U.S. NUCLEAR REGULATORY COMMISSION

DRAFT REGULATORY GUIDE DG-7011

Proposed Revision 3 to Regulatory Guide 7.9

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STANDARD FORMAT AND CONTENT OF PART 71 APPLICATIONS FOR APPROVAL OF PACKAGES FOR RADIOACTIVE MATERIAL

A. INTRODUCTION

Purpose

The purpose of this regulatory guide (RG) is to assist applicants in preparing applications for new and amended certificates of compliance for Type B and fissile material transportation packages that demonstrate the ability of the given package to meet the applicable regulations for transport of radioactive material.

Applicability

The "Standard Format and Content of Part 71 Applications for Approval of Packages for Radioactive Material" (hereinafter called "Standard Format") applies specifically to applicants for, and holders of, a certificate of compliance for Type B and fissile material transportation packages, as specified in Part 71 of Title 10 of the *Code of Federal Regulations* (10 CFR), "Packaging and Transportation of Radioactive Material" (Ref. 1).

Applicable Regulations

- 10 CFR Part 71, "Packaging and Transportation of Radioactive Material," provides regulations for package approval standards, transportation of licensed material and establishing and implementing a quality assurance program.

- 10 CFR Part 20, "Standards for Protection Against Radiation" (Ref. 2), establishes standards for protection against ionizing radiation resulting from activities conducted under licenses issued by the NRC.

    - 10 CFR 20.1906, "Procedures for receiving and opening packages," provides regulations for licensees to receive and open a package containing radioactive material.

This RG is being issued in draft form to involve the public in the development of regulatory guidance in this area. It has not received final staff review or approval and does not represent an NRC final staff position. Public comments are being solicited on this DG and its associated regulatory analysis. Comments should be accompanied by appropriate supporting data. Comments may be submitted through the Federal rulemaking Web site, http://www.regulations.gov, by searching for draft regulatory guide DG-7011 or Docket ID NRC-2016-0179. Alternatively, comments may be submitted to the Office of Secretary, U.S. Nuclear Regulatory Commission, Washington, DC 20555-0001, ATTN: Rulemakings and Adjudications Staff. Comments must be submitted by the date indicated in the *Federal Register* notice.

Electronic copies of this DG, previous versions of DGs, and other recently issued guides are available through the NRC's public Web site under the Regulatory Guides document collection of the NRC Library at https://nrc.gov/reading-rm/doc-collections/reg-guides/index.html. The DG is also available through the NRC's Agencywide Documents Access and Management System (ADAMS) at http://www.nrc.gov/reading-rm/adams.html, under Accession No. ML22223A085. The regulatory analysis may be found in ADAMS under Accession No. ML22209A039.

- 10 CFR 20.1101, "Radiation Protection Programs," provides regulations for licensee radiation protection programs.

- 49 CFR 173.428, "Empty Class 7 (Radioactive) Materials Packaging" (Ref. 3), provides regulations for transporting empty packages.

Related Guidance

- RG 7.4, "Leakage Tests on Packages for Shipment of Radioactive Material" (Ref. 4), endorses the methods and procedures developed by the Standards Committee on Packaging and Transportation of Radioactive and Nonnuclear Hazardous Materials, N14, Subcommittee of the American National Standards Institute (ANSI) in ANSI N14.5-2014, "American National Standard for Radioactive Materials—Leakage Tests on Packages for Shipment," issued on June 19, 2014, as a process that the NRC staff considers acceptable for meeting the regulatory requirements.

- RG 7.6, "Design Criteria for the Structural Analysis of Shipping Cask Containment Vessels" (Ref. 5), describes design criteria acceptable to the NRC staff for use in the structural analysis of the containment vessels of Type B packages used to transport irradiated nuclear fuel.

- RG 7.7, "Administrative Guide for Verifying Compliance with Packaging Requirements for Shipments of Radioactive Material" (Ref. 6), describes an approach that the staff considers acceptable for meeting the administrative requirements associated with transferring, shipping, and receiving radioactive material.

- RG 7.8, "Load Combinations for the Structural Analysis of Shipping Casks for Radioactive Material" (Ref. 7), provides the load combinations to be used in package design evaluation for both normal conditions of transport and hypothetical accident conditions.

- RG 7.10, "Establishing Quality Assurance Programs for Packaging Used in Transport of Radioactive Material" (Ref. 8), provides licensees, certificate holders, and applicants with an acceptable method to prepare and submit quality assurance program descriptions for NRC staff review.

- RG 7.11, "Fracture Toughness Criteria of Base Material for Ferritic Steel Shipping Cask Containment Vessels with a Maximum Wall Thickness of 4 Inches (0.1 m)" (Ref. 9), describes criteria for precluding brittle fracture in package containment components made of ferritic steels with a maximum wall thickness of 4 inches.

- RG 7.12, "Fracture Toughness Criteria of Base Material for Ferritic Steel Shipping Cask Containment Vessels with a Wall Thickness Greater than 4 Inches (0.1 m) But Not Exceeding 12 Inches (0.3 m)" (Ref. 10), describes criteria for precluding brittle fracture in package containment components made of ferritic steels that have a wall thickness greater than 4 inches.

- NUREG-2216, "Standard Review Plan for Transportation Packages for Spent Fuel and Radioactive Material" (Ref. 11), provides guidance to the NRC staff for reviewing an application for package approval issued under 10 CFR Part 71.

- NUREG-2224, "Dry Storage and Transportation of High Burnup Spent Nuclear Fuel" (Ref. 12), provides information on the mechanism of hydride reorientation in high burnup spent fuel cladding and an engineering assessment of the results of research on the mechanical performance of high burnup spent fuel following hydride reorientation. Based on the conclusions of that assessment, the NUREG presents example approaches for licensing and certification of high burnup spent fuel.

- NUREG/CR-3019, "Recommended Welding Criteria for Use in the Fabrication of Shipping Containers for Radioactive Materials" (Ref. 13), presents criteria for transportation package welds.

- NUREG/CR-3854, "Fabrication Criteria for Shipping Containers" (Ref. 14), identifies codes and standards that may be used for fabricating components of spent fuel transportation packaging based on the contents.

- NUREG/CR-4775, "Guide for Preparing Operating Procedures for Shipping Packages" (Ref. 15), provides guidance for writing operating procedures for transportation packages used for radioactive materials.

- NUREG/CR-5502, "Engineering Drawings for 10 CFR Part 71 Package Approvals" (Ref. 16), provides guidance on the content of drawings provided in applications for a certificate of compliance.

- NUREG/CR-5661, "Recommendations for Preparing the Criticality Safety Evaluation of Transportation Packages" (Ref. 17), provides recommendations on the approach to use in the preparation of criticality safety evaluations for transportation packages containing fissile material.

- NUREG/CR-6322, "Buckling Analysis of Spent Fuel Basket" (Ref. 18), provides guidance for buckling analysis of spent fuel baskets.

- NUREG/CR-6007, "Stress Analysis of Closure Bolts for Shipping Casks" (Ref. 19), provides guidance and criteria for design analysis of package closure bolts.

- NUREG/CR-6361, "Criticality Benchmark Guide for Light-Water-Reactor Fuel in Transportation and Storage Packages" (Ref. 20), provides guidance for performing criticality benchmark calculations for evaluations of light-water reactor fuel for use in applications for fissile material transportation package and spent fuel dry storage cask approval.

- NUREG/CR-6487, "Containment Analysis for Type B Packages Used to Transport Various Contents" (Ref. 21), provides sample containment analyses and examples of leakage rate calculations for various contents for Type B packages.

- NUREG/CR-6673, "Hydrogen Generation in TRU [Transuranic] Waste Transportation Packages" (Ref. 22), provides information on potential sources of hydrogen gas, and methodologies for prediction of hydrogen gas generation concentrations for various packaging configurations.

- NUREG/CR-6802, "Recommendations for Shielding Evaluations for Transport and Storage Packages" (Ref. 23), provides recommendations on the approach to use in the preparation of

radiation shielding evaluations for transportation and storage of packages containing radioactive material.

Purpose of Regulatory Guides

The NRC issues RGs to describe to the public methods that the staff considers acceptable for use in implementing specific parts of the NRC's regulations, to explain techniques that the staff uses in evaluating specific issues or postulated events, and to provide guidance to applicants on information that the staff needs in its review of applications for package approval. Regulatory guides are not substitutes for regulations and compliance with them is not required. Methods and solutions that differ from those set forth in RGs will be deemed acceptable if they provide a basis for the findings required for the issuance or continuance of a permit or license by the Commission.

Paperwork Reduction Act

This RG provides voluntary guidance for implementing the mandatory information collection in 10 CFR Part 71 that is subject to the Paperwork Reduction Act of 1995 (44 U.S.C. 3501 et. seq.). This information collection was approved by the Office of Management and Budget (OMB) under approval number 3150-0008. Send comments regarding this information collection to the FOIA, Library, and Information Collections Branch (T6-A10M), U.S. Nuclear Regulatory Commission, Washington, DC 20555-0001, or by e-mail to Infocollects.Resource@nrc.gov, and to the OMB reviewer at: OMB Office of Information and Regulatory Affairs (3150-0008), Attn: Desk Officer for the Nuclear Regulatory Commission, 725 17th Street, NW Washington, DC20503; e- mail: oira_submission@omb.eop.gov.

Public Protection Notification

The NRC may not conduct or sponsor, and a person is not required to respond to, a collection of information unless the document requesting or requiring the collection displays a currently valid OMB control number.

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B. DISCUSSION

Reason for Revision

This revision of the guide (Revision 3) is to provide guidance to implement amendments to 10 CFR Part 71 that were made to harmonize the NRC's regulations with International Atomic Energy Agency (IAEA) standards for the transport of radioactive material in Specific Safety Requirements No. 6 (SSR-6), "Regulations for the Safe Transport of Radioactive Material" (Revision 1), 2018 Edition (Ref. 24). These changes include the evaluation of aging of packaging components and the assurance of adequate space for containing liquids.

Additionally, the RG was reorganized to conform to the structure of the NRC's Standard Review Plan in NUREG-2216 and more explanatory material was added to Sections 2.6, 2.7, 3.6 and 3.7 for the structural and thermal requirements to evaluate the accident conditions tests for air shipment of plutonium and fissile material.

Background

Since its inception in 1979, RG 7.9 has been revised twice to account for changes in the transportation regulations in 10 FR Part 71. In addition, the regulations in 10 CFR Part 71 have been revised several times since publication of the initial revision of the RG. The first revision of the RG clarified some of the staff positions that may not have been clear in the initial revision. Revision 2 to the RG was published to account for changes in the package approval standards since March 1979. Some of the major changes to the package approval standards since 1979 that were incorporated into Revision 2 included development and use of A_1 and A_2 values, Type B(U) and Type B(M) packaging standards, special requirements for Type B packages containing more than $10^5 A_2$, changes from fissile classes to criticality safety index to control the number of packages in a shipment, and inclusion of criteria for both transport of fissile material by air and plutonium.

ACCEPTANCE REVIEW

The NRC staff finds the Standard Format described in Section C, Staff Regulatory Guidance, of this RG acceptable for use in preparing applications under 10 CFR Part 71. However, conformance with the Standard Format is not required. Applications prepared in other formats will be deemed acceptable if they provide an adequate basis for the findings required to approve the package. Nonetheless, the use of other formats may increase the time required to review the application, because it may be more difficult for the staff to locate the needed information.

