MANUAL

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NUCLEAR MATERIAL PACKAGING MANUAL

U.S. DEPARTMENT OF ENERGY

Office of Nuclear Safety and Environment

AVAILABLE ONLINE AT:
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INITIATED BY:
Office of Health, Safety and Security

NUCLEAR MATERIAL PACKAGING MANUAL

1. PURPOSE. This Manual provides detailed packaging requirements for protecting workers from exposure to nuclear materials stored outside of an approved engineered contamination barrier. The nuclear materials of concern in this Manual are those whose composition and quantity create the potential for an airborne contamination hazard that could result in a facility worker receiving an internal radiation dose in excess of 5 rem committed effective dose equivalent (CEDE). This Manual does not address the shielding of nuclear materials that generate significant direct external radiation fields because those situations are addressed in other directives and rules. The requirements in this Manual are consistent with—

   a. Department of Energy (DOE) Policy (P) 441.1 *Department of Energy Radiological Health and Safety Policy*, dated 4-26-96;

   b. DOE P 450.4, *Safety Management System Policy*, dated 10-15-96;

   c. Title 10 Code of Federal Regulations (CFR) Part 835, *Occupational Radiation Protection*; and

   d. The 10 CFR Part 830, *Nuclear Safety Management*

   e. This Manual is not intended to conflict with DOE safety, health, and security requirements applicable to nuclear operations and criteria established in Department directives such as DOE Standard (DOE-STD) 3013, *Stabilization, Packaging, and Storage of Plutonium-Bearing Materials*; DOE-STD-3028, *Criteria For Packaging and Storing Uranium-233-Bearing Materials*; and DOE Handbook (DOE-HDBK)-1129, *Tritium Handling and Safe Storage*.

2. CANCELLATIONS. None.

3. APPLICABILITY.

   a. Departmental Elements. Except for the exclusions in paragraph 3c, this Manual applies to all Departmental elements (Go to http://www.directives.doe.gov/pdfs/reftools/org-list.pdf for the current listing of Departmental elements).

      The Administrator of the National Nuclear Security Administration (NNSA) will require that NNSA employees and contractors comply with their respective responsibilities under this Manual. Nothing in this Manual will be construed to interfere with the NNSA Administrator's authority under section 3212(d) of Public Law (P.L.) 106-65 to establish Administration-specific policies, unless disapproved by the Secretary.

   b. DOE Contractors. Except for the exclusions in paragraph 3c, the Contractor Requirements Document (CRD) (Attachment 1 of this Manual) sets forth requirements that are intended to be applied to contractors performing design, construction, operation, maintenance, and decommissioning of DOE-owned facilities. The CRD will apply to the extent set forth in each contract.

c. Exclusions.

(1) In accordance with Executive Order 12344, "*Naval Nuclear Propulsion Program,*" activities under the cognizance of the Deputy Administrator for Naval Reactors are exempt from requirements of this Manual.

(2) Operations subject to Nuclear Regulatory Commission (NRC) regulation are excluded from requirements of this Manual.

(3) The Manual does not apply to the following departmental elements.

(a) Office of the Secretary

(b) Office of the Chief Financial Officer

(c) Office of the Chief Information Officer

(d) Office of Congressional and Intergovernmental Affairs

(e) Office of Economic Impact and Diversity

(f) Energy Information Administration

(g) Office of General Counsel

(h) Office of Hearings and Appeals

(i) Office of Human Capital Management

(j) Office of the Inspector General

(k) Office of Management

(l) Office of Policy and International Affairs

(m) Office of Public Affairs

(n) Bonneville Power Administration

(o) Southeastern Power Administration

(p) Southwestern Power Administration

(q) Western Area Power Administration

4. SUMMARY. This Manual is organized into three chapters.

   a. Chapter I, an overview of the Manual and responsibilities for packaging and storage of nuclear materials at the complex-wide and field element levels.

   b. Chapter II, the scope of materials for which the requirements of this Manual are applicable.

   c. Chapter III, detailed packaging, surveillance, and testing requirements.

5. REFERENCES. See Attachment 2 of this Manual

6. CONTACT. Questions concerning this Manual should be addressed to Office of Health, Safety and Security, Office of Nuclear Safety and Environment, at 202-586-5680.

