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REGULATORY GUIDE

OFFICE OF NUCLEAR REGULATORY RESEARCH

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

This regulatory guide provides guidance on preparing applications for approval of Type B and fissile material transportation packages. This guidance describes a method that is acceptable to the staff of the U.S. Nuclear Regulatory Commission (NRC) for complying with the agency's regulations in Title 10, Part 71, of the *Code of Federal Regulations* (10 CFR Part 71), "Packaging and Transportation of Radioactive Material." This guidance is not intended as an interpretation of NRC regulations, within the context of 10 CFR 71.2. Nothing contained in this guide is to be construed as having the force or effect of NRC regulations, or as indicating that applications supported by safety analyses and prepared in accordance with the recommendations of this regulatory guide will necessarily be approved, or as relieving any licensee from the requirements of 10 CFR Part 71 or any other pertinent regulations.

The primary purpose of this regulatory guide is to assist applicants in preparing applications that thoroughly and completely demonstrate the ability of the given packages to meet the regulations. In addition to package approval, applicants must have an approved quality assurance program in accordance with the provisions of 10 CFR 71.101 – 71.137. Regulatory Guide 7.10, "Establishing Quality Assurance Programs for Packaging Used in Transport of Radioactive Material," provides guidance on the details of developing quality assurance programs. The NRC may 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 preparing applications for package approval, applicants may find it useful to refer to other regulatory guides in Division 7, "Transportation," of the NRC's Regulatory Guide Series.

This regulatory guide contains information collections that are covered by the requirements of 10 CFR Part 71, which the Office of Management and Budget (OMB) approved under OMB control number 3150-0008. The NRC may neither conduct nor sponsor, and a person is not required to respond to, an information collection request or requirement unless the requesting document displays a currently valid OMB control number.

B. STANDARD FORMAT

PURPOSE OF THE STANDARD FORMAT

The application is the principal document in which an applicant provides the information and 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 and Content of Part 71 Applications for Approval of Packages for Radioactive Material" (hereinafter called "Standard Format") identifies the information to be provided and establishes a uniform format for presenting that information. Use of this format will help to ensure the completeness of an application, assist the NRC staff in locating the information, and aid in shortening the time needed to review the application.

APPLICABILITY OF THE STANDARD FORMAT

This Standard Format applies specifically to applications for approval of Type B and fissile material transportation packages, as specified in 10 CFR Part 71.

USE OF THE STANDARD FORMAT

The NRC staff finds the Standard Format 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. 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.

NUREG-1609, "Standard Review Plan for Transportation Packages for Radioactive Material," dated May 1999, and NUREG-1617, "Standard Review Plan for Transportation Packages for Spent Nuclear Fuel," dated March 2000, describe the practices that the NRC staff has 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

Applicants should 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. Claims regarding the adequacy of designs or design methods should be supported by technical bases (i.e., an appropriate engineering evaluation or description of actual tests). Terms should be used as defined in the packaging and transportation regulations.

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

Appendices to each section of an application should include detailed information omitted from the main text. The first appendix to a given section of an application should provide 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, it should also reference the nonproprietary summary description of that document.

Appendices to each section of an application should 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 regulatory guides and (2) supplementary information regarding calculational methods or design approaches used by the applicant.

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

Applicants should use abbreviations, symbols, and special terms consistently throughout an application and in a manner that is consistent with generally accepted usage. Each section of an application should define any abbreviations, symbols, or special terms used in the given section that are unique to the proposed packaging or not common in general usage.

Applicants should use drawings, diagrams, sketches, and charts when such means more accurately or conveniently present the information to be conveyed. However, applicants should ensure that drawings, diagrams, sketches, and charts present information in a legible form, with relevant symbols defined. In addition, applicants should not reduce drawings, diagrams, sketches, and charts to the extent that readers need visual aids to interpret pertinent information.

Applicants should number pages sequentially within each section and appendix. For example, the fourth page of Section 6 would be numbered 6-4.

