

**Safety Guide 100**

**DESIGN GUIDE FOR PACKAGING AND OFFSITE TRANSPORTATION  
OF NUCLEAR COMPONENTS, SPECIAL ASSEMBLIES, AND RADIOACTIVE  
MATERIALS ASSOCIATED WITH THE NUCLEAR EXPLOSIVES  
AND WEAPONS SAFETY PROGRAM**

**CHAPTER 1.0**

**INTRODUCTION TO THE GUIDE**

November 7, 1994

MARTIN MARIETTA ENERGY SYSTEMS, INC.

Oak Ridge, TN 37830

**THIS PAGE INTENTIONALLY LEFT BLANK**

## CONTENTS

	<u>Page</u>
ACRONYMS .....	v
1.0 INTRODUCTION TO THE GUIDE .....	1-1
1.1 PACKAGE DETERMINATION .....	1-3
1.2 PACKAGING DEVELOPMENT .....	1-9
1.3 PACKAGE DESIGN AND DEMONSTRATION .....	1-12
1.4 SARP PREPARATION .....	1-15
1.5 SARP REVIEW AND CERTIFICATION .....	1-22
1.6 PACKAGING FABRICATION .....	1-24
1.7 OPERATIONS .....	1-25
1.8 MAINTENANCE .....	1-26
1.9 PACKAGING MODIFICATION .....	1-27
1.10 MAINTAINING CERTIFICATION .....	1-29
1.11 PACKAGE USEFUL LIFE .....	1-30
1.12 DECOMMISSIONING AND DECERTIFICATION .....	1-31
1.13 DISPOSAL .....	1-32
1.14 REFERENCES .....	1-33
1.15 BIBLIOGRAPHY .....	1-37
APPENDIX A -DETERMINATION OF THE $A_1/A_2$ VALUE FOR MIXTURES .....	1-39
DESIGN PROCESS FLOW CHARTS .....	Separate Tab

**THIS PAGE INTENTIONALLY LEFT BLANK**

## ACRONYMS

ALARA	As Low As Reasonably Achievable
DOD	Department of Defense
DOE	Department of Energy
DOT	Department of Transportation
EPA	Environmental Protection Agency
IAEA	International Atomic Energy Agency
LSA	Low Specific Activity
MFP	Mixed Fission Product
NRC	Nuclear Regulatory Commission
OTC	Offsite Transportation Certificate
SARP	Safety Analysis Report for Packaging
SER	Safety Evaluation Report

**THIS PAGE INTENTIONALLY LEFT BLANK**

## 1.0 INTRODUCTION TO THE GUIDE

The United States Government in cooperation with other countries regulate the design and use of hazardous materials with special emphasis on radioactive materials. These regulations serve to protect the public and worker safety, health, and the environment from the inherent risks from transportation of radioactive materials.

The U.S. agencies charged with the regulation and control of radioactive materials are the Departments of Transportation (DOT)<sup>[1]</sup>, Energy (DOE)<sup>[2]</sup>, and Defense (DOD)<sup>[3]</sup> along with the Nuclear Regulatory Commission (NRC)<sup>[4]</sup>. DOT regulates the shipment by all modes of transport of all hazardous materials, substances, and wastes in commerce. They also establish the requirements for the manufacture, fabrication, marking, maintenance, reconditioning, repairing, or testing of packaging which is represented, marked, certified, or sold for use in transport. NRC establishes the requirements for the packaging, preparation for shipment, and transportation of licensed material; and procedures and standards for approval of packaging and shipping procedures for fissile or other licensed materials that exceed a given quantity. The Postmaster General<sup>[5]</sup> and DOE<sup>[6]</sup> establishes the requirements for transportation of radioactive materials under their directions against standards equivalent to those specified by NRC.<sup>[4]</sup> The U.S. Environmental Protection Agency (EPA)<sup>[7]</sup> has established transportation-related requirements for hazardous substances and wastes. Packaging containing hazardous materials sent by mail must comply with DOT. International shipments of radioactive materials are regulated through DOT by the International Atomic Energy Agency (IAEA).<sup>[8]</sup>

The packaging used to transport radioactive materials range in size from small, fiberboard packages to very large, concrete and steel casks. The design of these packages considers a wide range of problems, such as the removal of radioactive heat decay, shielding the public from gamma and neutron

particle emissions, ensuring nuclear subcriticality control, and controlling the dispersion of radioactive material. The regulations for transporting radioactive materials are based on internationally accepted performance standards. These standards divide the materials into three broad categories based on their radioactivity levels: low hazards or very low levels of radioactivity, somewhat higher levels of radioactivity requiring secure packages, and fissile materials and those with very high levels of radioactivity requiring exceptionally durable containers.

This safety design guide concentrates on the packaging that ship fissile or other radioactive materials under the direction of DOE for defense programs. The packagings tend to be small, have a mass that is less than 3000 kg, and do not have any special design features for radiation shielding. The design of large shipping casks that are typical of spent, nuclear reactor fuels and high-neutron emitting isotopes are addressed in the Cask Designer's Guide.<sup>[9]</sup>

## **DESIGN PROCESS FLOW CHARTS**

This chapter of the Design Guides introduces the design process as a whole. The design process, as well as the entire life cycle of a transportation package, is depicted on a series of flow charts found at the end of this chapter. The flow charts should be used in conjunction with all the chapters of this guide to formulate a complete and thorough package design. The flow charts provide the basic function for the package design process and the chapters of this guide provide elaboration of those functions. There are cross-references to this guide given with all the functions on the flow charts. A description of the numbering system on the charts is given on the first page of the tabbed section (entitled "Flow Charts") at the end of this chapter.

The remainder of Chap. 1 includes some general information needed by a design team for a package design project.

## **1.1 PACKAGE DETERMINATION**

Transporting radioactive material over public thoroughfares using radioactive material packaging is regulated by federal agencies. Anyone who knowingly or willfully violates provisions of the regulations is subject to civil and criminal penalties. Therefore, it is essential that the packaging be selected or designed and used correctly. Regulatory guidelines for packaging design ensures that radioactive material dispersion, radiation, and decay heat are limited to acceptable national standards and that a nuclear criticality event is prevented from occurring.

Procedures to ensure safe packaging for transporting radioactive materials include categorizing the materials according to radiation levels and material form and requiring the preparation and use of packaging appropriate for the form and quantity of material.

The quantity of radioactive material shipped is a function of specific activity. The specific activity is reported by federal agencies. A table of specific activities is given in 10 CFR 71, Table A-1 for most radionuclide for domestic shipments of radioactive material. International shipments of radioactive material should reference the specific activities given in Safety Series No. 6. There are differences between the domestic and international regulations for specific activity. International transport of radioactive materials must consider the more conservative of the two values for specific activity.