BY ORDER OF THE SECRETARY OF ENERGY:

JEFFREY F. KUPFER
Acting Deputy Secretary

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CHAPTER I. OVERVIEW AND RESPONSIBILITIES

1. INTRODUCTION.

a. DOE Policy 441.1, *Department of Energy Radiological Health and Safety Policy*, dated 4-26-96, states that DOE will conduct its radiological operations in a manner that ensures the health and safety of all its employees. Consistent with the Policy, this Manual provides detailed packaging requirements for protecting workers from internal exposure to nuclear materials stored outside of an approved engineered contamination barrier. The nuclear materials of concern in this Manual are those whose composition and quantity create the potential for an airborne contamination hazard that could result in a facility worker receiving an internal radiation dose in excess of 5 rem Committed Effective Dose Equivalent (CEDE). This Manual does not address the shielding of nuclear materials that generate significant external direct radiation fields because those situations are addressed in other directives and rules. This Manual is not intended to conflict with DOE safety, health and security requirements applicable to nuclear operations and criteria established in DOE directives such as DOE Standard (DOE-STD) 3013, *Stabilization, Packaging, and Storage of Plutonium-Bearing Materials*; DOE-STD-3028, *Criteria For Packaging and Storing Uranium-233-Bearing Materials*; and DOE Handbook (DOE-HDBK)-1129, *Tritium Handling and Safe Storage*.

b. In stating requirements, the verb "must" is used throughout this Manual to indicate that organizations are required to meet the requirement being defined. The verb "should" applies to recommended actions, practices and procedures. "May" denotes permission to do something and does not impose a requirement.

2. RESPONSIBILITIES.

a. Program Secretarial Officers are responsible within their respective programs for ensuring that their field element managers meet the requirements in this Manual.

b. DOE and NNSA Central Technical Authorities must concur with all changes to this Manual.

c. Chief, Health, Safety and Security Officer.

(1) Advises the Secretary of the status of Departmental compliance with the requirements in this Manual and applicable provisions of related DOE Orders.

(2) Provides guidance and interpretation of this Manual.

(3) Reviews and approves requested exemptions to requirements of this Manual. For NNSA, reviews and comments on requested exemptions to requirements of this Manual.

(4) Ensures that changes to regulations and DOE directives are reviewed and, when necessary, incorporated into revisions of this Manual to ensure that the basis for safe storage of nuclear materials is maintained.

d. Field Element Managers.

(1) Review and approve the following contractor products:

(a) technical basis for nuclear material packaging systems including;

1 the evaluation of the chemical, radiological, and physical characteristics of the stored nuclear material

2 the nuclear material storage packaging designs

(b) nuclear materials packaging surveillance programs; and

(c) process for documenting its nuclear materials storage program.

(2) Ensure oversight of contractor's implementation of the requirements of this Manual.

(3) Ensure that a process exists for proposing, reviewing, approving, and implementing site corrective actions when necessary to ensure that the requirements of this Manual are met and to address conditions that are not protective of the public, workers, or the environment.

(4) Establish a risk-based prioritized schedule for implementing the nuclear material packaging requirements for material stored prior to the issuance of this Manual.

(5) Maintain records according to National Archives and Records Administration-approved DOE Record Schedules.

CHAPTER II. SCOPE OF MATERIALS

1. Field element managers must ensure that nuclear materials that are stored outside engineered contamination barriers are packaged in accordance with the requirements described in Chapter III of this Manual. The nuclear materials of concern in this Manual are those whose composition and quantity create the potential for an airborne contamination hazard that could result in a facility worker receiving an internal radiation dose in excess of 5 rem CEDE. Nuclear materials of this type (i.e., that could become an airborne hazard upon package failure) with a total quantity in a storage package exceeding the A_2 thresholds established in 49 CFR § 173.435, *Table of A_1 and A_2 values for radionuclides*, are subject to the specific container requirements of this Manual. A detailed description of the methodology for determining the type and quantities of materials is contained in Attachment 3.

2. The following materials are not subject to material packaging requirements of this Manual because other DOE, national or international standards provide appropriate material containment requirements:

   a. gases;

   b. materials stored in packaging meeting criteria described in DOE-STD-3013, DOE-STD-3028, or DOE-HDBK-1129;

   c. materials designated as waste, which are transferred to appropriate waste containers in accordance with DOE O 435.1, *Radioactive Waste Management*, and all applicable facility specific requirements;

   d. fully clad nuclear reactor fuels;

   e. nuclear material packaged for shipment in approved shipping containers in compliance with Department of Transportation (DOT), DOE O 460.1B, *Packaging and Transportation Safety* (or successor document), or DOE O 461.1A, *Packaging and Transfer or Transportation of Materials of National Security Interest* (or successor document) requirements;

   f. sealed radioactive sources that meet any of the following testing specifications;

