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REGULATORY GUIDE

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FOR COMMENT

REGULATORY GUIDE 7.9

STANDARD FORMAT AND CONTENT OF PART 71 APPLICATIONS FOR APPROVAL OF PACKAGING OF TYPE B, LARGE QUANTITY, AND FISSILE RADIOACTIVE MATERIAL

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INTRODUCTION

This regulatory guide has been compiled by the United States Nuclear Regulatory Commission (NRC) as an aid in the preparation of applications for approval of packaging to be used for the shipment of type B, large quantity, and fissile radioactive material. It is not intended as an interpretation of Commission regulations, within the meaning of §§ 30.5, 40.6, 70.6, or 71.14, Parts 30, 40, 70, or 71, respectively, of Title 10 of the Code of Federal Regulations. Nothing contained in this guide may be construed as having the force and effect of NRC regulations, nor as indicating that applications supported by safety analyses and prepared in accordance with the recommendations of this regulatory guide necessarily will be approved, nor as relieving any licensee from the requirements of 10 CFR Parts 30, 40, 70, and 71,* and any other pertinent regulations.

This regulatory guide should not be considered a substitute for reference to 10 CFR Part 71, "Packaging of Radioactive Material for Transport and Transportation of Radioactive Material Under Certain Conditions." Its primary purpose is to assist the applicant in preparing an application that thoroughly and completely demonstrates the adequacy of the package in meeting the regulations. In addition to an approval of packaging, the applicant must have an approved quality assurance program in accordance with the provisions of § 71.51 of 10 CFR. Additional information will be requested in support of an application if NRC believes that such information is necessary to provide reasonable assurance of the safety of the proposed shipment. In preparing an application for approval of packaging, the applicant may find it useful to refer to other regulatory guides of Division 7, "Transportation." Inquiries about these regulatory guides may be directed to the U.S. Nuclear Regulatory Commission, Washington, D.C. 20555, Attention: Director, Division of Technical Information and Document Control.

Purpose of Standard Format

The purpose of the Standard Format and Content of Part 71 Applications for Approval of Packaging of Type B, Large Quantity, and Fissile Radioactive Material (hereinafter "Standard Format") is to indicate the information to be provided in the application and to establish a uniform format for presenting the information. Use of this format will help ensure the completeness of the information provided, will assist the NRC staff and others in locating the information, and will aid in shortening the time needed for the review process. The application is the principal document in which the applicant provides the information and bases for the NRC staff to determine whether or not the package meets the requirements of 10 CFR Part 71.

*The NRC staff is currently revising 10 CFR Part 71 to incorporate the IAEA-1973 revisions. Since the Commission has not approved publication of a proposed rule, this format guide does not attempt to incorporate possible changes to Part 71. As Part 71 is revised, this format guide will be appropriately modified.

Applicability of Standard Format

This Standard Format applies specifically to applications for approval of packaging of type B, large quantity, and fissile radioactive material under 10 CFR Part 71. The Standard Format identifies general and detailed information required and will help ensure the completeness of the information provided.

Use of Standard Format

The Standard Format presents a format for applications for approval that is acceptable to the NRC staff. Conformance with the Standard Format, however, is not required. Applications for approval with different formats will be acceptable to the staff if they provide an adequate basis for the findings requisite to the approval of packaging. However, because it may be more difficult to locate needed information, the staff review time for such applications may be longer.

Upon receipt of an application, the NRC staff will perform a preliminary review to determine if the application provides a reasonably complete presentation of the information that is needed to form a basis for the findings required before approval of a package in accordance with 10 CFR Part 71. The Standard Format will be used by the staff as a guideline to identify the type of information needed. If the application does not provide a reasonably complete presentation of the necessary information, further review of the application will not be initiated until a reasonably complete presentation is provided. The information provided in the application should be up to date with respect to the state of technology for transportation of radioactive materials and should take into account recent changes in NRC regulations and guides, industry codes and standards, results of recent developments in transportation safety, and experience in the construction and use of radioactive material packaging.

Style and Composition

The applicant should strive for clear, concise presentations of the information provided in the application. Confusing or ambiguous statements and unnecessarily verbose descriptions do not contribute to expeditious technical review. Claims of adequacy of designs or design methods should be supported by technical bases, i.e., by an appropriate engineering evaluation or description of actual tests. Terms as defined in the packaging and transport regulations must be used.

The application should follow the numbering system and headings of the Standard Format at least to the headings with three digits, e.g., 2.4.2 Positive Closure. When a particular requirement does not apply to a package, the corresponding subsection should not be omitted but addressed with the term "Not Applicable." A reason should be offered for not addressing a particular requirement when there is doubt as to its applicability.

Appendices to each chapter of the application should include detailed information omitted from the main text for clarity. A list of reports or other documents that are referenced in the text of the application should be included in the appendix at the end of the chapter in which they are referenced. When specific items are referenced, page numbers should be provided. In cases where proprietary documents are referenced, a nonproprietary summary description of the document should also be referenced.

All physical tests of components and packages should be supported by photographs in the appendices of the appropriate chapter. Appendices to the application may also be used to provide supplemental information not explicitly identified in the Standard Format. Examples of such information are (1) summaries of the manner in which the applicant has treated matters addressed in NRC regulatory guides and (2) supplementary information regarding calculational methods or design approaches used by the applicant or its agents.

Where numerical values are stated, the number of significant figures given should reflect the accuracy or precision to which the number is known. Where possible, estimated limits of error or uncertainty should be given. Significant figures should not be dropped or rounded off if, by doing so, subsequent conclusions are inadequately supported.

Abbreviations should be consistent throughout the application and should be consistent with generally accepted usage. Any abbreviations, symbols, or special terms unique to the proposed packaging or not in general usage should be defined in each chapter of the application where they are used.

Drawings, diagrams, sketches, and charts should be used where the information can be presented more adequately or conveniently by such means. Due concern should be taken to ensure that all information presented in drawings is legible, symbols are defined, and drawings are not reduced to the extent that visual aids are necessary to interpret pertinent items of information presented in the drawings.

Revisions

Data and text should be updated or revised by replacing pages. "Pen and ink" or "cut and paste" changes should not be used.

The changed or revised portion on each page should be highlighted by a "change indicator" mark consisting of a bold vertical line drawn in the margin opposite the binding margin. The line should be the same length as the portion actually changed.