Upon receiving an application, the NRC staff will perform a preliminary review to determine whether the application provides a reasonably complete presentation of the required information, as represented by the Standard Format. If not, the staff will not further review the application until the applicant provides a reasonably complete presentation. The NRC staff may also request additional information in support of an application if such information is necessary to provide reasonable assurance of the ability of the package to meet the regulations. In addition, the information provided in the application should be current with respect to the state of technology for transportation of radioactive materials and should account for any recent changes in NRC regulations and guides, industry codes and standards, developments in transportation safety, and experience in the construction and use of packages for radioactive materials.

PROPRIETARY WITHHOLDING

Proprietary information, such as specific design details shown on engineering drawings, may be withheld from public disclosure subject to the provisions of 10 CFR 2.390. The applicant's request for withholding must be accompanied by an affidavit to support the claim that the material is proprietary. The NRC's Office of the General Counsel may review such requests for compliance with the requirements of 10 CFR 2.390.

Consideration of International Standards

The International Atomic Energy Agency (IAEA) works with member states and other partners to promote the safe, secure, and peaceful use of nuclear technologies. The IAEA develops Safety Requirements and Safety Guides for protecting people and the environment from harmful effects of ionizing radiation. This system of safety fundamentals, safety requirements, safety guides, and other relevant reports, reflects an international perspective on what constitutes a high level of safety. To inform its development of this RG, the NRC considered IAEA Safety Requirements and Safety Guides pursuant to the Commission's "International Policy Statement," published in the *Federal Register* on July 10, 2014 (Ref. 25), and Management Directive 6.6, "Regulatory Guides" (Ref. 26).

The following documents, although not endorsed in this RG, provide similar guidance and are generally consistent with the basic safety principles provided in this guide.

- IAEA Specific Safety Guide No. SSG-26, "Advisory Material for the IAEA regulations for the Safe Transport of Radioactive Material" (Ref. 27), issued in 2012, provides explanatory information and the basis for the standards in SSR-6.

- IAEA Safety Standards Series No. TS-G-1.3, "Radiation Protection Programmes for the Transport of Radioactive Material" (Ref. 28), issued in 2007, provides guidance to meet the requirements for the establishment of radiation protection programs for transport of radioactive material.

- IAEA Safety Standards Series No. TS-G-1.4, "The Management System for the Safe Transport of Radioactive Material" (Ref. 29), issued in 2008, provides guidance to implement the requirements to establish, implement, assess and continually improve a management system for the transport of radioactive material.

- IAEA Safety Standards Series No. TS-G-1.5, "Compliance Assurance for the Safe Transport of Radioactive Material" (Ref. 30), issued in 2009, aims to ensure that dangerous properties in the transport of radioactive material are taken into account in the regulatory control of the design and transport of packages, and that the provisions of transport regulations are met in practice.

C. STAFF REGULATORY GUIDANCE

GENERAL CONSIDERATIONS

Use of the Standard Format for Applications

The application is the principal document in which an applicant provides the information and safety bases for the NRC staff to use in determining whether a given package meets the requirements of 10 CFR Part 71. Toward that end, the Standard Format described later in this section identifies the information to be provided and establishes a uniform format for presenting that information. An application that follows the Standard Format will likely decrease the time required to review the application.

The numbering system and headings of the Standard Format should be followed, at least to the third level (e.g., 2.1.2, Design Criteria). When a particular requirement does not apply to a given package, use the term "Not Applicable," rather than omitting the corresponding section. In addition, offer a reason for not addressing a particular requirement when its applicability is questionable.

The NRC's Standard Review Plan (SRP) in NUREG-2216 describes the practices that the NRC staff developed for use in reviewing applications for package approval. These standard review plans are intended to be compatible with this Standard Format.

Style and Composition

Strive for clear, concise presentation of the information required in the application. Confusing or ambiguous statements and unnecessarily verbose descriptions do not contribute to expeditious technical review. Support claims regarding the adequacy of designs or design methods by technical bases (i.e., an appropriate engineering evaluation or description of actual tests). Define terms consistent with those in the definitions in 10 CFR Part 71 and use them consistently.

Include in appendices to each section of an application detailed information omitted from the main text. Provide in the first appendix to a given section of an application a list of documents that are referenced in the text of that section, including page numbers, if appropriate. If an application references a proprietary document, also reference the nonproprietary summary description of that document, if appropriate.

Provide photographs to support all physical tests of components and packages addressed in the given section. Applicants may also use appendices to provide supplemental information that is not explicitly identified in the Standard Format. Examples of such information include (1) summaries of the manner in which the applicant has treated matters addressed in NRC RGs and (2) supplementary information regarding calculational methods or design approaches used by the applicant.

When an application cites numerical values, use the appropriate number of significant figures to reflect the accuracy or precision to which the number is known. When possible, specify the estimated limits of error or uncertainty. Do not drop or round off significant figures, if doing so would inadequately support subsequent conclusions.

Use abbreviations, symbols, and special terms consistently throughout an application and in a manner that is consistent with generally accepted usage. Define any abbreviations, symbols, or special terms used in the application that are unique to the proposed packaging or not common in general usage.

Use drawings, diagrams, sketches, and charts when such means more accurately or conveniently present the information to be conveyed. However, ensure that drawings, diagrams, sketches, and charts present information in a legible form, with relevant symbols defined.

Revisions

When submitting revised pages, ensure that it is clear what pages have been changed and delineate the revised text. Ensure the accuracy of all statements on a revised page as of the date of each submittal. Take special care to ensure that the main sections of the application are revised to reflect any design changes reported in supplemental information (e.g., responses to NRC staff requests for information or responses to regulatory positions).

STANDARD FORMAT FOR APPLICATIONS

1. GENERAL INFORMATION

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

1.1 Introduction

This section should identify the proposed use of the package, the package type, the model number, package category, a description of the applicant's quality assurance (QA) program (or reference to an approved QA program) and, in the case of fissile packages, the proposed criticality safety index (CSI).

1.2 Package Description

1.2.1 Packaging

The general description should include the following information about the packaging:

- the overall dimensions, maximum (fully loaded) weight, and minimum (empty) weight (if appropriate);
- containment features;
- neutron and gamma shielding features, including personnel barriers;
- criticality control features, including neutron poisons, moderators, and spacers;
- structural features, including lifting and tie-down devices, impact limiters or other energy-absorbing features, internal supporting or positioning features, outer shell or outer packaging, and packaging closure devices;
- heat transfer features; and
- packaging markings.

1.2.2 Contents

This section should state the quantity of radionuclides to be transported. The description should include the following information (if appropriate):

- identification and maximum quantity (radioactivity or mass) of the radioactive material;
- identification and maximum quantity of fissile material;
- chemical and physical form, including density and moisture content, and the presence of any moderating constituents;
- location and configuration of contents within the packaging, including secondary containers, wrapping, shoring, and other material not defined as part of the packaging;
- identification and quantity of non-fissile materials used as neutron absorbers or moderators;
- any material subject to chemical, galvanic, or other reaction, including the generation of gases;
- maximum weight of radioactive contents, and maximum weight of payload including secondary containers and packaging, if applicable;
- maximum decay heat; and
- any loading restrictions.

Additionally, this section should provide a description of the contents that is suitable for inclusion in the certificate of compliance, including the type and form of material and the maximum quantity of material per package.

1.2.3 Special Requirements for Plutonium

For packages that may contain plutonium in excess of 0.74 Tbq (20 Ci) per package, this section should show that these contents must be in solid form.

1.2.4 Operational Features

In the case of a complex package system, this section should describe the operational features of the package. This should include a schematic diagram showing all valves, connections, piping, openings, seals, containment boundaries, and so forth.

1.3 Summary of Compliance with 10 CFR Part 71

This section should include a high-level overview of the approach to showing compliance with the regulations and summary descriptions of the package after completion of the tests for normal conditions of transport and hypothetical accident conditions. In addition, the application should include a summary of the results for meeting the containment, radiation level, and subcriticality requirements. If the package is for commercial spent fuel, the section should include a discussion of the condition of the spent

fuel after the tests for normal conditions of transport and hypothetical accident conditions and how the effects of irradiation were considered for high burnup fuel.

1.4 Appendix

The appendix should include the engineering drawings for the packaging. The drawings should clearly detail the parts of the packaging considered in the package evaluation. The drawings should include a materials list, dimensions, valves, fasteners, and welder and welding procedure qualification requirements. The drawings should specify, by appropriate weld symbol, the specifications for all packaging weld joints, including the nondestructive examination method and the acceptance standard. Gasketed joints in the containment system should be sufficiently detailed to show, as a minimum, the surface finish and flatness requirements of the closure surfaces, the gasket or O-ring specification, and, if appropriate, the method of gasket or O-ring retention. The appendix should not include detailed construction drawings of large, complex packages. Packages authorized for shipment must conform to the approved design; that is, each package must be fabricated in conformance to the engineering drawings.

The appendix should also include a list of references, applicable pages from referenced documents that are not generally available, supporting information on special fabrication procedures, determination of the package category, and other appropriate supplemental information.

2. STRUCTURAL EVALUATION

This section of the application should identify, describe, discuss, and analyze the principal structural design of the packaging, components, and systems important to safety. In addition, this section should describe how the package complies with the performance requirements of 10 CFR Part 71.

2.1 Description of Structural Design

2.1.1 Discussion

This section should identify the principal structural members and systems (such as the containment vessel, impact limiters, radiation shielding, closure devices, and ports) that are important to the safe operation of the package. The discussion should reference the locations of these items on drawings and discuss their structural design and performance.

2.1.2 Design Criteria

This section should describe the load combinations and factors that serve as design criteria. For each criterion, this section should state the maximum allowable stresses and strains (as a percentage of the yield or ultimate values for ductile failure) and 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, this section should indicate the appropriate values for each case. This section should identify the criteria that are used for impact evaluation, as well as the codes and standards that are used to determine stress allowables, design limits, or methods of combining loads and stresses. In the event that the design criteria deviate from those specified by standard codes, or if such codes do not cover certain components, this section should provide a detailed description of the design criteria used as substitutes.

2.1.3 Weights and Centers of Gravity

This section should list the total weight of the packaging and contents and tabulate the weights of major individual subassemblies such that the sum of the parts equals the total of the package.

The discussion should identify the location of the center of gravity of the package and any other centers of gravity referred to in the application. 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. In general, the discussion need not provide the calculations used to determine the centers of gravity.

2.1.4 Identification of Codes and Standards for Package Design

This section should identify the established codes and standards proposed for use in package design evaluation. An assessment of the applicability of codes and standards should be included. The proposed codes or standards should be appropriate for the package category (see Table 2-1).

Table 2-1 Category Designations for Type B Packages (from Regulatory Guide 7.11)

Contents Form/Category	Category I	Category II	Category III
Special Form	Greater than 3,000 A_1* or greater than 1.11 PBq (30,000 Ci)	Between 3,000 A_1* and 30 A_1*, and not greater than 1.11 PBq (30,000 Ci)	Less than 30 A_1*, and less than 1.11 PBq (30,000 Ci)
Normal Form	Greater than 3,000 A_2* or greater than 1.11 PBq (30,000 Ci)	Between 3,000 A_2* and 30 A_2*, and not greater than 1.11 PBq (30,000 Ci)	Less than 30 A_2*, and less than 1.11 PBq (30,000 Ci)
* A_1 and A_2 are defined in 10 CFR 71.4			

2.2 General Requirements for All Packages

This section should address the requirements of 10 CFR 71.43, “General Standards for All Packages.”