      - DOT Special Form criteria per 49 CFR § 173.469;
      - Nuclear Regulatory Commission (NRC) Special Form criteria in 10 CFR § 71.75;
      - American National Standards Institute (ANSI) N43.6/ISO 2919 Annex E Special Form criteria; or
      - ANSI N43.6/ISO 2919 Class 4, Class 5 or Class 6 performance criteria for temperature, impact, and puncture.

g. material meeting the special form criteria in 49 CFR §173.403, *Definitions,* and 49 CFR § 173.469, *Tests for special form Class 7 (radioactive) materials*;

h. encapsulated (i.e., sealed or welded configurations) weapons components and heat source components**.** Welded payload containers (e.g., EP-61s and Russian Product Cans) used to ship nuclear material in DOE/DOT approved shipping casks (e.g., 9516, and 5320 shipping casks). Fully encapsulated materials or components (i.e., sealed or welded configurations) that are subject to more restrictive requirements than are included in this Manual such as those: 1) fabricated to American Society of Mechanical Engineers (ASME) NQA-1, *Quality Assurance Requirements for Nuclear Facility Applications* or *Weapon Quality Policy (QC-1)*, ; and 2) subject to rigorous inspection and surveillance protocols;

i. natural uranium (NU) and depleted uranium (DU); and

j. fixed contaminated or activated tools and equipment.

Specific packaging criteria of this Manual are not applicable to material packaged for short durations in bagged-out convenience containers or other appropriate containers while being transferred from one approved engineered contamination barrier to another or to the final package configuration (if performed in accordance with approved radiological controls).

Although a specific time limit for this short duration storage is not provided in this Manual, it is expected that the time would be on the order of hours or days and not weeks and that the hazards of the storage will be identified and evaluated and controls described and implemented. No specific time is given because specific situations may dictate what an appropriate time is. In all cases, however, field element line management is responsible for ensuring appropriate controls are in place to protect the workers.

CHAPTER III. NUCLEAR MATERIAL PACKAGING REQUIREMENTS[1]

1. STORED MATERIAL CHARACTERISTICS. Field elements must ensure that the chemical, radiological, and physical characteristics of the stored material are evaluated for the lifetime of the storage of the material and are appropriate for the material package including the following:

   a. Explosion Sensitive and/or Flammable Materials must be evaluated to determine if safe storage can be achieved or stabilization is necessary.

   b. Gas Generation rates and gas composition must be evaluated and measures must be taken to minimize the formation or accumulation of gases inside the storage package with particular attention paid to limiting flammable gases. Minimization measures may include placing limitations on contents of containers, stabilizing materials, or venting and filtering containers.

   c. Incompatible Materials whose interaction could lead to failure of a containment barrier must not be packaged together (e.g., oxidizers and nitrated ion exchange resins).

   d. Physical and Chemical Form of material must be evaluated including its corrosivity and potential for oxidative expansion to ensure proper packaging. For example, a Pu metal (because of the high potential for rapid and complete oxidation) should not be stored in a vented container while a Pu oxide powder could be depending on specific activity and particle size.

   e. Moisture Content must be evaluated to determine if safe storage can be achieved or if stabilization is necessary. Stabilization must be considered for materials that can absorb/adsorb significant quantities of moisture when in contact with air. Moisture content amount must not violate the requirements in item b or c by interacting with materials being stored to induce corrosion or to increase the potential for flammable mixtures or over-pressure.

   f. Pyrophoricity must be evaluated to determine if safe storage can be achieved or if stabilization is necessary.

   g. Radioactive Decay Heat must be evaluated to ensure no unacceptable thermal degradation occurs. Package designers must include a maximum heat load in the design specifications.

   h. Radiation Fields must be evaluated to ensure they will not cause failure of a containment barrier or other containers included in the storage package. Plastic should not be in direct contact with alpha emitting materials. Package designers must include radiation fields resulting from radioactive decay of the stored

[1] This Manual does not address criticality safety requirements that must be addressed per DOE O 420.1B, *Facility Safety*.

material including daughter products that might have worse radiation fields than the originally stored material. Consideration should also be given to the radiation fields of contiguous containers in a storage array.

i. Solution composition and its effect on the selection of packaging type, storage duration, and surveillance must be evaluated. Special consideration must be given to gas generation and venting during storage life.