All pages submitted to update, revise, or add pages to the report should show the date of change and a change or amendment number. A transmittal letter, including a guide page listing the pages to be inserted and the pages to be removed, should accompany the revised pages. Where applicable, supplemental pages may follow the revised page.

All statements on a revised page should be accurate as of the date of the submittals.

Special care should be taken to ensure that the main sections of the report are revised to reflect any design changes reported in supplemental information, i.e., responses to NRC staff requests for information or responses to regulatory positions.

Physical Specifications

All material submitted as part of the application should conform to specific standards as to the physical dimensions of page size, quality of paper and inks, and numbering of pages, exhibits, and attachments. More specifically:

1. Paper Size (not to exceed)

Text pages: 8-1/2 x 11 inches.
Drawings and graphics: 8-1/2 x 11 inches preferred; however, a larger size is acceptable provided:

a. After reduction, the size does not exceed 11 x 17 inches, including a 2-inch margin at left for binding.

b. The finished copy when folded does not exceed 8-1/2 x 11 inches.

All drawings should have a drawing number, revision number, company name, title, date of revision, and sheet number.

2. Paper Stock

Weight or substance: 20 pound for printing on both sides.
16 to 20 pound for printing on one side only.

Composition: Wood chemical sulphite (no groundwood) and a pH of 5.5.

Color: White is preferred, but pastel colors are acceptable provided the combination of paper stock and ink is suitable for microfilming.

3. Ink

Color sufficiently dense to record on microfilm or image-copying equipment.

4. Page Margins

A margin of no less than one inch should be maintained on the top, bottom, and binding side of all pages.

5. Printing

Composition: Text pages should be single spaced.
Type font and style: Must be suitable for microfilming.
Reproduction: May be mechanically or photographically reproduced. Text pages should preferably be printed on two sides with the image printed head to head.

6. <u>Binding</u>

Pages should be punched for standard 3-hole looseleaf binder and contained within a binder supplied by the applicant.

7. <u>Page Numbering</u>

Pages should be numbered by chapter and sequentially within the chapter.

8. <u>Separators</u>

Separators should be provided between each chapter of the application.

9. <u>Number of Copies</u>

Ten copies of the application should be provided.

1. GENERAL INFORMATION

This chapter of the application should present an introduction and general package description.

1.1 Introduction

This section should include the proposed use of the package, the model number, and, in the case of fissile packages, the proposed fissile class or classes, and the number of packages per shipment or transport index, as appropriate.

1.2 Package Description

1.2.1 Packaging

The packaging description should include the gross weight, materials of construction, materials used as neutron absorbers or moderators, external dimensions and cavity size, internal and external structures, receptacles, valves, sampling ports, means of heat dissipation, volumes and types of coolant, outer and inner protrusions, lifting and tiedown devices, amount of shielding, pressure relief systems, closures, and means of containment. The containment vessel should be clearly identified. Overall and cutaway sketches (8-1/2 x 11 inches) of the package should be included as part of the description.

Drawings that clearly summarize the safety features considered in the analysis should be included in Appendix 1.3; e.g., material lists, dimensions, valves, gaskets, and weld specifications should be included on the drawings. Detailed construction drawings of large, complex packages should not be included.

1.2.2 Operational Features

In the case of a complex package system, a discussion of the operation of the package should be provided. This would include a schematic diagram showing all valves, connections, piping, openings, seals, containment boundaries, etc.

1.2.3 Contents of Packaging

State the quantity of radionuclides (in the case of irradiated fuel shipments, also estimate the quantity of radionuclides available for immediate release within the void space of the fuel rods), chemical and physical form, material density, moderator ratios, configurations as required for nuclear safety evaluation, the maximum amount of decay heat, maximum pressure buildup in the inner container, and any other loading restrictions.

1.3 Appendix

This appendix should include detailed information describing the packaging, operational features, and contents of the packaging such as dimensional drawings, detailed operational schematics, and loading configurations.

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This appendix should include detailed information describing the packaging, operational features, and contents of the packaging such as dimensional drawings, detailed operational schematics, and loading configurations.

2. STRUCTURAL EVALUATION

This chapter of the application should identify, describe, discuss, and analyze the principal structural engineering design of the packaging, components, and systems important to safety and to compliance with the performance requirements of 10 CFR Part 71.

2.1 Structural Design

2.1.1 Discussion

Identify the principal structural members and systems such as the containment vessel, impact limiters, closure devices, and valves that are vital to safe operation of the package. Reference the location of these items on drawings, and discuss their structural design and performance.

2.1.2 Design Criteria

Describe the load combinations and factors that serve as design criteria. Design criteria may be used if judged acceptable by the NRC staff in meeting the structural requirements of §§ 71.35 and 71.36 of 10 CFR Part 71. For each of these criteria, state the maximum allowable stresses and strains (as a percentage of the yield or ultimate values) for ductile failure; describe how the other structural failure modes (e.g., brittle fracture, fatigue, buckling) are considered. If different design criteria are to be allowed in various parts of the packaging or for different conditions, the appropriate values for each case should be indicated. Include the criteria that will be used for impact evaluation. Identify all codes and standards that are used to determine material properties, design limits, or methods of combining loads and stresses. In cases of deviation from standard codes, or if certain components are not covered by such codes, provide a detailed description of the design criteria used as substitutes.

2.2 Weights and Centers of Gravity

List the total weight of the packaging and contents. Tabulate the weights of major individual subassemblies such that the sum of the parts equals the total of the package. Locate the center of gravity of the package and any other centers of gravity referred to in the application. It is not necessary to include the calculations made to determine these values, but a sketch or drawing that clearly shows the individual subassembly referred to and the reference point for locating its center of gravity should be included.

2.3 Mechanical Properties of Materials

List all the material mechanical properties used in the structural evaluation. This may include yield stress, ultimate stress, modulus of elasticity, ultimate strain, Poisson's ratio, density, and coefficient of thermal expansion. If impact limiters are used, include either a compression stress-strain curve for the material or the force-deformation relationship for the limiter, as appropriate. For materials that are subjected to dynamic loadings or elevated temperatures, the appropriate mechanical properties under these conditions should be specified to the extent used in the structural evaluation. The source of all information in this section should be clearly and specifically referenced as to publication and page number. Where material properties are determined by testing, the test procedure, conditions, and measurements should be described in sufficient detail to allow the staff to conclude that the results are valid.

2.4 General Standards for All Packages

This section should state that the general standards for all packaging, specified in § 71.31, are complied with, as demonstrated in the following paragraphs.