2.2.1 Minimum Package Size

This section should specify the smallest overall dimension of the package, which should not be less than 10 cm (4 in.).

2.2.2 Tamper-Indicating Feature

This section should describe the package closure system in sufficient detail to show that it incorporates a protective feature that, while intact, is evidence that unauthorized persons have not tampered with the package. The description should include covers, ports, or other access that must be closed during normal transportation. Tamper indicators and their locations should be described.

2.2.3 Positive Closure

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

2.3 Lifting and Tie-Down Standards for All Packages

2.3.1 Lifting Devices

This section should identify all devices and attachments that can be used to lift the package or its lid and show by testing or analysis that those devices comply with the requirements of 10 CFR 71.45(a). This section should also include drawings or sketches that show the locations and construction of these devices and should show the effects of the forces imposed by lifting devices on other packaging surfaces.

Documented values of the yield stresses of the materials should be used as the criteria for demonstrating compliance with 10 CFR 71.45(a), including failure under excessive load.

2.3.2 Tie-Down Devices

This section should describe the overall tie-down system for the package. Any device that is a structural part of the package and can be used for tie-down should be identified. Drawings or sketches that show the locations and construction of the overall tie-down system and the individual devices should be provided. This section should also discuss the testing or analysis that show these devices comply with the requirements of 10 CFR 71.45(b) and should show the effect of the imposed forces on vital package components, including the interfaces between the tie-down devices and other package surfaces. Documented values of the yield stresses of the materials should be used as the criteria for demonstrating compliance with 10 CFR 71.45(b), including failure under excessive load.

2.4 Normal Conditions of Transport

This section should describe the evaluation that shows the package meets the appropriate standards specified in 10 CFR 71.43, 71.47, 71.51, and 71.55(d), when subjected to the tests and conditions specified in 10 CFR 71.71 (normal conditions of transport). The package should be evaluated against each condition individually. The evaluation should show that the package satisfies the applicable performance requirements specified in the regulations.

The structural evaluation of the package may be performed by analysis or test or a combination of both. In describing the structural evaluation of the package, this section should clearly show that the most limiting initial test conditions and most damaging orientations have been considered, and the evaluation methods are appropriate and properly applied.

In addressing the evaluation details listed below, which apply also to the hypothetical accident conditions in Section 2.5, the following general information should be considered and included, as appropriate.

- For evaluation by test, this section should describe the test method, procedures, equipment, and facilities that were used.

- The package orientations evaluated for the tests should be clearly identified and justified as being most damaging, if applicable.

- If the package tested is not identical in all respects to the package described in the application, the differences should be identified, and justification given to show that the differences would not affect the test results.

- The materials used as substitutes for the radioactive contents during the tests should be described and justification should be given that shows that this substitution would not affect the results, including an assessment of the effects of internal decay heat and pressure buildup, if appropriate.

- A detailed and quantitative description of the damage caused by the tests should be provided, along with the results of any measurements that were made, including both interior and exterior damage, as well as photographs of the damaged packaging.

- For prototype and model testing, this section should provide a complete description of the test specimen, including detailed drawings that show its dimensions and materials of construction and dimensional tolerances to which the prototype or model was fabricated. The fabrication tolerances of the test specimen should be compared to those that will be used for the package.

- For scale models, this section should identify the scale factor that was used and should provide a detailed description of the laws of similitude that were used for testing, considering time scale, material density, velocity at impact, and kinetic energy. Information should be provided to show that the model test will give conservative results for peak g-force, maximum deformation, and dissipated energy. In addition, the damage done to the model should be correlated to damage to the package.

- For evaluation by analysis, this section should describe the methods and calculations used in the package evaluation in sufficient detail to enable the staff to verify the results. In so doing, this section should clearly describe and justify all assumptions used in the analysis, and include adequate narration, sketches, and free body force diagrams. In addition, for equations used in the analysis, this section should either cite the source or include the derivation.

- The computer programs should be identified and described, and should be shown to be well benchmarked, widely used for structural analyses, and applicable to the evaluation.

- Computer models and related details should be well described and justified. For example, the number of discrete finite elements used in the model should reflect the type of analysis performed and should be appropriate considering such factors as stress or displacement.

- Sensitivity studies used to determine the appropriate number of nodes or elements for a particular model should be provided.

- A detailed description of the modeling of bolted connections, including element types, modeling technique, and material properties should be included.

- For impact analysis, information should be provided that shows how all of the kinetic energy will be dissipated, and what local deformation and dynamic forces would occur during impact, the package response in terms of stress and strain to components and structural members, the structural stability of individual members, stresses attributable to impact combined with those stresses caused by temperature gradients, differential thermal expansions, pressure, and other loads.

- The analytical results should be directly compared to the acceptance criteria.

- An assessment should be included to show that structural performance for the tests/conditions evaluated does not reduce the effectiveness of the package.

2.4.1 Heat

The thermal evaluation for the heat test should be described and reported in Chapter 3, "Thermal Evaluation." The results of the thermal evaluation should be used as input to the following sections.

2.4.1.1 Summary of Pressures and Temperatures

This section should summarize all pressures and temperatures derived in Chapter 3, "Thermal Evaluation," that will be used to perform the calculations needed for Sections 2.4.1.2 – 2.4.1.4.

2.4.1.2 Differential Thermal Expansion

This section should present calculations of the circumferential and axial deformations and stresses (if any) that result from differential thermal expansion. Steady-state and transient conditions should be considered. These calculations should be comprehensive to demonstrate package integrity under normal conditions of transport.

2.4.1.3 Stress Calculations

This section should present calculations of the stresses that are attributable to the combined effects of thermal gradients, pressure, and mechanical loads (including fabrication stresses from lead pour and lead cooldown). Sketches that show the configuration and dimensions of the members or systems being analyzed and the points at which the stresses are calculated should be provided. The analysis should consider whether repeated cycles of thermal loadings, together with other loadings (e.g., fabrication stresses and internal or external pressure), will cause fatigue failure or extensive accumulations of deformation.

2.4.1.4 Comparison with Allowable Stresses

This section should present the appropriate stress combinations and compare the resulting stresses with the design criteria specified in the application and should show that all relevant performance requirements have been satisfied as specified in the regulations.

2.4.2 Cold

The thermal evaluation under cold conditions should be described and reported in Chapter 3, "Thermal Evaluation." Using the results from Section 3 of this RG, the evaluation should assess the effects that the cold condition has on the package, including material properties and possible liquid freezing and lead shrinkage. The resulting temperatures and their effects on package components and operation of the package should be reported. Brittle fracture should be evaluated. Stresses should be within the limits for normal condition loads. For the sequential hypothetical accident test series, -29 °C (-20 °F) is the lowest service temperature that needs to be considered, as specified in 10 CFR 71.73(b).

2.4.3 Reduced External Pressure

This section should describe the evaluation of the package for the effects of reduced external pressure, as specified in 10 CFR 71.71(c). The evaluation should include the greatest pressure difference

between the inside and outside of the package, as well as the inside and outside of the containment system, and evaluate this condition in combination with the maximum normal operating pressure.

2.4.4 Increased External Pressure

This section should describe the evaluation of the package for the effects of increased external pressure, as specified in 10 CFR 71.71(c). The evaluation should include the greatest pressure difference between the inside and outside of the package, as well as the inside and outside of the containment system, and evaluate this condition in combination with the minimum internal pressure. This section should include a buckling evaluation.

2.4.5 Vibration

This section should describe the evaluation of the package for the effects of vibrations that are normally incident to transport. The combined stresses attributable to vibration, temperature, and pressure loads should be considered, and a fatigue analysis should be included, if applicable. If closure bolts are reused, the bolt preload should be considered in the fatigue evaluation. Packaging components, including internals, should be evaluated for resonant vibration conditions that can cause rapid fatigue damage.

2.4.6 Water Spray

This section should show that the water spray test has no significant effect on the package. Specifically, it should not impair the package's ability to meet the dose rate and containment criteria, and, if applicable, to maintain criticality safety.

2.4.7 Free Drop

This section should describe the package evaluation for the effects of a free drop. The general comments in Section 2.5.1 may also apply to this condition. Note that the free drop test follows the water spray test. This section should also address such factors as drop orientation; effects of free drop in combination with pressure, heat, and cold temperatures; and other factors discussed in Section 2.4.

2.4.8 Corner Drop

If applicable, this section should describe the effects of corner drops on the package.

2.4.9 Compression

For packages weighing up to 5,000 kg (11,000 lbs), this section should describe the effects of compression on the package.

2.4.10 Penetration

This section should describe the effects of penetration on the package and should identify the most vulnerable location on the package surface.

2.5 Hypothetical Accident Conditions

This section should describe the evaluation that shows the package meets the standards specified in 10 CFR 71.51, 71.55(e), and 71.59(a)(2), when subjected to the tests specified in 10 CFR 71.73 (hypothetical accident conditions).

The structural evaluation should consider the hypothetical accident conditions specified in 10 CFR 71.73, in the indicated sequence, to determine their cumulative effect on a package. 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. This section should address that the tests under normal conditions of transport must not affect the package's ability to withstand the hypothetical accident condition tests. Brittle fracture should also be considered. This section should include applicable information regarding tests and analyses, as described in Section 2.4, above.

2.5.1 Free Drop

This section should evaluate the package under the free drop test. The performance and structural integrity of the package should be evaluated for the drop orientation that causes the most severe damage, including center-of-gravity-over-corner, oblique orientation with secondary impact (slap down), side drop, and drop onto the closure. Orientations for which the center of gravity is directly over the point of impact should also be considered. An orientation that results in the most damage to one system or component may not be the most damaging for other systems and components. If a feature such as a tie-down component is a structural part of the package, it should be considered in selecting the drop test configurations and drop orientation. For these reasons, it is usually necessary to consider several drop orientations.

The following items should be addressed, if applicable:

- For packages with lead shielding, the package should be evaluated for the effects of lead slump. The lead slump determined should be consistent with that used in the shielding evaluation.

- The closure lid bolt design should be assessed for the combined effects of free drop impact force, internal pressures, thermal stress, O-ring compression force, and bolt preload.

- The buckling of package components should be evaluated.

- Other package components, such as port covers, port cover plates, and shield enclosures, should be evaluated for the combined effects of package drop impact force, puncture, internal pressures, and thermal stress.

- Inelastic deformation of the containment closure and seal system is generally unacceptable for the containment evaluation.

- The deformation of shielding components with respect to the shielding evaluation.

- The deformation of components required for heat transfer or insulation, in terms of the thermal evaluation.

- The deformation of components required for subcriticality, in terms of criticality evaluation.

2.5.1.1 End Drop

This section should describe the effects of the end drop test on the package.

2.5.1.2 Side Drop

This section should describe the effects of the side drop test on the package.

2.5.1.3 Corner Drop

This section should describe the effects of the corner drop test on the package.

2.5.1.4 Oblique Drops

This section should describe the effects of oblique drops on the package, or should provide information that shows that the end, side, and corner drops are more damaging to all systems and components that are vital to safety.

2.5.1.5 Summary of Results

This section should describe the condition of the package after each drop test, and describe the damage for each orientation.

2.5.2 Crush

If applicable, this section should describe the effects of the dynamic crush test on the package.