REVISIONS

Applicants should update data and text by replacing pages, rather than using "pen and ink" or "cut and paste" changes. In addition, applicants should highlight the updated or revised portion of each page using a "change indicator" consisting of a bold vertical line drawn in the margin opposite the binding margin. The line should be the same length as the portion actually changed.

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

All statements on a revised page should be accurate as of the date of each submittal. Applicants should take special care to ensure that they revise the main sections of the application to reflect any design changes reported in supplemental information (e.g., responses to NRC staff requests for information or responses to regulatory positions).

PHYSICAL SPECIFICATIONS FOR PAPER SUBMISSIONS

All material submitted as part of the application should conform to the following specific standards for the physical paper size (dimensions); paper and ink quality; and numbering of pages, exhibits, and attachments.

Paper Size

Paper size should not exceed the following guidelines:

Text pages:	8½ × 11 inches
Drawings and graphics:	8½ × 11 inches preferred; however, a larger size is acceptable, provided that the following criteria are fulfilled: a. After reduction, the size does not exceed 11 × 17 inches, including a 2-inch left margin for binding. b. When folded, the finished copy does not exceed 8½ × 11 inches.

Each new or revised drawing should have a drawing number; sheet number; title; revision number and date; company name; and signature, initials, or other identifier indicating approval of the drawing and each revision thereto.

Paper Stock

Weight or substance:	20 – 28 pound for printing on both sides 16 – 20 pound for printing on one side only
Composition:	Wood chemical sulfite (no groundwood) and a pH of 5.5
Color:	White is preferred, but pastel colors are acceptable provided the combination of paper stock and ink is suitable for microfilming.

Ink

The ink color should be sufficiently dense to record on microfilm or image-copying equipment.

Page Margins

Applicants should maintain a margin of at least 1 inch on the top, bottom, and binding side of all pages.

Printing

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

Binding

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

Separators

Applicants should provide separators to demarcate each section of the application.

Number of Copies

Applicants must provide one copy and may submit additional convenience copies as desired.

ELECTRONIC SUBMISSIONS

If an applicant submits all or part of an application electronically, the submission must be made in a manner that enables the NRC to receive, read, authenticate, distribute, and archive the submission, and process and retrieve it one page at a time. Requirements for electronic submissions are detailed in 10 CFR 71.1.

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 and must include information 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.

C. REGULATORY POSITION

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 model number, and, in the case of fissile packages, the proposed criticality safety index (CSI).

1.2 Package Description

1.2.1 Packaging

The general packaging description should include the following information:

- 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
- 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 nonfissile 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
- 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 Appendix

The appendix should include the engineering drawings for the packaging. The drawings should clearly detail the safety features 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 material properties, 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, fabrication, assembly, testing, maintenance, and use. 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 Materials

2.2.1 Material Properties and Specifications

This section should list the material mechanical properties used in the structural evaluation. These may include yield stress, ultimate stress, modulus of elasticity, ultimate strain, Poisson's ratio, density, and coefficient of thermal expansion. If impact limiters are used, this section should include either a compression stress-strain curve for the material or the force-deformation relationship for the limiter, as appropriate. For materials that are subjected to elevated temperatures, the appropriate mechanical properties under those conditions should be specified. The source of the information in this section should be identified by publication and page number. Where material properties are determined by testing, this section should describe the test procedures, conditions, and measurements in sufficient detail to enable the staff to evaluate the validity of the results.

2.2.2 Chemical, Galvanic, or Other Reactions

This section should describe possible chemical, galvanic, or other reactions in the packaging or between the packaging and the package contents, as well as methods used to prevent significant reactions. For each component material of the packaging, this section should list all chemically or galvanically dissimilar materials in contact with it. Coatings used on internal or external package surfaces, any reactions resulting from water inleakage or cask flooding, and the possible generation of hydrogen or other gases from chemical or radiolytic interactions should be considered. Galvanic interactions and the formation of a eutectic for components that are, or may be, in physical contact should also be considered.

2.2.3 Effects of Radiation on Materials

This section should describe any aging or damaging effects of radiation on the packaging materials. These may include degradation of seals, sealing materials, coatings, adhesives, and structural materials.

