis model. The reviewer should quickly be able to discern what elements and materials are associated with specific components of the analysis model.

Verify that a sufficient explanation of the logic behind the creation of each specific computer model (such as the mesh) is provided so that effective confirmatory calculations can be performed.

The applicant should provide the input files for the models used in the analysis. If input files are not provided or do not adequately describe model assembly, the applicant should provide in the appropriate SAR chapters or related documents an adequate explanation of how computer models were assembled using the CMS.

4A.8 Loads, Time Steps, and Impact Analyses

Verify that the applicant has clearly explained the loads, load combinations, and, if used by the analytical code, the load steps used in the computer model. Evaluate all loads, how they are placed on the computer models, load combinations, and, if used, the time steps applied in the analysis.

Verify that the time steps specified for the solution of the analysis are sufficiently small to accurately capture the behavior of the structures, systems, or components being modeled.

For impact analyses using software such as LS-DYNA, examine the output files for hour-glassing energy in each part of the system in addition to the package as a whole. Verify that the impact analyses output is realistic. Parts of a model should not pass each other without deformation or through one another unrealistically. Disassemble the model by component and examine them for breaches or other unseen damage. For instance, components can be perforated, but this damage may be hidden from view by other components in the model.

4A.9 Sensitivity Studies

The discussion of the general development of the computer model should cover sensitivity studies, with relevant references to examples included in the SAR or related documents.

Verify that the applicant has completed sensitivity studies for relevant CMS modeling parameters. This includes element type and mesh 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 and refinement in areas of thermal or structural concern or where performance of the material is crucial, such as seal areas and lid bolts. A mesh sensitivity is also needed to make sure the analysis results are mesh independent.

Verify that the results of applicable sensitivity studies are clearly described in the SAR or related documentation and can be independently verified, if necessary.

Verify that the applicant's documentation includes at least a brief discussion of the different models used in its mesh sensitivity studies.

4A.10 Results of the Analysis

Verify that the SAR or related document(s) includes 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 and deformations) are clearly identified in the tables and on plots.

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