The radionuclide may be either special or normal form. Special form radioactive material must satisfy the following conditions: it is either a single piece or is contained in a sealed capsule that can be

opened only by destroying the capsule; the piece or capsule has a least one dimension not less than 5 mm (0.197 in.); and it satisfies the packaging test requirements of 49 CFR 173.469. Special form materials are generally encapsulated solids that present a hazard due to direct external radiation if they escape from the package. Special form solid material is not readily dispersible and has high physical integrity; thus, it poses relatively little risk to personal health from inhalation or ingestion. If the radionuclide does not satisfy these conditions, then it is normal form.

The referenced tables for specific activity gives two values,  $A_1$  for special form material and  $A_2$  for normal form material. The quantity of material that may be shipped as special form is much larger than that allowed for normal form. Thus,  $A_1$  is equal to or larger than  $A_2$ .

The activity for an unknown radionuclide use conservative values that are dependent on the atomic number of that radionuclide (see 10 CFR 71, Appendix A, Sections I and II for the determination). The values for  $A_1$  and  $A_2$  for those elements with an atomic number of 82 or greater (starting with lead) are equated to the most reactive values which are represented by the plutonium isotopes  $^{239}\text{Pu}$  and  $^{240}\text{Pu}$ . Transportation of these fissionable elements present concerns associated with nuclear criticality and radiation hazards. The values for  $A_1$  and  $A_2$  for those elements with an atomic number less than 82 are equated to the those established for mixed fission products (MFPs) or for the strontium isotope  $^{90}\text{Sr}$ . Transportation of these elements present concerns associated with radiation hazards.

The specific activity for mixtures of radionuclides is determined where the identify and activity of each radionuclide is known. If either the identify or the activity or both are unknown, then the specific activity uses conservative values which are based on the type of radiation present. The activity becomes:

$$F_n = \text{total activity of } R_n/A_1 \text{ of } R_n$$

where:

$A_1(R_1, R_2, \dots R)$  is the  $A_1$  or  $A_2$  value as appropriate for the nuclide  $R_1, R_2, \dots R_n$ . The permissible activity of a source to be carried in a Type A packaging is such that  $F_1 + F_2 + \dots F_n$  must be less than unity.

The radioactivity in the material determines the packaging standards regardless of the design of the packaging or the built-in safety features. Radioactive packaging is represented by five subdivisions: not radioactive, excepted or limited quantity, low specific activity, Type A, and Type B. The packaging is considered to be a fissile material, Type A or B package if the radioactive material is fissile ( $^{233}\text{U}$ ,  $^{235}\text{U}$ ,  $^{238}\text{Pu}$ ,  $^{239}\text{Pu}$ , and  $^{241}\text{Pu}$ ).

**Not Radioactive.** A material with a specific activity that is less than 0.002 microcuries per gram of material is not, by definition, a radioactive material. There are no federal regulations for transportation packaging for such material.

**Excepted or Limited Quantity.** A material with a specific activity greater than 0.002 microcuries per gram of material but less than the limits established by Table 7 (49 CFR 173.423) is an excepted or limited quantity radioactive material. This material can be shipped in a strong, tight container. After October 1, 1996, this material will require performance oriented packagings that are certified to material-related performance parameters.

**Low Specific Activity (LSA) Material.** A material is LSA material if the specific activity is sufficiently low that the radiological hazard presented by inhalation or ingestion of the material is very small. This material may be shipped in either DOT Specification 7A Type A packages, 49 CFR 178.350. It may also be transported in a strong, tight container when consigned as exclusive use. After October 1, 1996, a strong-tight container will not be allowed. Transportation of such material will require performance oriented packages that are certified to material-related performance parameters. Generally, such packages will be Industrial Packages that require an increasing level of test verification approaching test required for Type A or B packages. It is possible to exceed an  $A_2$  quantity of radioactive material in an LSA shipment, providing it meets the three criteria of activity concentration and mixing.

**Type A.** A Type A package can ship a radioactive content that is less than or equal to  $A_1$  or  $A_2$ . It is designed to contain the radioactive material below the regulatory release limit ( $A_1$  or  $A_2 \times 10^{-6}$  per hour). It is also designed to maintain radiation exposure below that allowed (49 CFR 173.441). Both the dispersion and radiation under normal conditions of transport must be demonstrated by the tests set forth by DOT in 49 CFR 173.465 or 173.466. If the radioactive material is also fissile, the package must also meet the test requirements set forth by DOT in 49 CFR 173.467 and NRC in 10 CFR 71. These tests represent hypothetical accident conditions in transportation. Such a package would be designated as Type AF.

**Type B.** Type B packaging together with its radioactive content that is greater than  $A_1$  or  $A_2$ , requires certifying official approval. It is designed to retain the integrity of containment and shielding required by DOT and NRC under normal conditions of transport and hypothetical accident test conditions set forth in 10 CFR 71.17 and 71.73. International shipments of Type B packaging may either be approved unilaterally or multilaterally. Packaging with an operating pressure that exceeds 0.69 MPa (100 psig) or a relief device that would allow the release of radioactive material to the environment under

hypothetical accident conditions specified by NRC in 10 CFR 71.73, requires multilateral approval. Such a package is designated as Type B(M). Otherwise, the package is approved unilaterally and is designated as Type B(U). Incidentally, the shipping route for Type B packages whose contents exceed 3000 A<sub>1</sub>, 3000 A<sub>2</sub>, or 30,000 Curies must be controlled to provide additional safety to the public, such as avoiding large population centers.

Packaging together with its radioactive and fissile contents requires competent authority approval. This is true for any quantity of fissile material (<sup>238</sup>Pu, <sup>239</sup>Pu, <sup>241</sup>Pu, <sup>233</sup>U, and <sup>235</sup>U) whose specific activity is greater than the limits of Table 7 (49 CFR 173.423). The packaging is designed to retain the integrity of containment and shielding required by DOT and NRC under normal conditions of transport and hypothetical accident test conditions set forth in 10 CFR 71.17 and 71.73. The fissile materials are classified according to the controls needed to provide nuclear criticality safety during transportation, as provided by DOT in 49 CFR 173.455 and NRC in 10 CFR 71.55 through 71.63. Type B packaging whose radioactive contents is also fissile is designated as Type B(M)F or Type B(U)F.

The total amount of material to be shipped will determine which of the packaging described above is used. There are some exceptions for small quantities of radioactive material. Transporting small amounts requires the minimum of design control and demonstration, but this is offset by requiring either more packages or more shipments to transport all of the radioactive material. Thus, the package user and designer must determine an optimum balance between transportation and packaging costs.

Once the form and quantity of the radioactive material have been determined and the packaging type determined, the package can be selected. The first choice should be to use an existing certified package. There are a number of packages certified by DOT (49 CFR 173.413-173.427) or NRC (NUREG-0383<sup>[10]</sup>) and authorized by DOE for use. If the packaging type, and material form and

quantity meets the content requirements of these certified packages, then the user may be able to use them directly. The user must meet all the requirements of quality assurance and operations according to the DOT or NRC standards. The applicant must petition either the NRC competent authority or DOE certifying official for authorization to use the package. The quality assurance and operational procedures must be in place prior to the packaging use.