2.4.1 Chemical and Galvanic Reactions

Discuss possible chemical, galvanic, or other reactions in the packaging or between the packaging and the package contents. For each component material of the packaging, list all chemically or galvanically dissimilar materials with which it has contact. Indicate any specific measures that have been taken to prevent contact or reaction between materials, and discuss the effectiveness of such measures.

2.4.2 Positive Closure

Describe and discuss the package closure system in sufficient detail to show that it cannot be inadvertently opened. This demonstration should include covers, valves, or any other access that must be closed during normal transportation.

2.4.3 Lifting Devices

Identify all devices and attachments that can be used to lift the package or its lid. Show by testing or analysis that these devices comply with the requirements of § 71.31(c) of 10 CFR Part 71. Provide drawings or sketches that show the location and construction of these items. Determine the effects of the forces imposed by lifting on vital package components, including the interfaces between the lifting device and other packaging surfaces. Documented values of the yield stresses of the materials should be used as the criteria to demonstrate compliance with § 71.31(c).

2.4.4 Tiedown Devices

Identify all devices that are a structural part of the package and can be used as tiedowns. Discuss the overall tiedown system. Show by testing or analysis that these devices comply with the requirements of § 71.31(d) of 10 CFR Part 71. Provide drawings or sketches that show the location and construction of these devices and the overall tiedown system. Determine the effect of the imposed forces on vital package components, including the interfaces between the tiedown devices and other package surfaces. Documented values of the yield stresses of the materials should be used as the criteria to demonstrate compliance with § 71.31(d).

2.5 Standards for Type B and Large Quantity Packaging

This section should state that the standards for type B and large quantity packaging, specified in § 71.32, are complied with, as demonstrated in the following paragraphs.

2.5.1 Load Resistance

Show by analysis or test that the package, if regarded as a simple beam supported at its ends along any major axis, can support a uniformly distributed load equal to five times its fully loaded weight. Document values of the yield stresses of the materials should be used as the criteria to demonstrate compliance.

2.5.2 External Pressure

Show by test or analysis that the containment vessel would suffer no loss of contents if the package were subjected to an external pressure of 25 psig.

2.6 Normal Conditions of Transport

In this section, state that the package, when subjected to the normal conditions of transport specified in Appendix A to 10 CFR Part 71, meets the standards specified in § 71.35 of 10 CFR Part 71, as demonstrated in the following paragraphs. The package should be assessed against each condition separately and a determination made that the applicable performance requirements specified in the regulations have been satisfied.

2.6.1 Heat

The thermal evaluation for the heat test should be reported in Section 3.4.

2.6.1.1 Summary of Pressures and Temperatures. Summarize all pressures and temperatures, determined in the thermal evaluation (Chapter 3), that will be used to perform the calculations required for paragraphs 2.6.1.2, 2.6.1.3, and 2.6.1.4.

2.6.1.2 Differential Thermal Expansion. Calculate the circumferential and axial deformations and stresses (if any) that result from differential thermal expansion. Consider steady-state and transient conditions. These calculations must be sufficiently comprehensive to demonstrate package integrity under normal transport conditions.

2.6.1.3 Stress Calculations. Calculate the stresses due to the combined effects of thermal gradients, pressure, and mechanical loads. Provide sketches that show the configuration and dimensions of the members or systems being analyzed, and locate the points at which the stresses are being calculated. The analysis should consider whether repeated cycles of thermal loadings, together with other loadings, will cause fatigue failure or extensive accumulations of deformation.

2.6.1.4 Comparison with Allowable Stresses. Make the appropriate stress combinations and compare the resulting stresses with the design criteria in paragraph 2.1.2 of the application. Show that all the performance requirements specified in the regulations have been satisfied.

2.6.2 Cold

Assess the package for the effects of a steady-state ambient temperature of -40°F (-40°C). Consider both material properties and possible freezing of liquids under this condition. Identify, for vital components of the package, the resulting temperatures and their effect on operation of the package. Brittle fracture should be considered.

2.6.3 Pressure

Assess the package for the effects of external pressure equal to 0.5 standard atmospheric pressure.

2.6.4 Vibration

Assess the package for the effect of vibrations normally incident to transport.

2.6.5 Water Spray

Assess the package for the effects of the water spray test.

2.6.6 Free Drop

Assess the package for the effects of the free drop test. The general comments in paragraph 2.7.1 also apply to this condition. (Note that the free drop test follows the water spray test.)

2.6.7 Corner Drop

If applicable, assess the package for the effects of corner drops.

2.6.8 Penetration

Assess the package for the effects of penetration. Note that the point of impact could be at any location on the exterior surface of the package.

2.6.9 Compression

As applicable, assess the package for the effects of compression.

2.7 Hypothetical Accident Conditions

In this section, state that the package, when subjected to the hypothetical accident conditions as specified in Appendix B to 10 CFR Part 71, meets the standards specified in § 71.36 of 10 CFR Part 71, as demonstrated in the following paragraphs.

The hypothetical accident conditions are to be considered in the sequence specified by the regulations. Damage caused by each test is cumulative, and the evaluation of the ability of a package to withstand any one test must consider the damage that resulted from the previous tests. It should be noted that a determination must have been made in Section 2.6 that the effectiveness of the package has not been reduced as a result of the normal conditions of transport. Brittle fracture should be considered.

2.7.1 Free Drop

The performance and structural integrity of a package must be evaluated for the drop orientation that causes the most severe damage. An orientation that results in the most damage to one system or component may not be the most damaging for other systems and components. For this reason, it is usually necessary to consider several drop orientations. The minimum requirement is that orientations for which the center of gravity is directly over the point of impact must be considered.

The assessment of the package may be by analysis, prototype testing, model testing, or comparison to a similar package.

a. Analysis

Calculations should be presented in sufficient detail to allow the results to be verified. Adequate narration and use of sketches and free body force diagrams should be included. For equations used in the analysis, either the source should be referenced or the derivation should be included.

The analysis should show how all the kinetic energy will be dissipated and which local deformation and dynamic forces occur during impact. The response of the package in terms of stress and strain to components and structural members should be shown. The structural stability of individual members as applicable should be investigated as well as stress due to impact combined with those stresses caused by temperature gradients, differential thermal expansions, pressure, and other loads. Show that the performance requirements of 10 CFR Part 71 are met.

b. Prototype Testing

Describe the test method, procedures, and target that were used. Indicate the package orientation at time of impact. If the package tested is not identical in all respects to the package described in the application, explain the differences and show that these differences would not affect the test results.