2.3 Fabrication and Examination

2.3.1 Fabrication

This section should describe the fabrication processes used for the package, such as fitting, aligning, welding and brazing, heat treatment, and foam and lead pouring. For fabrication specifications prescribed by an acceptable code or standard (e.g., those promulgated by the American Society of Mechanical Engineers or the American Welding Society), the code or standard should be clearly specified on the engineering drawings. Unless the application justifies otherwise, specifications of the same code or standard used for design should also be used for fabrication. For components for which no code or standard is applicable, the application should identify the specifications on which the evaluation depends, and describe the method of control to ensure that these specifications are achieved. This description may reference quality assurance or other appropriate specifications documents, which should be identified on the engineering drawings.

2.3.2 Examination

This section should describe the methods and criteria by which the fabrication is determined to be acceptable. Unless the application justifies otherwise, specifications of the same code or standard used for fabrication should also be used for examination. For components for which no fabrication code or standard is applicable, the application should summarize the examination methods and acceptance criteria in Section 8, "Acceptance Tests and Maintenance Program."

2.4 General Requirements for All Packages

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

2.4.1 Minimum Package Size

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

2.4.2 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.

2.4.3 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.

2.5 Lifting and Tie-Down Standards for All Packages

2.5.1 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.

2.5.2 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.

2.6 Normal Conditions of Transport

This section should describe the evaluation that shows the package meets the standards specified in 10 CFR 71.43 and 7.51, 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 under normal conditions of transport 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 sections listed below, 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 with the acceptance criteria.
- An assessment should be included that shows that the normal conditions do not reduce the effectiveness of the package.

2.6.1 Heat

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

2.6.1.1 Summary of Pressures and Temperatures. This section should summarize all pressures and temperatures derived in Section 3, "Thermal Evaluation," that will be used to perform the calculations needed for Sections 2.6.1.2 – 2.6.1.4.

2.6.1.2 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 sufficiently comprehensive to demonstrate package integrity under normal transport conditions.

2.6.1.3 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, will cause fatigue failure or extensive accumulations of deformation.

2.6.1.4 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.

2.6.2 Cold

The thermal evaluation under cold conditions should be described and reported in Section 3, "Thermal Evaluation." Using the results from Section 3, this section 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 EC (-20 EF) is the lowest service temperature that needs to be considered, as specified in 10 CFR 71.73(b).

2.6.3 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.

2.6.4 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.

2.6.5 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.

2.6.6 Water Spray

This section should show that the water spray test has no significant effect on the package.

2.6.7 Free Drop

This section should describe the package evaluation for the effects of a free drop. The general comments in Section 2.7.1 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 2.6.

2.6.8 Corner Drop

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

2.6.9 Compression

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

2.6.10 Penetration

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

2.7 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 confirm that the package effectiveness has not been reduced as a result of the normal conditions of transport, as included in Section 2.6. Brittle fracture should also be considered. This section should include applicable information regarding tests and analyses, as described in Section 2.6, above.

2.7.1 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.

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

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

2.7.1.3 Corner Drop. This section should describe the effects of the corner drop test.

2.7.1.4 Oblique Drops. This section should describe the effects of oblique drops, 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.

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

2.7.2 Crush

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

2.7.3 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 2.6 and 2.7.1 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.

2.7.4 Thermal

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

2.7.4.1 Summary of Pressures and Temperatures. This section should summarize all of the temperatures and pressures, as determined in Section 3, "Thermal Evaluation," of the application.

2.7.4.2 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.

2.7.4.3 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.

2.7.4.4 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.

2.7.5 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.

2.7.6 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.

2.7.7 Deep Water Immersion Test (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.

2.7.8 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.

2.8 Accident Conditions for Air Transport of Plutonium

If applicable, this section should address the accident conditions specified in 10 CFR 71.74.

2.9 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).

2.10 Special Form

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 when subjected to the applicable test conditions of 10 CFR 71.77. 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.

2.11 Fuel Rods

In Section 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.

2.12 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, discuss, 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 source terms assumed in the shielding and containment analyses.

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
- 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 and the radioactivity of the contents should be specified. This section should show the derivation of the decay heat and that it is consistent with the maximum quantity of radioactive contents.