The second choice should be to use an existing package whose certification may be renewed. However, this may require a complete recertification if the quality assurance records have not been kept or if the package design could not meet current standards.

The third choice would be to petition DOT, NRC, or DOE for authorization to allow a different material or quantity of material in a certified package. This may reduce some of the safety documentation; it would reduce the design and verification efforts.

A fourth choice would be to request for a DOT or NRC exemption or a DOE alternative. These are limited to one-time-only shipments or for shipments of national security. This type of package would be approved by the appropriate federal agency. The user would be required to demonstrate the various levels of administrative controls required to ship safely. The exemptions and alternatives are not easily obtained and should not be included in one's plans. These are generally held for very special circumstances and require a very high level of authority signature.

If none of the options for package selection is satisfactory, then a new package design is the only recourse.

## 1.2 PACKAGING DEVELOPMENT

If there are no options available to use existing packaging, then the applicant must develop new packaging to fulfill the mission. Prior to the development of the packaging, the applicant must understand all of the packaging requirements which includes federal, state, and local requirements and your requirements. This includes DOT, NRC, DOE, and IAEA regulations. These requirements are often extended or supplemented at the applicant's facility to meet more stringent safety requirements. Also, the content to be shipped may add unique requirements. Requirements unique to the facility and content should be documented in a system requirements document to include all functional and operational requirements. The system requirements document should be baselined within a configuration management system. It should be revised to reflect changes as the project proceeds.

The system requirements are prepared by project management and provided to the project participants as the basis for their work. The number of requirements should be minimized to allow the designers and analysts as much freedom as possible. The systems requirements should include the following, as a minimum:

1. **Material characteristics.** This should include any parameter that may influence design decisions. This data should be documented through drawings, data sheets, procurement certificates, measures, material log books, or any first hand account of the data. The data should be signed and dated by a witness. This information should be kept in the records system for the life of the packaging. Some material parameters of interest are:
  - Chemical
  - Radioactivity

- Physical form
  - Mass
  - Density
  - Volume
  - Age
- **Transportation campaign.** The criticality and shielding evaluations, federal shipping restrictions, and the campaign information will determine the maximum quantity of material allowed per package. This information will also help the designers to decide between reusable and single-use packaging. Some transportation campaign information of interest are:
    - Quantity of material
    - Mode of transport
    - Shipping schedule
    - Number of shipments
  - **Special operational requirements.** The material and packaging operations may require design features and impose special operational procedures or more stringent safety standards. Some special requirements are:
    - Absorption of moisture
    - Cost
    - Handling
    - Inner packaging
    - Maintenance

- Moderation control
- Quality
- Radiation shielding
- Security measures
- Tie-down

It is prudent to assess the activities needed to verify that all federal regulations and system requirements have been met before the designer and analyst prepare a verification plan. The verification assessment is a team effort by management, designers, analysts, test engineers, operators, quality, and procurement. Each must examine the federal regulations and system requirements and prepare a statement of how the requirements will be met. A verification plan should be prepared that documents each requirement and their respective action plan. A matrix for each federal regulation may be prepared that identifies each requirement, who is responsible, when the verification activity should be completed, and how the requirement will be achieved. The verification plan should be baselined within a configuration management system. It should be revised to reflect changes as the project proceeds. It is important that this plan be completed early. It is easy to overlook requirements.

Integral with the federal regulations are quality requirements. Total quality management is essential from the time packaging ideas are conceived until the packaging no longer exists. Each federal agency espouses its own brand of quality assurance (see below); however, a close look at these will show that they are all basically the same:

<u>Federal Agency</u>	<u>Quality Regulations</u>
DOT	49 CFR 173
NRC	10 CFR 71, Subpart H/NQA-1 <sup>[11]</sup>
DOE	5700.6C <sup>[12]</sup> /QC-1 <sup>[13]</sup>
IAEA	Safety Series No. 6/ISO 9000 <sup>[14]</sup>

Quality assurance plans should address all of the elements applicable to the packaging development effort. This plan should identify what procedures will be used to achieve the quality requirements. This plan should be available prior to the initiation of the packaging effort. The quality assurance plan should be submitted to the federal agency prior to initiation of the packaging effort. This allows the competent authority to assess the adequacy of your packaging program to develop packaging consistent with the federal regulations.

### **1.3 PACKAGE DESIGN AND DEMONSTRATION**

The design and demonstration phase of the packaging consists of very important activities that translate the system requirements, verification plan, and quality assurance plan into a successful packaging design. The designer should developed design criteria based on all requirements. This document should describe the functional and physical requirements of the packaging, define the developmental and engineering evaluations necessary to establish the design basis, and provide guidelines to evaluate, demonstrate, or substantiate the fulfillment of the design objectives. The following information should be contained in the design criteria, as a minimum:

- Scope and general description of the proposed packaging

- Method of accomplishing the project
- Applicable codes, standards, and specifications and requirements for verification of design calculations and any software used to perform design calculations
- Reference documents, drawings, and sketches
- Packaging test plan requirements
- Design parameters and design requirements
- Special requirements and provisions (quality, environmental, safety, security, health physics, nuclear safety, reliability, maintainability, handling)
- Appropriate cost and schedule information

From the design criteria, the designers will prepare the drawings, equipment specifications, and material specifications. The procurement instructions and specifications will use the information from these documents for items or services purchased to perform verification activities and subsequently for packaging production.

The selected method of verification may include testing, analysis, or a combination of both. A detailed verification plan should be developed that addresses the methods of achieving the packaging requirements. This plan may be a further refinement of the verification plan discussed in the previous subsection. Either way, this plan should include the specific test or analysis plan requirements. The test

or analysis plan should then be followed by detailed test or analysis procedures. The test or analysis acceptance or rejection criteria should be stated in the plans and procedures.

Reviews should be conducted several times during the design phase, such as a preliminary, critical, and final design review. The information presented below should be presented, either in draft or final form.

- Design criteria
- Design drawings
- Equipment specifications
- Material data sheets
- Test verification plan and procedures
- Analysis verification plan and procedures
- Design calculations
- Analysis results
- Test results
- Test report

The last four items listed above should be reviewed by the project in a timely manner. The data should demonstrate compliance with requirements. The results should be presented on calculation data sheets; test results data forms, photographs, and videos; and computer generated graphs, plots, and charts. The test results should be well documented in a test report that will be used in the Safety Analysis Report for Packaging (SARP) directly or by reference.

The documents presented above should be baselined within a configuration management system. The document should be revised accordingly.