Describe the materials used as substitutes for the radioactive contents during the tests. Show that this substitution would not affect the test results. Consider the effects of internal decay heat and pressure buildup if these effects would have arisen with the actual loading.

Indicate in a quantitative manner the damage caused by the impact and the results of any measurements that were made. Include both interior and exterior damage. Provide photographs of the damaged packaging.

Show that the performance requirements of 10 CFR Part 71 have been met for the damaged package.

c. Model Testing

Describe the model completely and provide detailed drawings that show its dimensions and materials of construction. Specify the dimensional tolerances to which the model was fabricated, and compare these to the tolerances that will be used for the prototype.

State the scale factor that was used for the model. Describe in detail the laws of similitude that were used for testing, considering time scale, material density, velocity at impact, and kinetic energy. Justify that the model test will give conservative results for peak g-force, maximum deformation, and dissipated energy.

For the actual model tests, provide all the information required for item b above.

Correlate the damage done to the model with damage to a prototype, and show that the prototype would be adequate to meet all the performance requirements of 10 CFR Part 71.

d. Comparison to Similar Packages

The comparison must demonstrate that the proposed package is, in all respects, better than or equal to the package previously approved and that the proposed package can meet all the regulatory performance requirements. The comparison of the two packages should provide the following details:

(1) The dimensions, materials, and configurations of both packages,
(2) The overall weight of both packages,
(3) The weight and form of the contents of both packages,
(4) That the packages will have a similar response to the specified tests,
(5) That the forces acting on all vital safety systems and components of the proposed package are less than the tested package or that all vital safety systems and components of the proposed package have sufficient structural integrity, and
(6) That the proposed package will meet all the regulatory performance requirements.

2.7.1.1 End Drop. Assess the package for the effects of the end drop test.

2.7.1.2 Side Drop. Assess the package for the effects of the side drop test.

2.7.1.3 Corner Drop. Assess the package for the effects of the corner drop test.

2.7.1.4 Oblique Drops. Assess the effects of oblique drops, or provide information that shows that the end, side, and corner drops are more damaging to all systems and components vital to safety.

2.7.1.5 Summary of Results. Discuss the condition of the package after each drop test. Summarize the extent to which the packaging would be damaged in each orientation.

2.7.2 Puncture

Assess the effects of the puncture test. Consider both local damage near the point of impact and the overall effect on the package. Note that the point of impact could be at any location on the exterior surface of the package. It is particularly important that all valves and fittings necessary for containment be considered. Most of the general comments in paragraph 2.7.1 also apply to this test condition.

2.7.3 Thermal

The thermal test should follow the free drop and puncture tests and should be reported in Section 3.5.

2.7.3.1 Summary of Pressures and Temperatures. Summarize all of the temperatures and pressures, as determined in the thermal evaluation (Chapter 3) of the application, that are used in paragraphs 2.7.3.2, 2.7.3.3, and 2.7.3.4.

2.7.3.2 Differential Thermal Expansion. Calculate the circumferential and axial deformations and stresses (if any) that result from differential thermal expansion. Consider peak conditions, postfire steady-state conditions, and all transient conditions.

2.7.3.3 Stress Calculations. Calculate the stresses due to thermal gradients, differential expansion, pressure, and other mechanical loads. Provide sketches showing configuration and dimensions of the members of systems under investigation, and locate the points at which the stresses are being calculated.

2.7.3.4 Comparison with Allowable Stresses. Make the appropriate stress combinations, and compare the resulting stresses with the design criteria in paragraph 2.1.2 of the application. Show that all the performance requirements specified in the regulations have been satisfied.

2.7.4 Water Immersion

Assess the effects and consequences of the water immersion test condition for fissile packages.

2.7.5 Summary of Damage

Discuss the safety of the package after the accident test sequences. Summarize the extent to which vital safety systems and components have been damaged.

2.8. Special Form

As applicable, in this section when special form is claimed, state that the material meets special form requirements given in paragraph 71.4(o) when subjected to the applicable test conditions of Appendix D to 10 CFR Part 71, as demonstrated in the following paragraphs.

2.8.1 Description

Describe the chemical and physical form. Provide detailed drawings of the encapsulation showing the dimensions, materials, and manner of construction.

2.8.2 Free Drop

Assess the package for the effects of the free drop test.

2.8.3 Percussion

Assess the package for the effects of percussion.

2.8.4 Heating

Assess the package for the effects of heating.

2.8.5 Immersion

Assess the package for the effects of immersion.

2.8.6 Summary

Provide results of above analyses, and show that requirements of paragraph 71.4(o) of 10 CFR Part 71 are met.

2.9 Fuel Rods

When required, fuel rod analyses or simulated tests should show that the mechanical integrity of the cladding is adequate to provide containment of the pellets and gases for both normal and hypothetical accident conditions of transportation. End-of-life fuel rod measures and maximum volumes should be clearly stated and considered in the analysis. For normal conditions of transport, the cladding should be capable of withstanding the resulting loads without yielding. For the accident damage tests, the cladding integrity may be demonstrated by using either plastic or elastic analyses. Possible creep rupture and fatigue failure should be considered.

2.10 Appendix

This appendix should include information such as justification of assumptions or analytical procedures, test results, photographs, computer program descriptions and input/output, reference lists, and applicable pages from referenced documents.

3. THERMAL EVALUATION

This chapter of the application should identify, describe, discuss, and analyze the principal thermal engineering design of the packaging, components, and systems important to safety and to compliance with the performance requirements of 10 CFR Part 71.

3.1 Discussion

Describe the significant thermal design features and operating characteristics of the package. The operation of all subsystems (e.g., auxiliary cooling systems, expansion tanks) should be discussed. Summarize the significant results of the thermal analysis or tests and the implication of these results on the overall package. State the minimum and maximum decay heat loads assumed in the thermal evaluation.

3.2 Summary of Thermal Properties of Materials

List the thermal properties of all materials used in the thermal evaluation. References for the data cited should be provided.

3.3 Technical Specifications of Components

Include the technical specifications of package components. For example, in the case of valves or relief valves, the operating pressure range and temperature limits should be included. The properties of fabricated insulation and coatings should be tabulated. Test data should be supplied in support of performance specifications and should be presented in detail in Section 3.6.