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
- 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 absorptivities and emissivities 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
- minimum allowable service temperature of all components, which should be less than or equal to -40 EC (-40 EF)

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, the differences should be described and justification given 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)
- changes in material conditions or properties (e.g., expansion, contraction, 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)
- 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
- 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, 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.

3.4.5 Accident Conditions for Fissile Material Packages for Air Transport

If applicable, address the expanded fire test conditions specified in 10 CFR 71.55(f).

3.5 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 and input and output files, specifications of O-rings and other components, detailed materials test data, and other supplemental information.

4. CONTAINMENT

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
- 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
- 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. For Type B packages, the evaluation should show that there is no release under normal conditions of transport to the required sensitivity.

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 dose 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 Table 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, 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 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 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)
- 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 uncertainty, the bias, 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
- 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
- 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 inleakage to the containment system as specified in 10 CFR 71.55(b)
- 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 that water would not leak into the package, water inleakage need not be assumed)
- 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
- 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
- no water inleakage

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 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. PACKAGE OPERATIONS

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 Sections 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 the "Standards for Protection Against Radiation" in 10 CFR 20.1101(b).

7.1 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 not damaged and radiation and surface contamination levels are within allowable limits of the regulations.

7.1.1 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.

7.1.2 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.

7.1.3 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.

7.2 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.

7.2.1 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."

7.2.2 Removal of Contents

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

7.3 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 and 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."

7.4 Other Operations

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

7.5 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.

8. 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.

8.1 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.

8.1.1 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.

8.1.2 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.

8.1.3 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.

8.1.4 Leakage Tests

This section should describe the leak tests 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.

8.1.5 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.

8.1.6 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.

8.1.7 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 (Section 3 of the application) is achieved in the fabrication process.

8.1.8 Miscellaneous Tests

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

8.2 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.

8.2.1 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.

8.2.2 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.

8.2.3 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.

8.2.4 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.

8.2.5 Miscellaneous Tests

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

8.3 Appendix

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

REGULATORY ANALYSIS

The NRC staff did not prepare a separate regulatory analysis for this regulatory guide. The staff found it necessary to revise this regulatory guide to ensure consistency with the final rule that brings 10 CFR Part 71 into harmony with the 1996 Edition of the "Regulations for Safe Transport of Radioactive Material (TS-R-1) promulgated by the International Atomic Energy Agency. NUREG/CR-6713, "Draft Regulatory Analysis of Major Revision of 10 CFR Part 71," provides a related regulatory analysis. A summary of the analysis follows:

> The resulting rulemaking would modify 10 CFR Part 71 requirements pertaining to the packaging and transport of radioactive materials, including fissile materials. The rulemaking is intended to: (1) harmonize 10 CFR Part 71 with the most recent transportation standards established by the International Atomic Energy Agency (IAEA), and the U.S. Department of Transportation's (DOT) requirements at 49 CFR; and (2) address the Commission's goals for risk-informed regulations and eliminating inconsistencies between Part 71 and other parts of 10 CFR. Based on this analysis, none of the 19 potential changes evaluated are expected to result in significant impacts. In fact, the analysis indicates that most of the changes will have negligible impacts or result in slight increases in values.

A copy of NUREG/CR-6713 is available for inspection and copying (for a fee) at the NRC's Public Document Room (PDR), which is located at 11555 Rockville Pike, Rockville, Maryland. The PDR's mailing address is USNRC PDR, Washington, DC 20555-0001. The PDR can also be reached by telephone at (301) 415-4737 or (800) 397-4205, by fax at (301) 415-3548, and by email to PDR@nrc.gov. Copies of NUREG/CR-6713 are also available (at current prices) from the U.S. Government Printing Office (GPO) at P.O. Box 37082, Washington, DC 20402-9328; GPO can also be reached by telephone at (202) 512-1800. In addition, copies of NUREG/CR-6713 are available (at current prices) from the National Technical Information Service at 5285 Port Royal Road, Springfield, VA 22161, on the Internet at http://www.ntis.gov, or by telephone at (703) 487-4650.