The ultimate goal of the design and verification effort is to obtain a certificate to ship the material identified. This will require the preparation of a SARP and its subsequent review and acceptance by the certifying official. It is important that the certifying official be cognizant of the design and verification results as early as possible to preclude any problems that may occur. Thus, all baseline documents should be forwarded to the certifying official. Furthermore, the certifying official and agents should be invited to participate in formal design reviews and witness tests as appropriate.

The culmination of the design and verification phase will lead to the preparation of the SARP. The SARP, which is discussed in the next subsection, should clearly demonstrate that all of the requirements have been met with a clear margin of safety to protect the public, the workers, and the environment.

#### **1.4 SARP PREPARATION**

The SARP is the final resting place for proving compliance to all the requirements for the packaging. It is very important that the SARP provide convincing information that demonstrates to the certifying official that the package meets all of the requirements with a clear margin of safety to protect the public, the workers, and the environment.

The basis for the safety document comes from the requirements given in 49 CFR 17 1-180 and 10 CFR 71. The package is also subject to other parts of Title 10 (e.g., Parts 20, 21, 30, 39, 40, 70, and 73). Requirements for packaging for international shipments are provided by IAEA Safety Series

No. 6 and 9. Packaging certified through DOE must adhere to the safety requirements of DOE Order 5480.3<sup>[15]</sup> or 5610.1<sup>[16]</sup> (or 5610.12). These orders refer to the NRC, DOT, and IAEA requirements where applicable. Where these are not applicable, DOE provides additional guidance for Transportation Safety Risk Assessments<sup>[17]</sup>.

The information in the SARP is unique to the packaging and content; however, the format of the SARP has been provided by NRC in the Regulatory Guides 7.9<sup>[18]</sup> and 7.10<sup>[19]</sup> is uniform. These guides were established over the years through experience with the purpose of standardizing the SARP preparation and review process. Even though these are only guides (and not requirements), it is highly recommended that they be used to the letter. By using these guides, the SARP is more easily reviewed which should ultimately reduce the time for certification. If the applicant needs to change the format or add sections, it is recommended that such deviations be well documented in the SARP to guide the reviewer.

There are a number of additional documents published by the NRC or other authoritative bodies that may be used by the applicant in the preparation of the SARP. These included the following:

- NUREG/CR-3854, *Fabrication Criteria for Shipping Containers*<sup>[20]</sup>
- NUREG/CR-5717, *Packaging Supplier Inspection Guide*<sup>[21]</sup>
- NUREG/CR 4775, *Guide for Operating Procedures for Shipping Packages*<sup>[22]</sup>
- ANSI N14.5, *Leakage tests on package for shipment*<sup>[23]</sup>

The certifying official reviews the SARP following the guidance provided in the reviewer's guide (UCID-21210<sup>[24]</sup>). In a reverse process, the SARP can be prepared to provide at least the information outlined in the reviewer's guide. This should result in the minimum information required by the

certifying official; however, this should not always arbitrarily be assumed to be true. However, this guide does give the applicant a clear indication of the direction of the reviewer's intentions and the depth of demonstration needed for each of the SARP sections.

It is also prudent for the applicant to approach the certifying official with basic information about the packaging and SARP. This may be a brief meeting between the participants to establish lines of communications, present the SARP preparation schedules, and to discuss technical issues and potential trouble areas. The applicant should not expect to receive design guidance or explicit directions for analysis. The applicant may receive information taken from other SARP reviews, analytical techniques, documentation. Any information that would be helpful to the reviewers to reduce the evaluation cycle time.

Regulatory Guide 7.9 outlines what goes into the SARP. The following are additional refinements that reduce the burden on the reviewers and improves that likelihood of receiving a timely review:

- Complete set of design drawings with tolerances and weld symbols
- Complete set of material specifications with certification and testing
- Exploded view of the packaging with contents
- Operating, acceptance testing, maintenance, and quality assurance requirements

The SARP preparation may take many difference routes. One route that has proven to be successful is to develop a team of highly motivated, professionals who are expert in their field. It is recommended that everyone on the SARP team be experienced in preparing SARPs, be knowledgeable on transportation and packaging regulations, be trained in quality assurance procedures, and be well

versed in scientific, business, and legal communications skills. A description of a proposed SARP team and their respective responsibilities are presented below.

**Coordinator:** The coordinator should be knowledgeable on all SARP subject matter. The coordinator must be able to blend all of the SARP sections into a single, cohesive document. The coordinator is responsible for identifying and securing all personnel to prepare the SARP and to manage to SARP effort. The coordinator should establish SARP policy, arbitrate technical differences, and be the focus for text preparation and publication. The coordinator may prepare the sections on introduction, operations, acceptance testing, maintenance, and quality assurance with support from the respective facility staff. The coordinator should lead a sub-team consisting of the technical editor, word processor, and graphic designer.

**Design engineer:** The designer is the responsible engineer of design for the packaging. The designer must be versed in ASME Boiler and Pressure Vessel Code<sup>[25]</sup>, material standards, equipment specifications, weld standards, test procedures, and transportation and packaging regulations. The designer must understand the requirements for containment, radiation shielding, and nuclear criticality. The designer should lead a subteam consisting of a computer aided drafting operator, metallurgist, and test engineer. The designer should also be responsible for evaluating the containment criteria for the package, since this is directly related to closure, such as welds, seals, flanges, and valves.

**Structural analyst:** The structural analyst should be well trained in the field of structural analysis for pressure, temperature (high and low), gas generation, dynamics, fatigue, fracture mechanics, and nonlinear and large displacement analysis techniques. This generally requires experience with finite element computer programs. This will also require experience with material properties at low and high temperatures.

**Thermal analyst:** The thermal analyst should be experienced with thermal analysis of high- and low-temperature structures that are made of steel, brittle materials, molded products, combustible materials, and radioisotopes. This generally requires experience with finite difference and finite element computer programs. This will also required experience with material properties at low and high temperatures. The thermal analyst should work closely with the structural analyst and designer to optimize model development and information gathering. The thermal analyst should work with the radiation shielding analyst to evaluate the radioactive source decay heat.

**Radiation shielding analyst:** The radiation shielding analyst should be very experienced with radiation shielding of the radioactive material. This requires experience with source calculations and shielding evaluations which are generally done with computer programs. The analyst should be well versed in the transportation and packaging regulations for minimum dose rates, as well as implementing as-low-as-reasonably-achievable (ALARA) principles for radiation exposure. It is important that the analyst review other SARPs for techniques and data reporting requirements.

**Nuclear criticality analyst (fissile material only):** The nuclear criticality analyst should be very experienced with criticality analysis techniques and transportation and packaging regulations. This requires several years of experience with complicated computer programs and analysis of materials similar to the content.

**Operations and maintenance:** Facility personnel who will be responsible for the packaging operations and maintenance should provide the respective requirements to the coordinator for incorporation into the SARP. They should review the pertinent sections of the SARP. The coordinator should also contact similar persons from other facilities who may be using the packaging to reduce operational and maintenance requirements to a minimum and minimize operational problems.