3.4 Thermal Evaluation for Normal Conditions of Transport

Appendix A to 10 CFR Part 71 defines the normal conditions of transport. These conditions are to be applied to the test item or analytical model. The test item or analytical model should be described. Particular attention should be given to justifying the use of simplifying or scaling assumptions. When the package design involves various operating modes or configurations such as different fuel loadings and different coolants, each mode must be evaluated within its operating range to determine the adequacy of the design.

3.4.1 Thermal Model

3.4.1.1 Analytical Model. Describe the analytical thermal model in detail. The model should include gaskets, valves, fuel assemblies, and the overall package. Modeling assumptions should be fully justified.

3.4.1.2 Test Model. Describe the test item and procedures used. Provide the details of the procedures used to correlate the test data to the thermal environment for normal conditions of transport, as defined in Appendix A to 10 CFR Part 71. Temperature data should be taken from gaskets, valves, and other containment boundaries, as well as from the overall package.

3.4.2 Maximum Temperatures

List the maximum temperature distribution for the package for normal conditions of transport, including the contents, containment vessel, shielding material, gaskets, valves, etc.

3.4.3 Minimum Temperatures

List the minimum temperature distribution for the package for normal conditions of transport. This evaluation should include the minimum decay heat load that will be transported. When a decay heat load greater than zero is required for safe operation, assurance of that heat load must be provided. The temperatures of significant components such as gaskets and valves should be reported.

3.4.4 Maximum Internal Pressures

The conditions within the range of normal conditions of transport that result in the worst internal pressures or the worst combination of thermal loadings should be identified. The internal pressures for these conditions should be determined. The evaluation should consider the effects of phase change, gas generation, chemical decomposition, etc., as well as fluid expansions and compressions. The additional pressure buildup that would result from fuel rod failure while in transport should also be considered if the ability of the rods to provide containment under all circumstances cannot be demonstrated.

3.4.5 Maximum Thermal Stresses

Determine the conditions within the range of normal conditions of transport that result in the worst combination of thermal gradient and isothermal stresses. List the resulting temperature distribution.

3.4.6 Evaluation of Package Performance for Normal Conditions of Transport

Evaluate the package performance, including system and subsystem operation, for normal conditions of transport with respect to the results of the thermal analysis or tests performed. Take into account significant conditions to be found in the ranges bounded by the minimum and maximum ambient temperatures and minimum and maximum decay heat loads. Compare the results with allowable limits of temperature, pressure, etc., for the package components. Designate the information that is to be used in other chapters of the review. Present the information in summary tables along with statements and appropriate comments.

3.5 Hypothetical Accident Thermal Evaluation

In this section, the effects of the hypothetical accident thermal condition on the package should be evaluated. Appendix B to 10 CFR Part 71 defines the hypothetical accident conditions, which are to be applied sequentially. The thermal test follows the free drop and puncture tests. Discuss the tests or analytical procedures used to evaluate the package performance for the hypothetical thermal accident condition. When the package design involves various operating modes or configurations such as different fuel loadings and different coolants, each mode must be evaluated within its operating ranges to determine the adequacy of the design.

3.5.1 Thermal Model

3.5.1.1 Analytical Model. Describe the analytical thermal model in detail. The model should include gaskets, valves, fuel assemblies, and the overall package. Modeling assumptions should be fully justified.

3.5.1.2 Test Model. Describe the test item and procedures used. Provide the details of the procedures used to correlate the test data to the thermal environment for the hypothetical accident conditions, as defined in Appendix B to 10 CFR Part 71. Temperature data should be taken from gaskets, valves, and other containment boundaries, as well as from the overall package.

3.5.2 Package Conditions and Environment

Describe and discuss any damage to the package resulting from the free drop or puncture tests. The effect of any such damage on the package thermal performance is to be evaluated. The worst possible package condition from a thermal standpoint will be chosen from the range of damage conditions following the free drop and puncture. This worst case is to be used in the thermal analysis.

3.5.3 Package Temperatures

The transient results of the thermal analysis or test should be presented. The temperatures reported should include those temperatures at locations in the package that are significant to the safety analysis and review. The temperatures for such items as contents, gaskets, valves, and lead shielding are especially important and should be reported. The calculations of transient temperatures should trace the temperature time-history up to and somewhat past the time at which temperature maximums are achieved. It may be assumed that visible flames from packaging material are extinguished in 3 hours.

3.5.4 Maximum Internal Pressures

Determine the maximum internal pressures that result during the fire test and cooldown (include the added pressure caused by fuel rod failure during transport). The pressures that result in the most severe loading in combination with any other loads developed should be determined. Provide details of the pressure calculations. These details should include temperatures and quantities of fluids as well as the associated fluid volumes. Where chemical reactions or phase changes occur, the following should be discussed: (a) the reaction or phase change mechanism, (b) the reactants and products involved, (c) estimates of the extent and the rate of reaction or phase change, and (d) the consequences of the reaction or phase change. The additional pressure buildup due to fuel rod failure during the fire should also be considered.

If the package is tested, the pressure determination can be neglected in some cases. The internal pressure need not be determined if actual test conditions properly simulate the conditions that would cause the severe pressure buildup in cavities. This approach is acceptable when similarity is demonstrated between the test item and casks for such things as cavity fluid, components, and internal geometries.

3.5.5 Maximum Thermal Stresses

Determine the most severe thermal stress conditions that result during the fire test and subsequent cooldown. Report the temperatures corresponding to the maximum thermal stresses. If the package is tested in such a way that similarity is demonstrated between the test item and the cask concerning internal pressure, the maximum thermal stresses need not be calculated.

3.5.6 Evaluation of Package Performance for the Hypothetical Accident Thermal Conditions

Evaluate the package performance, including system and subsystem operation, for the hypothetical accident thermal conditions with respect to the results of the thermal analysis or tests performed. Compare the results with allowable limits of temperature, pressure, etc., for the package components. Estimate the damage to the package either from interpretation of the analysis or from test observation. This assessment should include structural damage, breach of containment, and loss of shielding.

Designate the information to be used in other chapters of the review. This information should be presented in summary tables and statements with appropriate comments. The comments are to include destination and use information and the specific conditions that the data simulate.

3.6 Appendix

This appendix should include information such as justification of assumptions or analytical procedures, test results, photographs, computer program descriptions and input/output, and applicable pages from referenced documents.

4. CONTAINMENT

This chapter of the application identifies and discusses the package containment for the normal conditions of transport and the hypothetical accident conditions.

4.1 Containment Boundary

Identify the containment boundary claimed for the package.