2.5.3 Puncture

This section should describe the effects of puncture on the package and identify and justify that the orientations for which maximum damage would be expected have been evaluated. This description should consider any damage resulting from the free drop and crush tests, as well as both local damage near the point of impact of the puncture bar and the overall effect on the package. Containment system valves and fittings should be addressed. Punctures at oblique angles, near a support valve, at the package closure, and at a penetration, should be considered, as appropriate. General comments provided in Sections 2.4 and 2.5.1 may also apply to this test condition.

Although analytical methods are available for predicting puncture, empirical formulas derived from puncture test results of laminated panels are usually used for package design. The Nelm's formula developed specifically for package design provides the minimum thickness needed for preventing the puncture of the steel surface layer of a typical steel-lead-steel laminated cask wall.

2.5.4 Thermal

The thermal test should follow the free drop and puncture tests, and should be reported in Chapter 3, "Thermal Evaluation." This section should evaluate the structural design for the effects of a fully engulfing fire, as specified in 10 CFR 71.73(c)(4). Any damage resulting from the free drop, crush, and puncture conditions should be incorporated into the initial condition of the package for the fire test. The temperatures resulting from the fire and any increase in gas inventory caused by combustion or decomposition processes should be considered when determining the maximum pressure in the package

during or after the test. The maximum thermal stresses that can occur either during or after the fire should be addressed.

2.5.4.1 Summary of Pressures and Temperatures

This section should summarize all temperatures and pressures, as determined in Chapter 3, "Thermal Evaluation," of the application.

2.5.4.2 Differential Thermal Expansion

This section should include calculations of the circumferential and axial deformations and stresses (if any) that result from differential thermal expansion. Peak conditions, post-fire steady-state conditions, and all transient conditions should be considered.

2.5.4.3 Stress Calculations

This section should include calculations of the stresses caused by thermal gradients, differential expansion, pressure, and other mechanical loads. Sketches showing configuration and dimensions of the members of systems under investigation, and locations of the points at which the stresses are being calculated should be included.

2.5.4.4 Comparison with Allowable Stresses

This section should make the appropriate stress combinations and compare the resulting stresses with the design criteria in Section 2.1.2 of the application. This section should show that all the performance requirements specified in the regulations have been satisfied.

2.5.5 Immersion — Fissile Material

If the contents include fissile material subject to the requirements of 10 CFR 71.55, and if water leakage has not been assumed for the criticality analysis, this section should assess the effects and consequences of the water immersion test condition. The test should consider immersion of a damaged specimen under a head of water of at least 0.9 m (3 ft.) in the orientation for which maximum leakage is expected.

2.5.6 Immersion — All Packages

This section should evaluate an undamaged package for water pressure equivalent to immersion under a head of water of at least 15 m (50 ft.) for 8 hours. For test purposes, an external water pressure of 150 kPa (21.7 psi) gauge is considered to meet these conditions.

2.5.7 Special Requirements for Type B Packages Containing More than 10^5 A_2

If applicable, this section should evaluate the package for an external water pressure of 2 MPa (290 psi) for a period of no less than 1 hour, as specified in 10 CFR 71.61.

2.5.8 Summary of Damage

This section should summarize the condition of the package after the accident test sequence. The description should address the extent to which safety systems and components have been damaged and relate the package condition to the acceptance standards.

2.6 Accident Conditions for Air Transport of Plutonium

If applicable, this section should address the accident conditions specified in 10 CFR 71.74. Note that the water and ambient conditions for the applicable tests are described in 10 CFR 71.64(b)(1)(ii). The description of the post-test package in the application should include evaluation of:

- Rupture of the containment closure and seal system;
- Deformation of shielding components to be considered in the shielding evaluation;
- Deformation of components required for heat transfer or insulation to be considered in the thermal evaluation; and
- Deformation of components required for subcriticality to be considered in the criticality evaluation.

2.6.1 Impact Test

The application should provide a description of the impact test and its setup to ensure it meets the requirements in 10 CFR 71.74(a)(1). Identify and justify that the orientations for which maximum damage would be expected have been evaluated. Provide a description of the effects of the impact test on the package.

2.6.2 Static Compressive Load Test

In this section, the applicant should provide a description of the effects of the static compressive load test on the package. Identify and justify that the orientations for which maximum damage would be expected have been evaluated.

2.6.3 Crush Test

If applicable, this section should describe the effects of the crush test described in 10 CFR 71.74(a)(3) on the package.

2.6.4 Structural Steel Angle Impact Test

In this section, the applicant should provide a description of the test setup, impact and results of a structural steel angle impacting the package as described in 10 CFR 71.71(a)(4).

2.6.5 Thermal Test

The thermal test should follow the impact test, static compressive load test, crush test, and steel angle impact tests, and should be reported in Chapter 3, "Thermal Evaluation." This section should evaluate the structural design for the effects of the fire, as specified in 10 CFR 71.74(a)(5). Any damage resulting from the impact test, static compressive load test, crush test, and steel angle impact tests should be incorporated into the initial condition of the package for this fire test. The temperatures resulting from the fire and any increase in gas inventory caused by combustion or decomposition processes should be considered when determining the maximum pressure in the package during or after the test. The maximum thermal stresses that can occur either during or after the fire should be evaluated in the application.

2.7 Accident Conditions for Fissile Material Packages for Air Transport

If applicable, this section should address the accident conditions specified in 10 CFR 71.55(f).

2.7.1 Free Drop

The free drop is the same test required for hypothetical accident conditions, discussed in section 2.5.1, above.

2.7.2 Crush Test

The crush test is the same test required for hypothetical accident conditions, discussed in section 2.5.2, above.

2.7.3 Thermal Test

After evaluation of the free drop and crush tests (see Sections 2.5.1 and 2.5.2, above, respectively), describe the effects of the puncture test required in 10 CFR 71.55(f)(1)(iii) on the package, and identify and justify that the orientations for which maximum damage would be expected have been evaluated. Note this puncture test is different from the puncture test for hypothetical accident conditions specified in 10 CFR 71.73(c)(3).

The thermal test should follow the free drop, crush and puncture tests, and should be reported in Chapter 3, "Thermal Evaluation." This section should evaluate the structural design for the effects of a fully engulfing, 60-minute fire, as specified in 10 CFR 71.55(f)(1)(iv). Any damage resulting from the free drop, crush, and puncture conditions should be incorporated into the initial condition of the package for this fire test. The temperatures resulting from the fire and any increase in gas inventory caused by combustion or decomposition processes should be considered when determining the maximum pressure in the package during or after the test. The maximum thermal stresses that can occur either during or after the fire should be addressed.

2.7.4 Impact Test

The applicant should provide a description of the package after the evaluation of the 90 m/s impact test in accordance with 10 CFR 71.55(f)(2). The applicant should evaluate the structural integrity for the drop orientation that produces the highest g-load and causes the most severe damage to the package, including center-of-gravity-over-corner, oblique orientation with secondary impact (slap down), side drop, and drop onto the closure with respect to the criticality evaluation. A separate, undamaged specimen can be used for this evaluation.

2.8 Special Form Radioactive Material

For packages designed to transport radioactive material only in special form, this section should state that the contents meet the requirements in 10 CFR 71.75. The chemical and physical form should be specified. In addition, if the source is not a doubly encapsulated right circular cylinder of welded construction, this section should include a detailed drawing of the encapsulation showing its dimensions, materials, manner of construction, and method of nondestructive examination.

2.9 Fuel Rods

In Chapter 4, "Containment," where fuel rod cladding is considered to provide containment of radioactive material under normal or accident test conditions, this section should provide an analysis or test results showing that the cladding will maintain sufficient mechanical integrity to provide the degree of containment claimed.

2.10 Appendix

The appendix should include a list of references, applicable pages from referenced documents if not generally available, computer code descriptions, input and output files, test results, test reports, and other appropriate supplemental information. This appendix should also include materials and manufacturing specifications for items that are significant with respect to safety but are not produced to generally recognized standards.

3. THERMAL EVALUATION

This section of the application should identify, describe, and analyze the principal thermal engineering design of the packaging, components, and systems that are important to safety, and describe how the package complies with the performance requirements of 10 CFR Part 71.

3.1 Description of Thermal Design

This section should describe the significant thermal design features and operating characteristics of the package and discuss the operation of all subsystems. The thermal criteria that will be directly applied to thermal results (e.g., maximum fuel temperature, shield temperature not to exceed melt) should be identified. Properties evaluated here but used to support other evaluations (e.g., pressure, temperature, distributions relative to thermal stress) should also be identified. The significant results of the thermal analysis or tests and the implication of these results on the overall package should be summarized. The minimum and maximum decay heat loads assumed in the thermal evaluation should be specified. The maximum decay heat load assumed should be consistent with the maximum quantity of radioactive contents allowed for transport.

3.1.1 Design Features

This section should describe the design features that are important to thermal performance, including the following:

- package geometry and materials of construction; and
- structural and mechanical features that may affect heat transfer, such as cooling fins, insulating materials, surface conditions of the package components, and gaps or physical contacts between internal components.

3.1.2 Content's Decay Heat

The maximum decay heat should be specified and reflect the maximum quantity of radioactive contents allowed for transport.

3.1.3 Summary Tables of Temperatures

This section should present summary tables of the maximum or minimum temperatures that affect structural integrity, containment, shielding, and criticality under both normal conditions of transport and hypothetical accident conditions. For the fire test condition, the tables should also include the following information:

- the maximum temperatures of various package components and the time at which they occur after fire initiation, and

- the maximum temperatures of the post-fire steady-state condition.

3.1.4 Summary Tables of Maximum Pressures

The summary tables should include the maximum normal operating pressure and maximum pressure under hypothetical accident conditions.

3.2 Material Properties and Component Specifications

3.2.1 Material Properties

This section should specify the appropriate thermal properties for materials that affect heat transfer both within the package and from the package to the environment. Liquids or gases within the package and gases external to the package for hypothetical accident conditions should be included. The thermal absorptivity and emissivity should be appropriate for the package surface conditions and each thermal condition. When reporting a property as a single value, the evaluation should show that this value bounds the equivalent temperature-dependent property. In addition, this section should include references for the data provided.

3.2.2 Component Specifications

This section should include the technical specifications of components that are important to the thermal performance of the package, as illustrated by the following examples:

- in the case of valves or seals, the operating pressure range and temperature limits,
- the properties of fabricated insulation and coatings, including a summary of test data that supports their performance specifications,
- maximum allowable service temperatures or pressures for each package component, and
- minimum allowable service temperature of all components, which should be less than or equal to -40 °C (-40 °F).

3.3 Thermal Evaluation under Normal Conditions of Transport

This section should describe the thermal evaluation of system and subsystem operation under normal conditions of transport. The temperature ranges bounded by the minimum and maximum ambient temperatures and minimum and maximum decay heat loads should be considered. The results should be compared with allowable limits of temperature, pressure, etc., for the package components. The information should be presented in summary tables, along with statements and appropriate comments. Information that is to be used in other sections of the review should be identified. The margins of safety for package temperatures, pressures, and thermal stresses, including the effects of uncertainties in thermal properties, test conditions and diagnostics, and analytical methods, should be addressed. The analysis or test results should be shown to be reliable and repeatable.

In addressing the sections below, the following general information should be considered and included, as appropriate:

- For thermal evaluation by analyses, the methods and calculations used in the package thermal evaluation should be described in sufficient detail to enable the staff to verify the results.