**Procurement:** Procurement should work with the designer for those items procured. Procurement should prepare the various requisitions, select vendors, and participate in acceptance reviews. For items made in-house, a similar function may be performed by shop schedulers, production control, or other manufacturing organizations. Procurement should provide to the coordinator the procurement documents to incorporate the acceptance criteria into the SARP.

**Quality assurance:** Quality should have experience with packaging regulations, facility quality assurance plans, vendor surveillance, auditing, and self-assessments. Quality should provide the quality requirements to the coordinator who would incorporate them into the quality assurance criteria. Quality should prepare or support the preparation of the packaging quality assurance plan and procedures.

The SARP team identified above should receive training in transportation and packaging regulations, design techniques, review procedures, technical writing, and quality assurance. There are a number of courses sponsored by various federal agencies that provided basic and advanced training in SARP related technologies.

Because the SARP is a lengthy document, it is important that it be assembled with great care. Experience has shown that the final week or so of the preparation should be devoted just to the SARP. Outside influence or parallel efforts will cause problems. Everyone should be focused on the SARP, such as the analyst, word processors, reproduction, editor, graphics, and the coordinator. A room should be set aside for the final preparation with a checklist of items to be done. Notices should be sent to all departments that this effort is underway and that they should be prepared for contingencies, such as overtime, extra help, or more supplies. Also, management should be notified if signatures and transmittal letters are required. Once the SARP has been assembled into its first draft, each analyst, the coordinator,

and the editor should review the SARP. Perhaps this could be done several days later to allow everyone some rest.

The draft SARP should be reviewed by an independent team with SARP experience. This team should be comprised of analysts who were not involved in the original preparation of the SARP, the more remote the better. Perhaps, a qualified subcontractor would be appropriate. This would improve the quality of the SARP by eliminating potential problems. This review should be limited to one or two months and consist of a comparison to Regulatory Guides 7.9 and 7.10, a check of the calculations and results, and confirmatory calculations. The results of this effort should be documented in an independent review report. The results, provided as findings or comments, should be evaluated by the appropriate analyst and the coordinator. Corrections to the SARP should be made and the SARP assembled for the final issue. A record of the findings and their subsequent affect on the SARP should be kept in the packaging files where they would be available for review by the appropriate federal agency. The independent review report, findings and comments, and the subsequent changes to the SARP should be provided to the certifying official when the SARP is submitted for review.

All sources of information that were not incorporated into the SARP should be collected and delivered to the appropriate federal agency along with the SARP. Sources such as reference books, computer manuals, and national standards should not be included. Published reports such as test results, plans, procedures, obscure journals, or out-of-print text should be provided in some fashion. This may require a lengthy request by the applicant for rights to reprint copyrighted material.

## 1.5 SARP REVIEW AND CERTIFICATION

In theory, the process to receive a certificate for a packaging by the federal agencies is basically simple; however, in practice, the process is quite often lengthy and subject to an ever increasing application of the regulations. This is a product of the increased safety consciousness being applied to all hazardous activities. What was acceptable yesterday, is not necessarily acceptable today. This fundamental credo is why everyone in the SARP process must continually be trained in the regulations. The certifying official will take considerable time to review the SARP and all accompanying information before the packaging is considered for certification.

The certifying official prepares a set of questions referred to as Qs. The initial set, called Q<sub>0</sub>, are asked if it is determined that the SARP does not include fundamental information or is not prepared in the recommended format. The official may also request additional data for their evaluations. The Q<sub>0</sub>s, are provided within one or two months and should be evaluated by the SARP team and the appropriate member resolve the questions. The coordinator should prepare a document that details the certifying official questions and the applicants response. The document should be provided to the certifying official along with proposed changes to the SARP. The mechanism for the SARP changes should be discussed with the reviewers and the certifying official.

The SARP team must be prepared to change the SARP to accommodate the certifying official. The certifying official is relying on their reviewers to provide recommendations for certification; therefore, repeated arguments will not resolve findings. The applicant must be able to objectively present their facts. The certifying official will arbitrate cases where agreement cannot be reached, however, this is a position that is neither encouraged nor desired. The applicant and the reviewers should reach an agreement that is ultimately safe or safer than either one or both positions.

The certifying official continues to review the SARP while response to the Q<sub>0</sub>'s are being prepared by the applicant. At some time interval agreed to by all parties, Q<sub>1</sub>'s are submitted to the applicant. The applicant should respond to these in a similar manner as the Q<sub>0</sub>'s, except these will be more technical in nature and may require significant reanalysis and changes to the SARP. Design changes may be required as demonstrated by previous packaging reviews. Such a change is generally very expensive and time consuming; thus, the applicant should try to prevent this.

The question and response process continues until the certifying official is convinced that the packaging design and SARP adhere to all federal regulations. The certifying official prepares the Safety Evaluation Report (SER). The SER documents the independent review results which demonstrate that the applicant's SARP clearly shows that the regulations were met. Additional information may be included to limit the use of the packaging.

The certifying official prepares the offsite transportation certificate (OTC). The packaging description, content description, and operational restrictions are taken from the SARP and included in the OTC. If the review discovered further restrictions, the certifying official may chose to add these to the OTC. The OTC is signed by the certifying official, a certificate number is assigned, and a expiration date is determined. The OTC is usually assigned an expiration date five years from the approval date; however, this is at the discretion of the certifying official.

The applicant must be authorized by the federal agency to use the packaging. This may require the federal agency to audit the applicants facilities, quality assurance plans and procedures, and training before the applicant can use the packaging.

In a logical sequence, the applicant receives the OTC before the production packaging is fabricated. This ensures that the quality assurance elements are correctly implemented for the fabrication and assembly. It also reduces the potential costs; however, it may impact project schedules. An applicant must decide what risk is acceptable to their project.

## **1.6 PACKAGING FABRICATION**

Methods for fabricating the packaging will usually depend on the quantity of packages made, schedule for completion, and funding. Complicated designs may require intricate fabrication techniques. How the package is fabricated will not be discussed here, rather, how the fabrication activity relates to the packaging life cycle will be discussed.

The applicant's quality assurance plan should detail their approach to the control of purchased items and services. Fabrication vendor evaluations are performed before a vendor is released for production, depending on the critical nature of the packaging and the vendor's performance. The applicant should complete the following activities for the vendors:

- Evaluate and select packaging component vendors.
- Establish controls to be imposed on these vendors.
- Perform audits at vendors' facilities (as required).
- Establish conditions for receiving inspection at applicant's facility.

Each vendor's quality assurance plan should detail their procedures for performing inspections and preparing certification of the delivered items. Certification papers should be delivered with the item and entered into the applicant's quality assurance records. If the item requires inspection and verification

by the applicant, then such inspections and certification should also be entered into the quality assurance records. If the packaging components are manufactured in-house, then similar steps should be conducted for those manufacturing elements.