4.1.1 Containment Vessel

A summary of design specifications for the containment vessel should be provided.

4.1.2 Containment Penetrations

Identify all penetrations into the primary containment. Provide a summary of the performance specifications for all components that penetrate the containment boundary.

4.1.3 Seals and Welds

Identify all seals and welds that affect the package containment. A summary of the design specifications for these seals and welds should be provided.

4.1.4 Closure

Identify the closure devices used for the containment vessel. Specify the initial bolt torque that will be required to maintain a positive seal during normal and accident conditions of transport.

4.2 Requirements for Normal Conditions of Transport

Summarize and use the pertinent results of the analysis or test performed in Chapters 1 and 2 to demonstrate the package containment under normal conditions of transport as defined in Appendix A to 10 CFR Part 71.

4.2.1 Release of Radioactive Material

Show that there will be no direct release of radioactive material from the containment vessel.

4.2.2 Pressurization of Containment Vessel

Any mixture of vapors or gases that could form in the containment vessel should be identified. Show that any increase in pressure or explosion within the containment vessel, due to these vapors or gases, could not significantly reduce the package effectiveness.

4.2.3 Coolant Contamination

Estimate the radioactive contamination of the primary coolant. Show that the contamination does not exceed the maximum levels specified in paragraph 71.35(a)(4) of 10 CFR Part 71.

4.2.4 Coolant Loss

Show that there will be no loss of coolant under the normal conditions of transport. Show that there will be no venting of the containment vessel directly to the atmosphere.

4.3 Containment Requirements for the Hypothetical Accident Conditions

Summarize and use the pertinent results of the analysis or test performed in Chapters 2 and 3 to demonstrate the package containment under the hypothetical accident conditions defined in Appendix B to 10 CFR Part 71.

4.3.1 Fission Gas Products

Establish the maximum quantity of fission gas products that could be available for release in the containment vessel under the hypothetical accident conditions.

4.3.2 Releases of Contents

Show that there can be no release of radioactive materials, except for gases and contaminated coolant, exceeding the maximum quantities defined in paragraph 71.36(a)(2) of 10 CFR Part 71.

4.4 Appendix

This appendix should include supporting information and analysis.

5. SHIELDING EVALUATION

This chapter of the application should identify, describe, discuss, and analyze the principal shielding design of the packaging, components, and systems important to safety and necessary to comply with the performance requirements of 10 CFR Part 71.

5.1 Discussion and Results

Discuss the significant shielding design features of the package and the adequacy of the shielding evaluation. Table 5.1 should be completed. For packaging designed for spent fuel transport, assumed fuel burnup, power density, and cooling times should be stated.

5.2 Source Specification

In this section, state the contents and the gamma and neutron source terms used in the shielding analysis.

5.2.1 Gamma Source

State the quantity of radioactive material included as contents, and tabulate the gamma decay source strength (MeV/sec and photons/sec) as a function of photon energy. Describe in detail the method used to determine the gamma source strength and distribution.

5.2.2 Neutron Source

State the quantity of radioactive material included as contents, and tabulate the neutron source strength (neutrons/sec) as a function of energy. Describe in detail the method used to determine the neutron source strength and distribution.

5.3 Model Specification

In this section, describe the model that was used in the shielding evaluation.

5.3.1 Description of the Radial and Axial Shielding Configuration

Include sketches, to scale, and dimensions of the radial and axial shielding materials. Dose point locations for the various calculations exterior to the package should be shown relative to the source regions in the sketches supplied. Voids or irregularities not taken into account in the model should be discussed in detail showing that the resultant dose rates are conservative. Differences between the models for the normal conditions and the accident conditions of transport should be clearly identified.

TABLE 5.1

SUMMARY OF MAXIMUM DOSE RATES
(mR/hr)

	Package Surface			3 Feet from Surface of Package		
	Side	Top	Bottom	Side	Top	Bottom
Normal Conditions						
Gamma						
Neutron						
Total						
Hypothetical Accident Conditions						
Gamma						
Neutron						
Total						
10 CFR Part 71 Limit	----	----	----	1000	1000	1000

5.3.2 Shield Regional Densities

The material densities (g/cm^3) and the atomic number densities (atoms/barn-cm) for constituent nuclides of all materials used in the calculational models for the normal and accident analyses are to be given in this paragraph. The source of the data for uncommon materials should be referenced.

5.4 Shielding Evaluation

Provide a general description of the basic method used to determine the gamma and neutron dose rates at the selected points outside the package for both the normal and accident conditions of transport. This should include a description of the spatial source distribution and any computer program used, with its referenced documentation. The basic input parameters should be discussed in detail. The basis for selecting the program, attenuation and removal cross sections, and buildup factors should be provided. Flux-to-dose rate conversion factors as a function of energy should be tabulated. Data are to be supported by appropriate references.

5.5 Appendix

This appendix should include information such as justification of assumptions or analytical procedures, test results, photographs, computer program descriptions and input/output, and applicable pages from referenced documents.

6. CRITICALITY EVALUATION

This chapter of the application should identify, describe, discuss, and analyze the principal criticality engineering-physics design of the packaging, components, and systems important to safety and necessary to comply with the performance requirements of 10 CFR Part 71. These requirements are summarized in Table 6.1.

6.1 Discussion and Results

Discuss the significant criticality design features of the package and the adequacy of the criticality evaluation. Table 6.2, summarizing the criticality evaluation, should be included in this section.

6.2 Package Fuel Loading

Provide a summary table stating the maximum fuel loading and fuel parameters for the package for normal and accident conditions of transport.

6.3 Model Specification

This section describes the model used in the evaluation.

6.3.1 Description of Calculational Model

Dimensioned sketches, to scale, or the geometric model used in the calculation are to be given. The sketch should identify the materials used in all regions of the model. Differences between the actual package configuration and the model should be identified, and the model should be shown to be conservative. Differences between the models for the normal conditions of transport and the accident conditions of transport should be clearly identified.

6.3.2 Package Regional Densities

The material densities (g/cm^3) and the atomic number densities (atoms/barn-cm) for constituent nuclides of all materials used in the calculational models for the normal and accident analyses are to be given in this paragraph. Fissionable isotopes are to be considered at their most reactive credible concentration. Masses for all regions are to be given consistent with atomic number densities and volumes occupied.

6.4 Criticality Calculation

This section should describe the calculational or experimental method used to determine the nuclear reactivity for the maximum fuel loading or other maximum contents loadings intended to be transported in the package.