- Assumptions that are used in the analysis should be clearly described and justified.

- For computer analyses, including finite element analyses, the computer program should be described, and should be shown to be well benchmarked and widely used for thermal analyses and applicable to the evaluation.

- Models and modeling details should be clearly described.

- For thermal evaluation by test, the test method, procedures, equipment, and facilities that were used should be described.

- If the specimen tested is not identical in all respects to the package described in the application, describe the differences, and justify that these differences would not affect the test results.

- Temperature data should be reported at gaskets, valves, and other containment boundaries, particularly for temperature-sensitive materials, as well as for the overall package.

- Some conditions, such as ambient temperature, decay heat of the contents, or package emissivity or absorptivity, may not be exactly represented in a thermal test, and appropriate corrections or evaluations that account for these differences should be described.

- Both interior and exterior temperatures should be included.

- The damage caused by the tests and the results of any measurements that were made should be reported in detail, including photographs of the testing and the test specimen.

3.3.1 Heat and Cold

This section should demonstrate that the tests for normal conditions of transport do not result in a significant reduction in packaging effectiveness. The following items should be considered and addressed:

- degradation of the heat-transfer capability of the packaging (such as creation of new gaps between components, for example due differential thermal expansion or contraction of components);

- changes in material conditions or properties (e.g., expansion, contraction, ullage, gas generation, and thermal stresses) that affect the structural performance;

- changes in the packaging that affect containment, shielding, or criticality (such as thermal decomposition or melting of materials); and

- ability of the packaging to withstand the tests under hypothetical accident conditions.

The component temperatures and pressures should be compared to their allowable values. This section should explicitly show that the package meets the maximum surface temperature requirements specified in 10 CFR 71.43(g).

3.3.2 Maximum Normal Operating Pressure

This section should report the maximum normal operating pressure and show how it was calculated, assuming the package has been subjected to the heat condition for 1 year. The calculation should consider possible sources of gases, including the following:

- gases initially present in the package,
- saturated vapor, including water vapor from the contents or packaging,
- helium from the radioactive decay of the contents,
- hydrogen or other gases resulting from thermal- or radiation-induced decomposition of materials such as water or plastics, and
- fuel rod failure.

This section should demonstrate that hydrogen and other flammable gases will not result in a flammable mixture within any confined volume of the package.

3.4 Thermal Evaluation under Hypothetical Accident Conditions

This section should describe the thermal evaluation of the package under hypothetical accident conditions. The hypothetical accident conditions defined in 10 CFR 71.73 should be applied sequentially. For the accident condition thermal evaluation, the general comments in Section 3.3, above, should be considered and addressed, as appropriate.

3.4.1 Initial Conditions

The thermal evaluation should consider the effects of the drop, crush (if applicable), and puncture tests on the package. This section should identify initial conditions, and justify that they are most unfavorable, including initial ambient temperature, insolation, internal pressure, decay heat, etc.

3.4.2 Fire Test Conditions

This section should provide a detailed description of the analysis or tests used to evaluate the package under the fire test conditions. The evaluation should address the requirements in 10 CFR 71.73(c).

3.4.3 Maximum Temperatures and Pressure

This section should report the transient peak temperatures of package components as a function of time both during and after the fire, as well as the maximum temperatures from the post-fire, steady-state condition. This section should include those temperatures at locations in the package that are significant to the safety analysis and review. In particular, the temperatures for such items as contents, gaskets,

valves, and shielding should be reported. The calculations of transient temperatures should trace the temperature-time history up to and past the time at which maximum temperatures are achieved and begin to fall.

The evaluation of the maximum pressure in the package should be based on the maximum normal operating pressure, and should consider fire-induced increases in package temperatures, thermal combustion or decomposition processes, fuel rod failure, phase changes, change of ullage in any system for containing liquid, etc.

This section should provide a general description of package performance and should compare the results of the thermal test with allowable limits of temperature, pressure, etc., for the package components. Damage to the package either from interpretation of the analysis or from test observation should be considered and described. The assessment should include structural damage, breach of containment, and loss of shielding.

3.4.4 Maximum Thermal Stresses

This section should evaluate the most severe thermal stress conditions that result during the fire test and subsequent cool-down. The temperatures corresponding to the maximum thermal stresses should be reported.

3.5 Accident Conditions for Air Transport of Plutonium

If applicable, address the fire test conditions specified in 10 CFR 71.74(a)(5). This section should provide a detailed description of the tests performed on the package.

This section should report the transient peak temperatures of package components as a function of time both during and after the fire, as well as the maximum temperatures from the post-fire, steady-state condition. This section should include those temperatures at locations in the package that are significant to the safety analysis and review. In particular, the temperatures for such items as contents, gaskets, valves, and shielding should be reported. The calculations of transient temperatures should trace the temperature-time history up to and past the time at which maximum temperatures are achieved and begin to fall.

The evaluation of the maximum pressure in the package should be based on the maximum normal operating pressure, and should consider fire-induced increases in package temperatures, thermal combustion or decomposition processes, fuel rod failure, phase changes, change of ullage in any system for containing liquid, etc.

This section should provide a general description of package performance and should compare the results of the thermal test with allowable limits of temperature, pressure, etc., for the package components. Damage to the package either from interpretation of the analysis or from test observation should be considered and described. The assessment should include structural damage, breach of containment, and loss of shielding.

This section should evaluate the most severe thermal stress conditions that result during the fire test and subsequent cool-down. The temperatures corresponding to the maximum thermal stresses should be reported.

3.6 Accident Conditions for Fissile Material Packages for Air Transport

If applicable, address the expanded fire test conditions specified in 10 CFR 71.55(f)(1)(iv). This section should provide a detailed description of the analysis or tests used to evaluate the package under the fire test conditions.

This section should report the transient peak temperatures of package components as a function of time both during and after the fire, as well as the maximum temperatures from the post-fire, steady-state condition. This section should include those temperatures at locations in the package that are significant to the safety analysis and review. In particular, the temperatures for such items as contents, gaskets, valves, and shielding should be reported. The calculations of transient temperatures should trace the temperature-time history up to and past the time at which maximum temperatures are achieved and begin to fall.

The evaluation of the maximum pressure in the package should be based on the maximum normal operating pressure, and should consider fire-induced increases in package temperatures, thermal combustion or decomposition processes, fuel rod failure, phase changes, change of ullage in any system for containing liquid, etc.

This section should provide a general description of package performance and should compare the results of the thermal test with allowable limits of temperature, pressure, etc., for the package components. Damage to the package either from interpretation of the analysis or from test observation should be considered and described. The assessment should include structural damage, breach of containment, and loss of shielding.

This section should evaluate the most severe thermal stress conditions that result during the fire test and subsequent cool-down. The temperatures corresponding to the maximum thermal stresses should be reported.

3.7 Appendix

The appendix should include a list of references, applicable pages from referenced documents, justification of assumptions or analytical procedures, test results, photographs, computer program descriptions and input and output files, specifications of O-rings and other components, detailed material test data, and other supplemental information.

4. CONTAINMENT EVALUATION

This section of the application should identify the package containment system and describe how the package complies with the containment requirements of 10 CFR Part 71.

4.1 Description of the Containment System

This section should define and describe the containment system, including such components as the containment vessel, welds, seals, lids, cover plates, valves, and other closure devices. The description should include materials of construction and applicable codes and standards. The containment boundary of the package should be explicitly identified, including the containment vessel, welds, drain or fill ports, valves, seals, test ports, pressure relief devices, lids, cover plates, and other closure devices. If multiple seals are used for a single closure, this section should identify the seal defined as the containment system seal. In addition, this section should include a sketch of the containment system.

This section should address the following items:

- containment system penetrations and their method of closure,
- performance specifications for such components as valves and pressure relief devices,
- the method used to protect any valve or similar device on the package against unauthorized operation, and the enclosure used to retain any leakage (except for a pressure relief valve),
- how the containment system is securely closed with a positive fastening device that cannot be opened unintentionally or by a pressure that may arise within the package, and
- the features that ensure continuous venting is precluded.

4.2 Containment under Normal Conditions of Transport

This section should include the evaluation of the containment system under normal conditions of transport. The evaluation should be performed for the most limiting chemical and physical forms of the contents. Significant daughter products should be included. The constituents of the releasable source term, including radioactive gases, liquids, and powder aerosols, should be identified.

The evaluation should address the following:

- maximum internal pressures,
- the structural performance of the containment system, including seals, closure bolts, and penetrations, and
- leakage testing of the containment system.

For Type A fissile packages, the evaluation should show that there is no loss or dispersal of radioactive material under normal conditions of transport (10 CFR 71.43(f)). For Type B packages, the evaluation should show that there is no release under normal conditions of transport to the appropriate sensitivity as required in 10 CFR 71.51.

4.3 Containment under Hypothetical Accident Conditions

This section should include the evaluation of the containment system under hypothetical accident conditions, considering factors given in Section 4.2, above. This section should demonstrate that the package meets the containment requirements of 10 CFR 71.51(a)(2) under hypothetical accident conditions. In particular, the structural performance of the containment system should be addressed, including seals, closure bolts, and penetrations, as well as leakage testing of the containment system.

4.4 Leakage Rate Tests for Type B Packages

This section should describe leakage tests that are used to show that the package meets the containment requirements of 10 CFR 71.51. These may include leakage tests of test units, newly fabricated packaging, periodic tests, and pre-shipment tests.

4.5 Appendix

The appendix should include a list of references, applicable pages from referenced documents, supporting information and analysis, test results, and other appropriate supplemental information.

5. SHIELDING EVALUATION

This section of the application should identify, describe, discuss, and analyze the principal radiation shielding design of the packaging, components, and systems that are important to safety.

5.1 Description of Shielding Design

5.1.1 Design Features

This section should describe the radiation shielding design features of the package, including dimensions, tolerances, materials of construction, and densities of material for neutron and gamma shielding.

5.1.2 Summary Table of Maximum Radiation Levels

This section should present the maximum radiation levels (dose equivalent rates) for both normal conditions of transport and hypothetical accident conditions at the appropriate locations for non-exclusive and exclusive use shipments, as applicable. Table 5-1 provides an example of the information to be provided.

Table 5-1 Example for Summary Tables of External Radiation Levels (Non-Exclusive Use)

Normal Conditions of Transport	Package Surface mSv/h (mrem/h)			1 Meter from Package Surface mSv/h (mrem/h)		
Radiation	Top	Side	Bottom	Top	Side	Bottom
Gamma						
Neutron						
Total						
10 CFR 71.47(a) Limit	2 (200)	2 (200)	2 (200)	0.1 (10)*	0.1 (10)*	0.1 (10)*
* Transport index may not exceed 10.						

Hypothetical Accident Conditions	1 Meter from Package Surface mSv/h (mrem/h)		
Radiation	Top	Side	Bottom
Gamma			
Neutron			
Total			
10 CFR 71.51(a)(2) Limit	10 (1000)	10 (1000)	10 (1000)

5.2 Source Specification

This section should describe the contents, as well as the gamma and neutron source terms used in the shielding analysis. Any increase in source terms over time should be considered. For packages designed for spent fuel transport, this section should also state the assumed fuel burnup, initial enrichment, power density, and cooling times.

5.2.1 Gamma Source

This section should specify 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. A detailed description of the method used to determine the gamma source strength and distribution should be provided.