The applicant should conduct a first-article evaluation for large-quantity buys. The evaluation may include a repeat of the demonstration tests given in 10 CFR 71.71 and 71.73. Although, this is not required, it does establish the ability of the design to be manufactured in quantity by a vendor.

## **1.7 OPERATIONS**

The package consignee and consignor should conduct readiness reviews with the packaging prior to first use. This provides on-the-job training for the operators and handlers and for shake-down of handling equipment. The operating procedures should be thoroughly exercised to ensure that all steps are appropriate. Furthermore, each packaging user should conduct training exercises for abnormal events and their corrective measures. This may involve all facility divisions, such as hazards response teams, contamination control, health physics, nuclear criticality safety, safeguards, security, fire department, medical staff, and plant management. Public notification and emergency response systems may also participate if regular emergency exercises are not already conducted. The carrier may participate in these training exercises.

The operating procedures with nuclear criticality safety approvals should be simple and straight forward where possible. Everything related to the package operations should be recorded (written down) to prevent the loss of valuable information. Video tapes of operations and training exercises are useful tools.

Users should periodically review their operating procedures. New and improved ways to reduce radioactive exposure to the workers and the public should be incorporated in the procedures. Consignors should be surveyed periodically to determine if the packaging operations are being followed, and if new ways are needed to enhance safety or quality.

The applicant must notify the proper facility managers and the appropriate federal agencies immediately if an unusual event occurs during packaging operations (loading, transport, unloading, storage) or if the packaging design becomes suspect. If the packaging design is questioned, then the applicant must issue a stop-use notice to anyone using the affected packaging. This may include other packaging with similar designs.

## **1.8 MAINTENANCE**

All packaging shall be maintained to the level of certification required by the drawings, specifications, SARP, and OTC. The packaging owner or user shall prepare refurbishment procedures consistent with the requirements outline in the SARP. Persons performing the refurbishment shall be trained accordingly.

Refurbishment may follow a replace or repair philosophy. If packaging parts are replaced, then only certified parts may be used as replacements. If packaging parts are repaired, then those parts must be recertified according to the drawings, specifications, and the SARP.

The packaging owner or user shall place special emphasis on refurbishment to prevent replacing parts with bogus parts, such as bolts, nuts, or seals. Furthermore, the refurbishment program shall

consider the shelf life of life-limited parts such as seals. They should be examined before use and discarded if the date listed on the part exceeds that shelf-life date.

## **1.9 PACKAGING MODIFICATION**

If a packaging needs to be modified, the owner must evaluate the proposed modification, and present the facts to the certifying official. These proposed modifications to the packaging must be authorized by the certifying official before they are completed and before the packaging may be used. The OTC must be revised and appropriate training conducted to make the modifications and to use the modified packaging.

There are a number of reasons why modifications to a packaging may occur. A certified part may have been changed, it may no longer be manufactured, or there may be a problem with the present packaging. The packaging may require refurbishment too often. New information on materials may disclose hazardous or toxic affects previously unknown. For whatever reason, some part of the packaging must be modified. The following steps, as a minimum, should be followed in processing a modification to the packaging.

**Modification.** Packaging modification can occur because of unacceptable damage during normal use, supply of certified parts or material no longer available, or newly discovered material information that is unacceptable. An investigation should be conducted to discover the root cause of the need to modify the packaging design. This investigation should be well documented and conclude with recommendations for action. If there are safety problems associated with the modification, the certifying official should be notified immediately. The certifying official may recommend a hold on all activities associated with the respective packagings (or similar packaging) until all the facts are discovered.

**Design.** The owner shall prepare drawing and specification changes to reflect the proposed modifications to the packaging. The drawing and specification revisions shall follow the owner's configuration management procedures. The documents shall not be issued for use until the certifying official authorizes such modifications.

**Changes to SARP.** The proposed modifications to the packaging shall be evaluated and reported in a manner like that originally conducted for the packaging and reported in the SARP. The modification may result in new analyses or tests. All of the impacts of the modifications shall be determined, such as changes to a new material may result in changes to weights, material compatibility, radiation shielding, criticality moderation, handling, stresses, dynamics, and thermal response. Revisions (changes to pages) to the SARP shall be prepared and submitted to the certifying official. These revisions will be evaluated commensurate with their importance to safety. If the modification is simple and does not change a safety class item, then the review by the certifying official may not require an extensive analysis. However, if a safety class item is modified, the certifying official will require a thorough review of the changes, or perhaps a review of the entire SARP. Following the discussions and review, the certifying official shall revise the SER and the OTC, accordingly.

**Field Change.** When the proposed modifications are authorized by the certifying official and the revised OTC is obtained, the owner of the packaging may perform the proposed modifications to the packaging. Old parts shall be discarded and removed from service to prevent them from being used by mistake. The modified packaging shall be marked to identify the change, as appropriate. The modified packaging shall be inspected and pass the appropriate certification tests, such as radiographs, surface smoothness, dimensional, pressure tests, leak tests, or thermal test. When the packaging is recertified,

the external marking shall be revised to indicate the date of certification. This packaging is now certified for use.

**Repair records.** The records of the modification shall be entered into the appropriate files for safe-keeping. The records for all packagings that were modified shall be amended. All base lined documents shall be revised accordingly, and changes distributed to the holders of those documents.

## **1.10 MAINTAINING CERTIFICATION**

The original package certificate is usually authorized for five years. The owner of the package shall submit a renewal request with about three years remaining on the certificate. This allows one year for the revision to the SARP, one year for review for approval. The time intervals may be over-estimated if there are no proposed design changes, no regulatory rules changes, and no problems encountered in using the package. Each one of these present unique problems that must be resolved.

The significance of a design change is proportional to the safety class of the items affected. If the change is related to the containment boundary, radiation shielding, or nuclear criticality, the respective evaluations in the SARP must be done again to account for the proposed change. This change would be incorporated throughout the SARP. The SARP would be subjected to a complete review by the certifying official, much like the original review. Thus, a design change to an important safetyclass item would take the full time for renewal. A change to an item that is not a safety class item would probably not result in a full review of the SARP. The change would be assessed and the SER revised accordingly.

If new or revised rules are implemented before the expiration date of the certificate, then the packaging must be reassessed and the SARP revised accordingly. The extent of the rule changes will

dictate the level of SARP revision and review. An example of a proposed rule change that could have significant impact on the packaging is the 1988 proposed rule change to require the dynamic crush test. The hypothetical test would require a 9-in free drop onto an unyielding surface followed by a 30-ft free drop of a 500-kg mass onto the previously damaged package. The remaining tests are the same.

A listing of all packagings serial numbers that were used under the certificate and their refurbishment history should be available for review by the certifying official. If the refurbishment history indicates an abnormal repair of packaging components, then changes may be warranted to more robust components. Like the design changes described above, the level of the change to the safety class items will determine the level of change to the SARP and probably review by the certifying official.