TABLE 6.1

REQUIRED NUMBER OF PACKAGES TO BE DEMONSTRATED AS SUBCRITICAL UNDER SPECIFIC MODERATION AND REFLECTION CONDITIONS AS PER SECTIONS 71.38, 71.39, AND 71.40 OF 10 CFR PART 71

CONDITIONS OF SHIPMENT

FISSILE CLASS	NORMAL CONDITIONS	ACCIDENT CONDITIONS
	(No more than 5% reduction in the total effective volume of the packaging on which nuclear safety is assessed.)	(All packages damaged as per hypothetical accident (HA) specifications)
I	Unlimited number of packages are to remain subcritical with optimum interspersed hydrogenous moderation. No water reflection necessary.	250 packages are to remain subcritical in any arrangement under HA conditions with optimum interspersed hydrogenous moderation and close reflection by water on all sides of array.
II	Five times the number of packages to be shipped are to remain subcritical in any arrangement when this array is closely reflected by water.	Two times the number of packages to be shipped are to remain subcritical in any arrangement under HA conditions with optimum interspersed hydrogenous moderation and close reflection by water on all sides of array.
	Since the maximum value of the Transport Index (TI) for an individual package of Fissile Class II is 10 and the TI equals 50 divided by the allowable number of packages, 5 is the smallest value for the maximum allowable number of packages in a shipment. Therefore, the minimum number of packages in the array that must be considered in the criticality analysis is:	
	5 x 5 or 25 packages for normal transport	2 x 5 or 10 packages for accident conditions
III	One shipment of packages is to remain subcritical when it is in contact with an identical shipment and the two-shipment array is reflected on all sides by water.	One shipment of packages is to remain subcritical under HA conditions with optimum hydrogenous moderation and close reflection by water.

TABLE 6.2

SUMMARY OF CRITICALITY EVALUATION

Fissile Class ______ (I, II, III)

	Fissile Class		
NORMAL CONDITIONS	I	II	III
Number of undamaged packages calculated to be subcritical (Fissile Class I must be infinite; Fissile Class II must be at least 25; and Fissile Class III must be at least identical shipment.)			
Optimum interspersed hydrogenous moderation (required for Fissile Class I)			
Closely reflected by water (required for Fissile Class II and III)			
Package size, cm^3			
ACCIDENT CONDITIONS			
Number of damaged packages calculated to be subcritical (Fissile Class I must be at least 250; Fissile Class II must be at least 10; and Fissile Class III must be at least 1.)			
Optimum interspersed hydrogenous moderation, full water reflection			
Package size, cm^3			
Other Transport Index (must not exceed 10 for Fissile Class II)			

6.4.1 Calculational or Experimental Method

A general description of the basic calculational method used to calculate the effective multiplication constant of the package under the normal conditions of transport and accident conditions of transport to demonstrate compliance with the appropriate NRC regulations should be provided. This should include a description of the computer program and neutron cross sections used with their referenced documentation. The basis for selecting the program and cross sections should be discussed.

If an experimental method was used to determine the compliance of the package with criticality requirements, include a complete description of the experiment and a discussion demonstrating that it conservatively takes into account the normal and accident conditions of transport for the package.

6.4.2 Fuel Loading or Other Contents Loading Optimization

Demonstrate that the correct fuel loading or other contents loading for the maximum reactivity has been evaluated for both the single package and arrays of packages for normal and accident conditions of transport. Approximations, boundary conditions, calculational convergence criteria, and cross-section adjustments are to be itemized and discussed.

The requirements of §§ 71.33, 71.34, 71.35, and 71.36 of 10 CFR Part 71 should be satisfied for a single package. The requirements of §§ 71.37 and 71.38, 71.39, or 71.40, as appropriate, should be satisfied for an array.

6.4.3 Criticality Results

Results of the reactivity calculations establishing the most reactive configurations for the single package and arrays of packages for both normal and accident conditions of transport should be displayed in tabular and graphic form. Justification should be provided for any interpolations and extrapolations. A discussion of the validity and conservatism of the analysis should be included. The bias established with the benchmark calculations in Section 6.5 should be taken into account.

6.5 Critical Benchmark Experiments

This section provides justification for the validity of the calculational method and neutron cross-section values used in the analysis by presenting the results of calculations for selected critical benchmark experiments.

6.5.1 Benchmark Experiments and Applicability

Provide a general description of selected critical benchmark experiments that are to be analyzed using the method and cross sections given in paragraph 6.4.1. The applicability of the benchmarks in relation to the package and its contents should be shown. All similarities and differences should be noted and resolved respectively. References giving full documentation on these experiments should be provided.

6.5.2 Details of the Benchmark Calculations

Actual nuclear and geometric input parameters used for the benchmark calculations should be provided.

6.5.3 Results of the Benchmark Calculations

Provide the results of the benchmark calculations. Establish and provide a discussion of any calculation bias.

6.6 Appendix

This appendix should include information such as justification of assumptions or analytical procedures, test results, photographs, computer program descriptions and input/output, and applicable pages from referenced documents.

7. OPERATING PROCEDURES

This chapter of the application should describe the operating procedures to be used in the preparation for and performance of the processes of loading and unloading the package. The discussion of these procedures should be presented sequentially in the actual order of performance. At a minimum, this chapter should demonstrate the ability to comply with the operating procedure requirements specified in Subpart D to 10 CFR Part 71.

7.1 Procedures for Loading the Package

The discussion should include inspections, tests, and special preparations of the package for loading. If applicable, a detailed description should be presented of the procedures used to ensure that liquids such as shield water and primary coolants are filled into their respective cavities, in compliance with the design specifications. Details should also be provided of the procedures used to remove residual moisture from cavities designed to be dry. The effectiveness of the procedures should be evaluated.

7.2 Procedures for Unloading the Package

This section should include inspections, tests, and special preparations of the package for unloading. As applicable, the procedures used to ensure safe removal of fission gases, contaminated coolant, and solid contaminants should be discussed. Also as applicable, describe any required cooldown procedure, and show that it does not affect the continued use of the package.

7.3 Preparation of an Empty Package for Transport

This section should discuss the inspections, tests, and special preparations of the packaging necessary to ensure that the packaging is properly closed, decontaminated to prevent the inadvertent spread of contamination, and delivered to a carrier in such a condition that subsequent transport will not reduce the effectiveness of the packaging (e.g., damage to sealing surfaces caused by the freezing of moisture not properly removed).