5.2.2 Neutron Source

This section should specify the quantity of radioactive material included as contents and tabulate the neutron source strength (neutron/sec) as a function of energy. A detailed description of the method used to determine the neutron source strength and distribution should be provided.

5.3 Shielding Model

5.3.1 Configuration of Source and Shielding

This section should provide a detailed description of the model used in the shielding evaluation. The effects of the tests on the packaging and its contents under normal conditions of transport and hypothetical accident conditions should be evaluated. The models used in the shielding calculation should be consistent with these effects.

This section should include sketches (to scale) and dimensions of the radial and axial shielding materials. The dimensions of the transport vehicle and package location for exclusive-use shipments for which the analysis is based on the radiation levels in 10 CFR 71.47(b) should be included, as appropriate.

The dose point locations in the shielding model, including all locations prescribed in 10 CFR 71.47(a) or 71.47(b) and 10 CFR 71.51(a)(2) should be identified. These points should be chosen to identify the locations of the maximum radiation levels. Voids, streaming paths, and irregular geometries in the model, should be included or otherwise treated in an adequate manner.

5.3.2 Material Properties

This section should describe the material properties (e.g., mass densities and atom densities) in the shielding models of the packaging and contents. Changes resulting under normal conditions of transport or hypothetical accident conditions, should be included, as appropriate. The sources of data for uncommon materials should be cited.

5.4 Shielding Evaluation

5.4.1 Methods

This section should provide a general description of the basic method used to determine the gamma and neutron dose equivalent rates at the selected points outside the package for both 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. This section should also include a detailed description of the basic input parameters, as well as the bases for selecting the program, attenuation and removal cross-sections, and buildup factors.

5.4.2 Input and Output Data

This section should identify the key input data for the shielding calculations and show that information from the shielding models is properly input into the code. At least one representative input file and output file, or key sections of those files, should be included. This section should show that the code achieved proper convergence.

5.4.3 Flux-to-Dose-Rate Conversion

This section should include a tabulation of the flux-to-dose-rate conversion factors as a function of energy and should cite appropriate references to support the data.

5.4.4 External Radiation Levels

This section should describe the results of the radiation analysis in detail. These should agree with the summary tables. The locations of maximum dose equivalent rates for the analysis should be identified, and sufficient data provided to show that the radiation levels are reasonable and their variations with location are consistent with the geometry and shielding characteristics of the package. The results should address normal and accident conditions.

5.5 Appendix

The appendix should include a list of references, applicable pages from referenced documents, justification of assumptions or analytical procedures, test results, photographs, computer program descriptions, input and output files, and other supplemental information.

6. CRITICALITY EVALUATION

This section of the application should identify, describe, discuss, and analyze the principal criticality safety design of the package, components, and systems important to safety, and describe how the package complies with the requirements of 10 CFR 71.55 and 71.59.

6.1 Description of Criticality Design

6.1.1 Design Features

This section should describe the design features of the package that are important for criticality control. These should include such information as the confinement system for the fissile material, neutron absorbing and moderating materials, flux traps, spacers, etc.

6.1.2 Summary Table of Criticality Evaluation

This section should provide a summary table of criticality analysis results for the package for the following cases, as described in Sections 6.4–6.6:

- a single package, under the conditions of 10 CFR 71.55(b), (d), and (e);
- an array of undamaged packages, under the conditions of 10 CFR 71.59(a)(1); and
- an array of damaged packages, under the conditions of 10 CFR 71.59(a)(2).

The maximum value of the effective neutron multiplication factor (k_{eff}), the bias, the Monte Carlo and bias uncertainties, and the number of packages evaluated in the arrays should be specified in the table.

6.1.3 Criticality Safety Index

This section should provide the criticality safety index (CSI) based on the number of packages evaluated in the arrays and show how it was calculated.

6.2 Fissile Material Contents

This section should describe in detail the fissile materials in the package. Mass, dimensions, enrichment, physical and chemical composition, density, moisture, and other characteristics should be defined.

6.3 General Considerations

This section should address general considerations used to evaluate criticality of the package. These may apply to the criticality evaluations of a single package and arrays of packages under both normal conditions of transport and hypothetical accident conditions.

6.3.1 Model Configuration

This section should describe and provide sketches of the calculation model used in the calculations. The sketches should identify the materials used in all regions of the model. Any differences between the model and the actual package configuration should be identified and justification given that the model is conservative. In addition, the differences between the models for normal and accident conditions of transport should be clearly identified.

6.3.2 Material Properties

This section should provide the appropriate mass densities and atomic number densities for materials used in the models of the packaging and contents. Material properties should be consistent with the condition of the package under the tests specified in 10 CFR 71.71 and 71.73. The differences between normal conditions of transport and hypothetical accident conditions should be clearly identified. Materials relevant to the criticality design, such as poisons, foams, plastics, and other hydrocarbons, should specifically be addressed.

6.3.3 Computer Codes and Cross-Section Libraries

This section should describe the basic methods used to calculate the effective neutron multiplication constant of the package to demonstrate compliance with the fissile material package standards. This should address the following:

- a description of the computer program and neutron cross-sections used,
- the bases for selecting the specific program and cross-sections, and
- key input data for the criticality calculations, such as neutrons per generation, number of generations, convergence criteria, mesh selection, etc.

6.3.4 Demonstration of Maximum Reactivity

This section should include a demonstration that the most reactive configuration of each case listed in Sections 6.4–6.6 (single package, arrays of undamaged packages, and arrays of damaged packages) has been evaluated. All assumptions and approximations should be clearly identified and justified.

This section should identify the optimum combination of internal moderation (within the package) and interspersed moderation (between packages), as applicable. The following should be considered:

- moderation by water and any hydrogen-containing packaging materials, such as polyethylene,
- preferential flooding of different regions within the package, and
- partial loadings (i.e., fissile masses less than the maximum allowable mass).

6.4 Single Package Evaluation

6.4.1 Configuration

This section should demonstrate that a single package is subcritical under both normal conditions of transport and hypothetical accident conditions. The evaluation should consider the following factors:

- fissile material in its most reactive credible configuration consistent with the condition of the package and the chemical and physical form of the contents,
- water moderation to the most reactive credible extent, including water in leakage to the containment system as specified in 10 CFR 71.55(b), and
- full water reflection on all sides of the containment system as specified in 10 CFR 71.55(b)(3), or reflection by the package materials, whichever results in the maximum reactivity.

6.4.2 Results

This section should present the results of the single package evaluation and should also address the additional specifications of 10 CFR 71.55(d)(2)–(d)(4) under normal conditions of transport.

6.5 Evaluation of Package Arrays under Normal Conditions of Transport

6.5.1 Configuration

This section should evaluate an array of 5N packages under normal conditions of transport. The evaluation should consider the following factors:

- the most reactive configuration of the array (e.g., pitch and package orientation) with nothing between the packages,

- the most reactive credible configuration of the packaging and its contents under normal conditions of transport (if the water spray test has demonstrated, and that water would not leak into the package, water in leakage need not be assumed), and

- full water reflection on all sides of a finite array.

6.5.2 Results

This section should present the results of the analyses for arrays and identify the most reactive array conditions.

6.6 Package Arrays under Hypothetical Accident Conditions

6.6.1 Configuration

This section should evaluate an array of 2N packages under hypothetical accident conditions. The evaluation should consider the following factors:

- the most reactive configuration of the array (e.g., pitch, package orientation, and internal moderation),

- optimum interspersed hydrogenous moderation,

- the most reactive credible configuration of the packaging and its contents under hypothetical accident conditions, including inleakage of water, and

- full water reflection on all sides of a finite array.

6.6.2 Results

This section should present the results of the analyses for arrays and identify the most reactive array conditions.

6.7 Fissile Material Packages for Air Transport

6.7.1 Configuration

This section should evaluate a single package under the expanded accident conditions specified in 10 CFR 71.55(f). The evaluation should consider the following factors:

- the most reactive configuration of the contents and packaging under the expanded accident conditions,

- full water reflection, and

- no water in leakage.

6.7.2 Results

This section should present the results of the analyses for the single package and identify the most reactive contents and packaging conditions.

6.8 Benchmark Evaluations

This section should include a description of the methods used to benchmark the criticality calculations. The computer codes for criticality calculations should be benchmarked against critical experiments. The same computer code, hardware, and cross-section library used to calculate the effective multiplication factor values for the package should be used in the benchmark experiments. This section should present the results of calculations for selected critical benchmark experiments to justify the validity of the calculational method and neutron cross-section values used in the analysis.

6.8.1 Applicability of Benchmark Experiments

This section should describe selected critical benchmark experiments that are to be analyzed using the method and cross-sections given in Section 6.3. This section should show the applicability of the benchmarks in relation to the package and its contents, noting all similarities and resolving all differences. References that give full documentation on these experiments should be provided. The overall quality of the benchmark experiments and any uncertainties in experimental data should be addressed. Results of the benchmark calculations, as well as the actual nuclear and geometric input parameters used for those calculations, should be provided.

6.8.2 Bias Determination

This section should present the results of the benchmark calculations and the method used to account for biases, including the contribution from uncertainties in the experimental data. This section should show a sufficient number of appropriate benchmark experiments and that the results of the benchmark calculations were appropriate to determine the bias for the package calculations. Parameters such as pitch-to-rod diameter, assembly separation, and neutron absorber material, should be considered. Statistical and convergence uncertainties should be addressed.

6.9 Burnup Credit for Spent Nuclear Fuel

This section should present the burnup credit approach used to demonstrate subcriticality for light water reactor spent nuclear fuel, if burnup credit is applied in the criticality analysis for the package.

6.9.1 Limits for the Certification Basis

This section should present a demonstration that the burnup credit criticality analysis is within the limits on initial enrichment, burnup, and cooling time identified in Section 6.4.7.1 of NUREG-2216. This section should also demonstrate that the nuclides credited in the burnup credit criticality analysis are limited to those identified in Table 6-2 of NUREG-2216.

6.9.2 Model Assumptions

This section should present the model assumptions used in the burnup credit criticality analysis, including fuel design and reactor operating parameters. This section should also address how the model considers axial and horizontal variation of the burnup within a fuel assembly, presence of burnable absorbers or control rods, and other operating conditions such as fuel temperature, moderator temperature and density, soluble boron concentration, specific power, and operating history.

6.9.3 Code Validation – Isotopic Depletion

This section should present the methodology used to validate the isotopic depletion code used to determine burned fuel composition of spent fuel modeled in the burnup credit criticality analysis, and the resulting depletion code bias and bias uncertainty. This section should identify the computer code and cross-section library used for the isotopic depletion analysis and identify the measurement data used for validation of the code and cross-section library.

6.9.4 Code Validation – k_{eff} Determination

This section should present the methodology used to validate the criticality code used to determine k_{eff} in the burnup credit criticality analysis and the resulting criticality code bias and bias uncertainty. This section should identify the computer code and cross-section library used for the criticality analysis and identify the critical experiments used for validation of the code and cross-section library. If the criticality analysis credits fission products, this section should verify that the analysis meets the criteria in Section 6.4.7.4 of NUREG-2216 for fission product credit or identify critical experiments containing fission products used to validate the code and cross-section library for use in determining the reduction in k_{eff} due to fission products.