The SARP should be submitted to the certifying official for renewal two to three years before the expiration date. This will allow ample time for the review to be completed. If there is not enough time, a request for a timely renewal may be submitted to the certifying official. It is at the certifying official's discretion to grant the request and to impose a time limit.

## **1.11 PACKAGE USEFUL LIFE**

When radioactive material packaging is no longer certified or usable for its intended purpose, it may be used as other hazardous or radioactive material packaging or it should be decommissioned and disposed. A Type B package may be downgraded to a Type A package or lower. A Type A package may be downgraded to an excepted-quantity package. Any of the above packages may be downgraded to a strong-tight container or industrial package. If such packaging are downgraded, the previous markings should be removed to prevent confusion with its use. Also, the records should be amended to reflect this change in status.

## **1.12 DECOMMISSIONING AND DECERTIFICATION**

If the owner of a packaging no longer needs the certified packaging, they must notify the proper federal agency of intent to decertify the packaging. If there are other users, the federal agency may choose to transfer ownership to another user. The previous owner would transfer all packaging to the new owner.

When a federal agency transmits a notification of decertification, all users must record the decertification and ensure that they are not used for off-site shipments. Each affected function at the facility should be notified of the decertification and the appropriate measures taken to ensure that it is no longer used for off-site shipments.

The user should segregate all the decertified packaging and remove the certification markings and affix the appropriate empty label or other hazardous material labels. Considering the purpose for the decertification, the packaging may be used for other contents, especially for on-site shipments or as strong-tight container. If the packaging is no longer needed, it should be disposed as waste material characterized to the appropriate hazardous waste material. The packaging should be decontaminated first to removed the surface contaminations to the lowest practical level.

The certified packaging data base should be updated for packaging that is downgraded or destroyed. It is important to note that the records for a decertified packaging must be kept for at least three years past the date of destruction.

### **1.13 DISPOSAL**

Decertified packaging must ultimately be disposed in a manner consistent with the national policy for radioactive waste or hazardous material disposal.

The level of surface contamination and imbedded radionuclides should be determined. The surface contamination should be removed to the lowest level practical. If the contamination level remains high, it may be necessary to dispose the packaging in one of the national radioactive burial grounds.

## 1.14 REFERENCES

1. U.S. Department of Transportation, Code of Federal Regulations, Title 49, *Transportation*, Parts 100-180, 393, 387, and 390-399, Washington, D.C.
2. U.S. Department of Energy, *Materials Transportation and Traffic Management*, DOE Order 1540.1, Change 4, July 2, 1990.
3. U.S. Department of Defense, *Performance Oriented Packaging of Hazardous Material*, DLAR 4145.41/AR 700-143 /AFR 71-5/NAVSUPINST 4030-55/MCO 4030.40.
4. U.S. Nuclear Regulatory Commission, Code of Federal Regulations, Title 10, *Energy*, Parts 20, 21, 70, 71, 73, and 74, Washington, D.C.
5. U.S. Postal Service, Code of Federal Regulations, Title 39, *Postal Service*, Washington, D.C.
6. U.S. Department of Energy, *Hazardous Material Packaging for Transport*, DOE Order 1540.2, Washington, D.C., September 30, 1986.
7. U.S. Environmental Protection Agency, Code of Federal Regulations, Title 40, *Environment*, Parts 262, 263, 302, and 761, Washington, D.C.
8. International Atomic Energy Agency, *Regulations for the Safe Transport of Radioactive Material*, Safety Series No. 6, Safety Standard, Vienna, Austria, 1982 (as amended 1990).

9. Shappert, L. B., et al., *Cask Designers Guide*, Oak Ridge National Laboratory (ORNL-NSIC-68), Oak Ridge, Tennessee, February 1970. (This document is being revised as *Packaging Handbook*.)
10. U.S. Nuclear Regulatory Commission, *Directory of Certificates of Compliance for Radioactive Materials Packages*, NUREG-0383, Volumes 1 and 2, Revision 13, Washington, D.C., October 1990.
11. American National Standard Institute and American Society of Mechanical Engineers, *Quality Assurance Program Requirements for Nuclear Facilities*, NQA-1, New York, 1986.
12. U.S. Department of Energy, *Quality Assurance*, DOE Order 5700.6C, Washington, D.C., 1994.
13. U.S. Department of Energy, *Quality Control Policy (QC-1)*, Albuquerque Operations Office, Albuquerque, New Mexico.
14. International Organization of Standards, *Quality Management and Quality Assurance Standards: Guidelines for Selection and Use*, ISO 9000 (ANSI/ASQC Q90-1987).
15. U.S. Department of Energy, *Basic Safety Standards for the Packaging and Transportation of Hazardous Materials, Hazardous Substances, and Hazardous Wastes*, Order N (Notice) 5480.3, Washington, D.C., March 9, 1989.
16. U.S. Department of Energy, *Packaging and Transporting of Nuclear Explosives, Nuclear Components, and Special Assemblies*, DOE Order 5610.1, Washington, D.C.

17. U.S. Department of Energy, *Memorandum of Understanding, Transportation System Risk Assessment Report Content and Format for Non 10 CFR 71 Packages*, Albuquerque Operations Office, Albuquerque, New Mexico, December 12, 1991.
18. U.S. Nuclear Regulatory Commission, *Standard Format and Content of Part 71, Applications for Approval of Packaging of Type B, Large Quantity, and Fissile Radioactive Material*, Regulatory Guide 7.9 (Revision 1), Washington, D.C., 1986.
19. U.S. Nuclear Regulatory Commission, *Establishing Quality Assurance Programs for Packaging Used in the Transport of Radioactive Material*, Regulatory Guide 7.10 (Revision 1), Washington, D.C., 1986.
20. U.S. Nuclear Regulatory Commission, *Fabrication Criteria for Shipping Containers*, NUREG/CR-3854, Washington, D.C.
21. Boyle, C. D., Kido, C., Gregg, R. E., and Stromberg, H. M., *Packaging Supplier Inspection Guide*, Idaho National Engineering Laboratory, EG&G Idaho, Inc., NUREG/CR-5717, Washington, D.C., 1985.
22. Witte, M. C., *Guide for Preparing Operating Procedures for Shipping Packages*, Lawrence Livermore National Laboratory (UCID-20820) and U.S. Nuclear Regulatory Commission (NUREG/CR-4775), December 1988.
23. American National Standards Institute, *American National Standard for Radioactive Materials- Leakage Tests on Packages for Shipments*, ANSI N14.5, New York, 1987.

24. Fisher, L. E., et al., *Packaging Review Guide for Reviewing Safety Analysis Reports for Packagings*, Lawrence Livermore National Laboratory (UCID-21210, Revision 1) Livermore, California, October 1988.
  