7.4 Appendix

This appendix should include supporting documentation, detailed discussions and analysis of procedures, and graphical presentations.

8. ACCEPTANCE TESTS AND MAINTENANCE PROGRAM

This chapter of the application should discuss the acceptance test and maintenance program to be used on the packaging, in compliance with Subpart D of 10 CFR Part 71.

8.1 Acceptance Tests

Discuss the tests to be performed prior to the first use of the package.

8.1.1 Visual Inspection

The visual inspections to be performed and the intended purpose behind each inspection should be discussed. State the criteria for acceptance for each of these inspections as well as the action to be taken if noncompliance is encountered.

8.1.2 Structural and Pressure Tests

Describe the tests to be performed. Present the acceptance criteria. Describe the action taken when the prescribed criteria are not met. An estimate of the sensitivity of the tests should be provided.

8.1.3 Leak Tests

Describe the leak tests to be performed. Leak tests should be performed on the containment vessel as well as auxiliary equipment such as shield tanks. Describe the criteria for acceptance and the action to be taken if the criteria are not met. Estimate the sensitivity of these tests, and give the basis for the estimate.

8.1.4 Component Tests

Discuss the tests for those components to be tested. Provide acceptance criteria and discuss the action to be taken if the criteria are not met.

8.1.4.1 Valves, Rupture Discs, and Fluid Transport Devices. These components should be tested under the most severe service conditions for which the package design assumes their acceptable performance. When the tests are presumed to adversely affect the continued performance of a component, the results of tests on components of the same model and type may be substituted.

8.1.4.2 Gaskets. Gaskets should be tested under conditions simulating the most severe service conditions under which the gaskets are assumed to perform. Since these acceptance tests may degrade the performance of either the gasket under test or the package into which it is assembled or both, the tests are not necessarily performed on gaskets or packages to be put into service. The simulation system must ensure adequate representation of those conditions that would prevail if the actual system were used in the test. In accordance with paragraphs 4, 7, and 18 of Appendix E to 10 CFR Part 71, the manufacturer of the gasket must maintain a quality assurance program adequate to ensure that acceptance testing of a given gasketing device is equivalent to acceptance testing of all gaskets supplied and identified by that manufacturer as that model gasket.

8.1.4.3 Miscellaneous. Any component not listed in paragraphs 8.1.4.1 and 8.1.4.2 whose failure would impair the package effectiveness should be tested under the most severe conditions for which it was designed. Since these acceptance tests may degrade the performance of either the component under test or the system into which it is assembled or both, the tests are not necessarily performed on components or systems to be put into service. The simulation system should ensure adequate representation of those conditions that would prevail if the actual system were used in the test. Furthermore, the manufacturer of the component should maintain a quality assurance program adequate to ensure that acceptance testing of a given component device is equivalent to acceptance testing of all devices supplied and identified by that manufacturer as that model device.

8.1.5 Tests for Shielding Integrity

Discuss the tests to be performed to establish shielding for both gamma and neutron sources. The acceptance criteria as well as the action to be taken if the criteria are not met should be described.

8.1.6 Thermal Acceptance Tests

Discuss the tests to verify that each package performs, within some defined variance, in accordance with the results of the thermal analyses or tests for normal conditions of transport.

8.1.6.1 Discussion of Test Setup. Describe the tests. The description should include heat source, instrumentation, and schematic showing thermocouple and heat source locations as well as the placement of other test equipment. Estimate the test sensitivity based on instrumentation, test item, and environmental variations.

8.1.6.2 Test Procedure. Discuss the procedures used in testing and data recording. Report the frequency of data recording during the test. The criteria used to define the steady-state (thermal equilibrium) condition of the test item should also be discussed.

8.1.6.3 Acceptance Criteria. Discuss the thermal acceptance criteria and the method employed to compare the acceptance test results with predicted thermal performance. Discuss the action to be taken if the thermal acceptance criteria are not met by a packaging unit.

8.2 Maintenance Program

This section should describe the maintenance program used to ensure continued performance of the packaging. The program should include periodic testing, inspection, and replacement schedules, as well as criteria for replacement and repair of components and subsystems on an as-needed basis.

8.2.1 Structural and Pressure Tests

Describe the tests to be performed and the frequency of performance. The instrumentation and test sensitivity should also be described.

8.2.2 Leak Tests

Describe the tests to be performed and the frequency of performance. Estimate the sensitivity of these tests.

8.2.3 Subsystems Maintenance

Describe the test and replacement schedule to be used for packaging subsystems (e.g., auxiliary cooling systems and neutron shield tanks) whose inadequate performance could impair the total package safety. Justify the schedules established, using verifiable test or manufacturers' data.

8.2.4 Valves, Rupture Discs, and Gaskets on Containment Vessel

Specify the test and replacement schedule to be used for these components. Justify the schedules established, using verifiable test or manufacturers' data.

8.2.5 Shielding

Describe the test and inspection schedules, as well as the corrective action to be used to ensure adequate shielding performance. Both gamma and neutron sources should be considered.

8.2.6 Thermal

Describe the tests proposed and the frequency of these tests that would be performed on the total system. Show that the proposed test frequency will detect thermal performance degradation of the packaging prior to compromise of the package safety.

8.2.7 Miscellaneous

Describe any additional test not considered previously that should be performed periodically on components and subsystems.

schedules, as well as criteria for replacement and repair of components and subsystems on an as-needed basis.

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Describe the tests to be performed and the frequency of performance. The instrumentation and test sensitivity should also be described.

8.2.2 Leak Tests

Describe the tests to be performed and the frequency of performance. Estimate the sensitivity of these tests.

8.2.3 Subsystems Maintenance

Describe the test and replacement schedule to be used for packaging subsystems (e.g., auxiliary cooling systems and neutron shield tanks) whose inadequate performance could impair the total package safety. Justify the schedules established, using verifiable test or manufacturers' data.

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Specify the test and replacement schedule to be used for these components. Justify the schedules established, using verifiable test or manufacturers' data.

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Describe the test and inspection schedules, as well as the corrective action to be used to ensure adequate shielding performance. Both gamma and neutron sources should be considered.

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Describe the tests proposed and the frequency of these tests that would be performed on the total system. Show that the proposed test frequency will detect thermal performance degradation of the packaging prior to compromise of the package safety.

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Describe any additional test not considered previously that should be performed periodically on components and subsystems.