6.9.5 Loading Curve and Burnup Verification

This section should present the loading curves calculated in the burnup credit criticality analysis for use in determining allowable initial enrichments, burnups, and cooling times for fuel to be loaded into the package. This section should also present methods used to verify minimum required burnup for fuel assemblies to be loaded into the package. If package loading procedures do not include a step for burnup measurement of fuel assemblies, this section should present the methodology and results of a misloading analysis, and a demonstration that this analysis meets the criteria in Section 6.4.7.5 of NUREG-2216.

6.10 Appendix

The appendix should include a list of references, applicable pages from referenced documents, justification of assumption or analytical procedures, test results, photographs, computer code descriptions, input and output files, and other supplemental information. Input files for representative or "most limiting" cases for a single package and arrays of damaged and undamaged packages should specifically be included.

7. MATERIALS EVALUATION

This section of the application should identify, describe, discuss, and analyze the materials design features of the packaging, components, and systems that are important to safety. This section should also describe package contents and ensure that the content properties support applicable regulatory requirements.

7.1. Codes and Standards

This section should identify the materials codes and standards proposed for use in package design, fabrication, assembly, testing, maintenance, and use in accordance with 10 CFR 71.31(c). Any exceptions or additions to those codes and standards should be identified. The use of proprietary, non-code materials should be supported by descriptions of qualification activities and data, key manufacturing procedures, and acceptance testing protocols.

For components of packaging that are not important to safety, sufficient information should be provided to assess their potential impacts on components of the packaging that are important to safety, such as the potential for chemical, galvanic, or other reactions.

7.2. Weld Design and Inspection

This section should describe the welding criteria used in the package design, fabrication, and testing in accordance with 10 CFR 71.31(c). Applicable codes or standards should be specified on the engineering drawings. For components for which no code or standard is applicable, the application should provide the welding criteria, including the welding processes, filler metal, qualification procedures, heat treatment, inspection, and testing.

7.3. Mechanical Properties

This section should provide material mechanical properties for components of the packaging that are important to safety. Mechanical properties (e.g., tensile, fracture toughness, and creep properties) should account for environmental and service conditions during normal conditions of transport and hypothetical accident conditions. For impact limiter materials, crush properties and the effects of strain rate should also be addressed. For materials for which no code or standard is applicable, the mechanical properties should be supported by technical references, qualification testing, or acceptance testing protocols.

7.4. Thermal Properties

This section should include the compositions and thermal properties of the materials that are used in heat transfer analyses, such as thermal conductivity, thermal expansion, specific heat, density, heat capacity, and emissivity over the range of service temperatures.

7.5. Radiation Shielding

This section should describe the compositions and geometries of shielding materials used in the package design. The application should include an assessment of material changes due to temperature extremes, radiation exposure, and aging mechanisms. The use of non-standard, proprietary materials should also be supported by material density data and qualification and acceptance testing protocols that demonstrate shielding performance.

This section should also describe manufacturing controls that are in place to ensure that cast materials, such as concrete, lead and polymers, are free of voids or other fabrication defects.

7.6. Criticality Control

This section should identify the materials used as neutron absorbers for criticality control. The application should describe the material's chemical composition, physical and mechanical properties, fabrication process, and minimum poison content. The application should also describe the qualification and acceptance testing requirements for neutron attenuation and other properties, such as the resistance to aging mechanisms. The basis for the level the absorber is credited in the criticality analysis should also be provided.

7.7. Corrosion Resistance

This section should identify the package materials and service environments and assess the effects of material degradation over the package's service life. Materials selection and other corrosion control measures should be described. For components that have been previously in service (e.g., dual-purpose cask systems), this section should evaluate the cumulative effects of corrosion during storage and transportation.

7.8. Protective Coatings

This section should describe all coatings and their intended functions. For coatings that are credited for maintaining an important to safety function, the application should list the components to be coated and provide the basis for the coating effectiveness and compatibility with the service environments, including a description of the coating qualification testing and ongoing maintenance activities.

7.9. Content Reactions

This section should assess the potential for significant chemical or galvanic reactions among package contents or between the packaging components and the package contents. In this assessment, the application should describe the package contents, including their physical and chemical form, and the contents' exposure environment. This section should evaluate the potential for flammable and explosive reactions, dissimilar material interactions, radiolysis, outgassing, and corrosion.

7.10. Radiation Effects

This section should evaluate the exposure of materials to radiation, which can cause microstructural changes that alter mechanical properties and reduce resistance to environmentally induced degradation. The application should assess potential damaging effects of radiation on all packaging components, such as seals, insulation, foams, coatings, adhesives, and structural materials.

7.11. Package Contents

This section should provide a description of the chemical and physical form of the package contents and define the role, if any, the contents fulfill in maintaining the package intended functions during normal conditions of transport and hypothetical accident conditions. The application should demonstrate that the chemical, physical, and mechanical properties of the contents are adequate to support the package's intended functions, considering content reactions (see Section 7.9), thermal properties, and structural properties, as applicable.

7.11.1 Fresh (Unirradiated) Fuel Cladding

For packages that contain fresh fuel, this section should identify the intended functions of the fuel cladding and, if applicable, demonstrate that the mechanical properties of the cladding materials are adequate to ensure that the fuel remains in the analyzed configuration during normal conditions of transport and hypothetical accident conditions.

7.11.2 Spent Fuel

For packages that contain spent fuel, this section should identify the intended functions of the fuel cladding and, if applicable, demonstrate that the mechanical properties of the cladding materials are

adequate to ensure that the fuel remains in the analyzed configuration during normal conditions of transport and hypothetical accident conditions.

This section should also describe the cladding alloys, maximum burnup, condition of the allowable fuel contents (i.e., intact, undamaged or damaged), and the physical characteristics that define those classifications. The application should also demonstrate that there are no credible degradation mechanisms during transport or prior storage that could affect the physical characteristics of the spent fuel or compromise the ability to meet fuel-specific or package-related functions. The effects of cladding oxidation, hydride rim, and drying and inerting methods (including their impact on cladding temperature) should be considered.

This section should further describe how damaged fuel is transported to ensure that subcriticality is maintained and that the geometric form of the fuel is not substantially altered, such as using a damaged fuel can. If the configuration of the fuel within an enclosure is not restricted, the application should contain an analysis to demonstrate that fuel can be safely transported assuming full reconfiguration.

7.12 Bolting Material

This section should identify the bolting materials and demonstrate that they have adequate resistance to corrosion, creep, and embrittlement under temperature and radiation exposures. The application should also demonstrate that the structural analysis accounts for stresses due to differential thermal expansion between the bolts and the joined components.

7.13 Seals

This section should identify the materials used in seals and demonstrate that the material properties are adequate for the application when considering the range of service temperatures and environments. The application should consider the effects of degradation due to corrosion, chemical reactions, and exposure to elevated temperatures and radiation. The application should also demonstrate that the permeability of the seal materials is adequate for the package's leak-tightness requirements.

7.14 Appendix

The appendix should include a list of references, applicable pages from referenced documents, supporting information and analysis, test results, and other appropriate supplemental information.

8. OPERATING PROCEDURES

This section of the application should describe the operations used to load a package and prepare it for transport, presenting the steps sequentially in the actual order in which they are performed. The operations should describe the fundamental steps needed to ensure that the package is properly prepared for transport, consistent with the package evaluation in Chapters 2–6 of the application.

The package should be operated in accordance with detailed written procedures that are based on and consistent with the operations described in this section of the application. The package operations should be consistent with maintaining occupational radiation exposures as low as reasonably achievable (ALARA) as required by 10 CFR 20.1101(b), "Radiation protection programs."

8.1 Package Loading

This section should describe loading-related preparations, tests, and inspections of the package, including the inspections made before loading the package to determine that the package is undamaged as required by 10 CFR 71.87(b) and that radiation and surface contamination levels are within the allowable limits in 10 CFR 71.87(j) and (i), respectively.

8.1.1 Preparation for Loading

At a minimum, the operations for preparing the package for loading should specify that the package is loaded and closed in accordance with detailed written procedures, the contents are authorized in the package approval, that the package is in unimpaired physical condition, and any required moderator or neutron absorber is present and in proper condition. The operations should also include any special controls and precautions for handling. In addition, the operations should describe the inspection of gaskets, criteria for replacement, and repair processes, if applicable, as well as the inspection of each closure device and criteria for replacement.

8.1.2 Loading of Contents

At a minimum, the operations for loading the contents should describe how the contents are loaded and how the package is closed.

8.1.3 Preparation for Transport

The operations for preparing the package for transport should address radiation and contamination surveys of the package, leakage testing of the package, measurement of the package surface temperature, package tie-down, and the application of tamper-indicating devices.

8.2 Package Unloading

This section should include inspections, tests, and special preparations of the package for unloading. As applicable, this section should also describe the operations used to ensure safe removal of fission gases, contaminated coolant, and solid contaminants.

8.2.1 Receipt of Package from Carrier

The process for receiving the package should address radiation and contamination surveys and inspection of the tamper-indicating device. This section should also describe any proposed special controls and precautions for handling and unloading, and address the appropriate requirements of 10 CFR 20.1906, “Procedures for Receiving and Opening Packages.”

8.2.2 Removal of Contents

This section should describe the appropriate operations and method for opening and removing contents from the package.

8.3 Preparation of Empty Package for Transport

This section should describe the inspections, tests, and special preparations needed to ensure that the packaging is verified to be empty, is properly closed, and that the radiation and contamination levels

are within allowable limits. In addition, this section should address the appropriate requirements of 49 CFR 173.428 “Empty Class 7 (Radioactive) Materials Packaging.”

8.4 Other Operations

This section should include the provisions for any special operational controls (e.g., route, weather, shipping time restrictions).

8.5 Appendix

The appendix should include a list of references, applicable pages form referenced documents, detailed descriptions and analysis of processes or protocols, graphic presentations, test results, and other supplemental information.

9. ACCEPTANCE TESTS AND MAINTENANCE PROGRAM

This section of the application should describe the acceptance tests and maintenance program to be used for the packaging in compliance with Subpart G of 10 CFR Part 71.

9.1 Acceptance Tests

This section should describe the tests to be performed before the first use of each packaging. Each test and its acceptance criteria should be described. The acceptance tests should confirm that each packaging is fabricated in accordance with the drawings referenced in the package approval.

9.1.1 Visual Inspections and Measurements

This section should describe the visual inspections to be performed and the intended purpose of each inspection. The criteria for acceptance of each inspection, as well as the action to be taken if noncompliance is encountered, should be described. The inspections should verify that the packaging has been fabricated and assembled in accordance with the drawings, and that all dimensions and tolerances specified on the drawings are confirmed by measurement.

9.1.2 Weld Examinations

This section should describe welding examinations used to verify fabrication in accordance with the drawings, codes, and standards specified in the application. The locations, types, and sizes of welds should be confirmed by measurement. Other applicable specifications for weld performance, nondestructive examination, and acceptance should be identified.

9.1.3 Structural and Pressure Tests

This section should identify and describe the structural or pressure tests. Such tests should comply with 10 CFR 71.85(b), as well as applicable codes or standards specified. The sensitivity of the tests, and the actions taken when the prescribed criteria are not met, should be specified.

9.1.4 Leakage Tests

This section should describe the leak tests (e.g., method, personnel qualification, test standard (see Ref. 4)) to be performed on the containment vessel, as well as auxiliary equipment. The sensitivity of

the tests should be specified including the basis of this value, the criteria for acceptance, and the action to be taken if the criteria are not met.