25. American Society of Mechanical Engineers, *Boiler and Pressure Vessel Code*, New York.

## 1.15 BIBLIOGRAPHY

Dircks, W., *Fission Product Release From Highly Irradiated Fuel*, NUREG/CR-0722), Oak Ridge, Tennessee, ORNL, 1980. (A series of experiments on irradiated fuel found a fractional release of 0.3 percent for cesium from the fuel elements--not from the cask. Such a release was estimated to produce no early fatalities.)

Pope, R., et. al. *An Assessment of Accident Thermal Testing and Analysis Procedures for Radioactive Materials Shipping Packages*, 80-HT-38, Washington, D. C., ASME, April 1981.

U.S. Nuclear Regulatory Commission, *Potential Crush Loading of Radioactive Material Packages in Highway, Rail, and Marine Accidents*, NUREG/CR-1588, Washington, D.C. October 1980.

**THIS PAGE INTENTIONALLY LEFT BLANK**

## **APPENDIX A**

### **DETERMINATION OF THE $A_1/A_2$ VALUE FOR MIXTURES**

**THIS PAGE INTENTIONALLY LEFT BLANK**

## APPENDIX A

### DETERMINATION OF THE $A_1/A_2$ VALUE FOR MIXTURES

The following is a determination of the  $A_1/A_2$  value of a mixture for radioactive content. This is limited to packages whose content is special nuclear materials that are characteristic of those shipped by the DOE Defense Programs.

Regulations (NRC, DOT, and IAEA) establish the methodology used to determine the activity of radioactive materials. The content activity establishes the degree of rigor applied to the design, test, fabrication, and operation of a package. The governing regulations provide methodology, specific activities, and  $A_1/A_2$  values for radionuclides to determine the  $A_1/A_2$  value of the mixture for the radioactive content.

It is essential to consider the daughter products in calculating the  $A_1/A_2$  value for the mixture. In the case of radioactive decay chains in which any daughter nuclide has a half-life either longer than 10 days or greater than that of the parent nuclide, the parent and such daughter nuclides shall be considered as mixtures of different nuclides (10 CFR 71, Appendix A.2). Furthermore, the specific activity for uranium from Table A-4 (10 CFR 71) should be used with caution when determining the  $A_2$  value for the mixture for Defense Program materials, it does not consider all the isotopic constituents that may be present, such as the  $^{232}\text{U}$  and  $^{236}\text{U}$ .

Examination of the decay chains of the plutonium and uranium radionuclides of interest shows a number of isotopes that meet the half-life criterion. Consequently, one must consider any daughter product whose half-life exceeds 10 days for plutonium and uranium systems.

Another subtlety occurs when calculating the  $A_1/A_2$  value for the mixture. Examination of the source calculations developed by the ORIGEN computer code reveals the time dependency of the  $A_1/A_2$  value.

### **A.1 Uranium $A_2$ Value Determination**

The uranium content is a mixture of 17 radionuclides (taken from the ORIGEN output). These radionuclides exceed the 10-d criterion for their respective half-life. Except for the uranium isotope  $^{234}\text{U}$ , only the isotope  $^{228}\text{Th}$  reaches sufficient mass to exceed its  $A_2$  value (a maximum of  $2A_2$  over 30 years) by the second year of decay. The masses for all the other daughter products remain very small.

The activity of the mixture reaches a level value of 1.4 Ci shortly after time equal zero.

The  $A_2$  value shows a marked decrease from the onset of decay. It has a minimum value of 0.0909 Ci at 10 years. This corresponds to the maximum decay peak of  $^{232}\text{U}$  at 10.5 years. This is a decrease of 10 percent from the original material (0.1013 Ci). There is a corresponding decrease in the leak-rate criteria for normal and accident conditions. One must use the minimum  $A_2$  value for the mixture when determining the leak-rate criterion for design and test of the package.

A summation of the ratios of the isotopic activities to their respective  $A_2$  values (about 15, maximum) is below the  $30 A_2$  criterion supported by the SARP Reviewer's Guide (UCID-21218). Below  $30 A_2$ , the containment vessel design should follow Section VIII of the ASME Boiler and Pressure Vessel Code. Above  $30 A_2$ , Section III should be followed.

From the data presented here for uranium systems, one must use the most conservative  $A_2$  value when determining the acceptance and post-load leak test criteria and the normal and accident conditions leakage criteria. Generally, this does not occur with the original material at zero time, rather, it occurs about 10 years in the decay cycle.

All the daughter products (not just those with a half-life of greater than 10 d) of the uranium systems must be considered in the analyses for decay heat, radiation shielding, and nuclear criticality safety. Generally, these respective computer programs incorporate the various decay chains and their neutron and gamma ray generations, as appropriate.

## **A.2 Plutonium $A_2$ Value Determination**

The plutonium content is a mixture of 28 radionuclides that meet the 10-d criterion for their half-life. All the original isotopes exceed their respective  $A_2$  values. The isotope  $^{237}\text{Np}$  is the only daughter product that exceeds its  $A_2$  value that occurs between 60 and 80 years of decay. The masses of all remaining daughter products are very small for the 80-year analysis.

The activity of the mixture decreases rapidly (140 Ci per year) for the first 50 years. It starts at about 7000 Ci with the original material and reduces to about 2000 Ci at 40 years.

The  $A_2$  value starts at its highest value (for the 80-year analysis) and rapidly decreases. Within 40 years, the  $A_2$  value for the mixture has decreased to less than 70% of its original value. There is a corresponding decrease in the leak-rate criteria for normal and accident conditions.

A summation of the ratios of the isotopic activities to their respective  $A_2$  values (about 445,000 maximum at zero time) exceeds the 3000  $A_2$  criterion that is supported by the SARP Reviewer's Guide (UCID-21218). Thus the containment vessel design should follow Section III, Subsection NB of the ASME Boiler and Pressure Vessel Code.

From the data presented here for plutonium systems, one must use the most conservative  $A_2$  value for the age of the material being shipped when determining the acceptance and post-load leak test criteria and the normal and accident conditions leakage criteria. Generally, this occurs well into the decay.

The daughter products (not just those with a half-life of greater than 10 days) must be considered in the analyses for decay heat, radiation shielding, and nuclear criticality safety. Generally, their respective computer programs incorporate the various decay chains and their neutron and gamma ray generations, as appropriate.

Three of the daughter products ( $^{225}\text{Ra}$ ,  $^{225}\text{Ac}$ , and  $^{229}\text{Th}$ ) from the plutonium-ameridium decay are not listed in Table A-1, 10 CFR 71. Their respective  $A_2$  values and specific activities were taken from Table 1 of IAEA, Safety Series No. 6. If the  $A_2$  value for a plutonium mixture is included in SARPs, DOE must authorize the use of these respective  $A_2$  values and specific activities from IAEA, Safety Series No. 6, or provide equivalent values.