9.1.5 Component and Material Tests

This section should specify the appropriate tests and acceptance criteria for components that affect package performance. In addition, this section should specify test sensitivity, if applicable, provide acceptance criteria, and describe the action to be taken if those criteria are not met.

This section should also specify the appropriate tests and acceptance criteria for packaging materials. Tests should include those components, such as gaskets, under conditions that simulate the most severe service conditions under which they are to perform, including performance at pressure and under high and low temperatures. Tests for neutron absorbers (e.g., boron) and insulating materials (e.g., foams, fiberboard) should ensure that minimum specifications for density and isotopic content are achieved. In addition, tests that demonstrate the ability of the materials to meet the performance specifications shown on the engineering drawings should be described.

9.1.6 Shielding Tests

This section should specify the appropriate shielding tests for both neutron and gamma radiation. These tests and acceptance criteria should be sufficient to ensure that no defects, voids, or streaming paths exist in the shielding.

9.1.7 Thermal Tests

This section should specify the appropriate tests to demonstrate the heat transfer capability of the packaging. These tests should confirm that the heat transfer performance determined in the thermal evaluation (Chapter 3 of the application) is achieved in the fabrication process.

9.1.8 Miscellaneous Tests

This section should describe any additional tests to be performed prior to use of the packaging.

9.2 Maintenance Program

This section should describe the maintenance program used to ensure continued performance of the packaging. This 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.

9.2.1 Structural and Pressure Tests

This section should identify and describe any periodic structural or pressure tests. Such tests would generally be applicable to codes, standards, or other procedures specified in the application.

9.2.2 Leakage Tests

This section should describe the tests to be performed, the frequency with which those tests are performed, and the sensitivity of each test. For most systems, this description should include a test of the package before each shipment and annually. In general, this section should specify that elastomeric seals should be replaced and leak-tested within the 12-month period before shipment, and that metallic seals should also be replaced and tested before each shipment.

9.2.3 Component and Material Tests

This section should describe the periodic tests and replacement schedules for components. Any process that could result in deterioration of packaging materials, including loss of neutron absorbers, reduction in hydrogen content of shields, and density changes of insulating materials should be addressed. Replacement intervals for components, such as bolts, that are susceptible to fatigue should be specified.

9.2.4 Thermal Tests

This section should describe the periodic tests used to ensure heat-transfer capability during the service life of the packaging. This section should describe periodic thermal tests, similar to the acceptance tests discussed in Section 8.1.7, and the interval for the tests, which is typically 5 years.

9.2.5 Miscellaneous Tests

Any additional tests to be performed periodically on the package or its components should be described.

9.3 Appendix

The appendix should include a list of references, applicable pages from referenced documents, test data and reports, and other supplemental information.

10. QUALITY ASSURANCE PROGRAM

This chapter should include a description of the applicant's quality assurance program description (QAPD) or reference a previously approved QAP. The QAPD must demonstrate that the applicant's QAPD complies with the requirements of Subpart H of 10 CFR Part 71, "Quality Assurance."

10.1 Quality Assurance Organization

This section should include a description of the structure, interrelationships, and areas of functional responsibility and authority for all organizational elements that will perform activities related to quality and safety.

10.2 Quality Assurance Program

In this section, the description should provide acceptable evidence that the proposed QAPD will be well documented, planned, implemented, and maintained to provide the appropriate level of control over activities and packaging components consistent with their relative importance to safety.

10.3 Package Design Control

In this section, the applicant should describe the approach used to define, control, and verify the design and development of the transportation packaging.

10.4 Procurement Document Control

In this section, the applicant should describe how documents used to procure packaging components or services include or reference applicable design bases and other requirements necessary to ensure adequate quality.

10.5 Instructions, Procedures, And Drawings

In this section, the applicant should describe its proposed procedures for ensuring that activities affecting quality will be prescribed by, and performed in accordance with, documented instructions, procedures, or drawings of a type appropriate for the circumstances.

10.6 Document Control

In this section, the applicant should describe its proposed procedures for preparing, issuing, and revising documents that specify quality requirements or prescribe activities affecting quality.

10.7 Control of Purchased Material, Equipment, and Services

In this section, the applicant should describe its proposed procedures for controlling purchased material, equipment, and services to ensure conformance with specified requirements.

10.8 Identification and Control of Materials, Parts, and Components

In this section, the applicant should describe how it will identify and control materials, parts, and components to ensure that incorrect or defective packaging components are not used.

10.9 Control of Special Processes

In this section, the applicant should describe its controls to ensure the acceptability of special processes (such as welding, heat treatment, nondestructive testing, and chemical cleaning) and that the proposed controls are performed by qualified personnel using qualified procedures and equipment.

10.10 Internal Inspection

In this section, the applicant should define its proposed provisions for the inspection of activities affecting quality to verify conformance with instructions, procedures, and drawings.

10.11 Test Control

In this section, the applicant should describe its proposed provisions for tests to verify that packaging components important to safety conform to specified requirements and will perform satisfactorily in service.

10.12 Control of Measuring and Test Equipment

In this section, the applicant should describe its proposed provisions to ensure that tools, gauges, instruments, and other measuring and testing devices are properly identified, controlled, calibrated, and adjusted at specified intervals.

10.13 Handling, Storage, and Shipping Control

In this section, the applicant should describe its proposed provisions to control the handling, storage, shipping, cleaning, and preservation of packaging components important to safety in accordance with work and inspection instructions to prevent damage, loss, and deterioration.

10.14 Inspection, Test, and Operation Status

This section should provide the applicant's proposed provisions to control the inspection, test, and operating status of packaging components important to safety to prevent the inadvertent use of components or bypassing of inspections and tests.

10.15 Nonconforming Materials, Parts, or Components

In this section, the applicant should describe its proposed provisions to control the use or disposition of nonconforming materials, parts, or components.

10.16 Corrective Action

In this section, the applicant should describe its proposed provisions to ensure that conditions adverse to quality are promptly identified and corrected, and for significant conditions adverse to quality, that measures are taken to preclude recurrence.

10.17 Quality Assurance Records

In this section, the applicant should describe its proposed provisions for identifying, retaining, retrieving, and maintaining records that document evidence of the control of quality for activities and packaging components important to safety.

10.18 Audits

In this section, the applicant should describe its proposed provisions for planning and scheduling audits to verify compliance with all aspects of the QAPD and to determine the effectiveness of the overall program.

D. IMPLEMENTATION

The NRC staff may use this regulatory guide as a reference in its regulatory processes, such as licensing, inspection, or enforcement. Backfitting, forward fitting, and issue finality considerations do not apply to 10 CFR Part 71 licensees, Certificate of Compliance holders, and applicants because 10 CFR Part 71 does not include backfitting or issue finality provisions and the forward fitting policy in Management Directive 8.4, "Management of Backfitting, Forward Fitting, Issue Finality, and Information Requests" (Ref. 31), does not apply to these licensees. In addition, backfitting, forward fitting, and issue finality considerations do not apply to 10 CFR Part 71 licensees and applicants that are also 10 CFR Part 50 "Domestic Licensing of Production and Utilization Facilities," 10 CFR Part 52 "Licenses, Certifications, and Approvals for Nuclear Power Plants" (Ref. 32) 10 CFR Part 70 "Domestic Licensing of Special Nuclear Material," 10 CFR Part 72 "Licensing Requirements for the Independent Storage of Spent Nuclear Fuel, High-Level Radioactive Waste, and Reactor-Related Greater than Class C Waste," or 10 CFR Part 76 "Certification of Gaseous Diffusion Plants" licensees and applicants because they are using the guidance in this regulatory guide to demonstrate compliance with the requirements in 10 CFR Part 71.

REFERENCES [1]

1. *U.S. Code of Federal Regulations* (CFR), "Packaging and Transportation of Radioactive Material," Part 71 Chapter I, Title 10, "Energy."

2. CFR, "Standards for Protection Against Radiation," Part 20 Chapter I, Title 10, "Energy."

3. CFR, "Shippers - General Requirements for Shipments and Packagings," Part 173, Chapter I, Title 49 "Transportation."

4. NRC, Regulatory Guide (RG) 7.4, "Leakage Tests on Packages for Shipment of Radioactive Material," Washington, DC. (ADAMS Accession No. ML19240B383)

5. RG 7.6, "Design Criteria for the Structural Analysis of Shipping Cask Containment Vessels," Washington, DC. (ML003739418)

6. RG 7.7, "Administrative Guide for Verifying Compliance with Packaging Requirements for Shipments of Radioactive Material," Washington, DC. (ML112160407)

7. RG 7.8, "Load Combinations for the Structural Analysis of Shipping Casks for Radioactive Material," Washington, DC. (ML003739501)

8. RG 7.10, "Establishing Quality Assurance Programs for Packaging Used in Transport of Radioactive Material," Washington, DC. (ADAMS Accession No. ML14064A505)

9. RG 7.11, "Fracture Toughness Criteria of Base Material for Ferritic Steel Shipping Cask Containment Vessels with a Maximum Wall Thickness of 4 Inches (0.1 m)," Washington, DC. (ML003739413)

10. RG 7.12, "Fracture Toughness Criteria of Base Material for Ferritic Steel Shipping Cask Containment Vessels with a Wall Thickness Greater than 4 Inches (0.1 m) but Not Exceeding 12 Inches (0.3 m)," Washington, DC. (ML003739424)

11. NRC, "Standard Review Plan for Transportation Packages for Spent Fuel and Radioactive Material," NUREG-2216, Washington, DC, August 2020. (ML20234A651)

12. NRC, "Dry Storage and Transportation of High Burnup Spent Nuclear Fuel," NUREG-2224, Washington, DC, July 2020. (ML20191A321)

13. NRC, "Recommended Welding Criteria for Use in the Fabrication of Shipping Containers for Radioactive Materials," NUREG/CR-3019, Washington, DC, March 1984.

14. NRC, "Fabrication Criteria for Shipping Containers," NUREG/CR-3854, Washington, DC, March 1985. (ML20100F724)

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1 Publicly available NRC published documents are available electronically through the NRC Library on the NRC's public Web site at http://www.nrc.gov/reading-rm/doc-collections/ and through the NRC's Agencywide Documents Access and Management System (ADAMS) at http://www.nrc.gov/reading-rm/adams.html The documents can also be viewed online or printed for a fee in the NRC's Public Document Room (PDR) at 11555 Rockville Pike, Rockville, MD. For problems with ADAMS, contact the PDR staff at 301-415-4737 or (800) 397-4209; fax (301) 415-3548; or e-mail pdr.resource@nrc.gov.

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27. IAEA Specific Safety Guide No. SSG-26, "Advisory Material for the IAEA Regulations for the Safe Transport of Radioactive Material," Vienna, Austria, 2012.

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29. IAEA Safety Standards Series No. TS-G-1.4, "The Management System for the Safe Transport of Radioactive Material," Vienna, Austria, 2008.

30. IAEA Safety Standards Series No. TS-G-1.5, "Compliance Assurance for the Safe Transport of Radioactive Material," Vienna, Austria, 2009.

2 Copies of IAEA documents may be obtained through their Web site: WWW.IAEA.Org/ or by writing the International Atomic Energy Agency, P.O. Box 100 Wagramer Strasse 5, A-1400 Vienna, Austria.

31. NRC Management Directive 8.4, “Management of Backfitting, Forward Fitting, Issue Finality, and Information Requests,” Washington, D.C. (ML18093B087)

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