2. PACKAGING DESIGN CRITERIA AND PERFORMANCE OBJECTIVES. Field elements must ensure that concerns with corrosion, radiolytic and thermal degradation, oxidative expansion, pressurization, incompatible materials, and usage (handling) that may result in container failure are addressed as part of the package design. Field elements must ensure that nuclear material storage packages meet the following design criteria and performance objectives[2, 3].

a. Corrosion Resistance. The container, including filter vent and seals, must be constructed entirely of materials that are resistant to corrosion and chemical degradation from the materials being stored and generated gases as well as the ambient storage environment.

b. Thermal Degradation Resistance. The container, including filter vent and seals, must be designed so that heat generation of the contents does not challenge the integrity of the container for the design life of the container.

c. Radiation Resistance. The container, including filter vent and seals, must be designed so that radiation from stored material and the storage environment does not challenge the integrity of the container for the container's design life.

d. Oxidative expansion accommodation. The container must be designed to accommodate the maximum volume increase and potential effects on the container from the oxidative expansion of stored material that may occur for the container's design life.

e. Pressurization. as generation, material oxidation, volume expansion, or release of volatiles during the design storage period. Measures should be taken to minimize the formation or accumulation of gases inside the storage package. Such measures include placing limitations on the contents of containers and permitted length of storage time, or providing mechanisms in the storage package design, such as venting.

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[2] Note: Multiple nested containers are a good practice to provide added assurance that nuclear material will not be released from a package during normal handling or potential drops. The criteria and performance objectives in this section are focused on the container credited for confinement of the nuclear material and its capabilities to provide an adequate contamination barrier; however, most of the criteria and performance objectives will also be appropriate for any other containers in the package and should be considered.

[3] Note: DOE sites may find it cost effective to utilize other site container designs. However, each site must ensure the container is appropriate for its specific storage conditions (material types, storage height, environmental condition, etc.).

f. Incompatible and Pyrophoric Materials. Incompatible materials must not be stored together. Furthermore, pyrophoric materials must be containerized to prevent interaction with oxidative environments using techniques such as inert environments (gas or liquid blanket), double hermetic seals, encapsulation, etc. to prevent a pyrophoric reaction. Sites are encouraged to stabilize pyrophoric materials prior to storage (refer to DOE-HDBK-1081, *Primer on Spontaneous Heating and Pyrophoricity*).

g. Filter Performance. Filters must be capable of venting the maximum credible gas flow rate.. Filters must be compatible with the material being stored including any product of reaction between the environment and the material (e.g., salts adsorbing moisture and corroding the can).

h. Design Life. The design life of the materials used in the container assembly as fabricated must be calculated or tested and the container must be examined under a regular documented maintenance and surveillance program. The impact of organic or other materials, such as silicone gaskets, that are subject to degradation must be accounted for in these calculations and in maintenance and surveillance plans. The container must meet design objectives such as the design release rate and design qualification release rate for the design life of the container. Container designs incorporating filters require useful-life determinations and performance verification measurements at the rated filtration efficiency.

i. Container Closure. Storage containers must be securely closed in a way that precludes accidental opening or breaching during normal operational conditions and/or postulated drops.

j. Design Release Rate Performance Objective. The package must have a design release rate that will maintain the potential internal exposure to workers as low as reasonable achievable (ALARA) during normal storage or handling of the package. Attachment 4 provides an acceptable design release rate value as well as details on the basis for release rate and appropriate testing methods.

k. Design Qualification Release Rate Performance Objective. The package must have a post drop design qualification release rate that will prevent the exposure of workers to greater than 5 rem CEDE. The drop test must be from the maximum working or storage height but not less than four feet. Attachment 4 provides an acceptable design qualification release rate value as well as additional details on the basis for this release rate and the appropriate testing methods.

l. Non-Destructive Examination. The package configuration should allow for non-destructive contents verification, inspection, and surveillance such as by radiography and weighing.

m. Quality Assurance. Packages must be designed, tested, and procured in accordance with the quality assurance requirements of 10 CFR Part 830 and DOE O 414.1C, *Quality Assurance*.

n. Labeling. Each storage container or package of radioactive material must have a unique permanent identification marking or bear a durable, clearly visible label for identification and documentation purposes. Labeling must meet the requirements of 10 CFR § 835.605. Where practical and appropriate, combine radiological, criticality safety, and material control and accountability (MC&A) data into a single label.

3. PACKAGING SURVEILLANCE PROGRAM. Field elements must ensure that a surveillance program is established and implemented to ensure the nuclear material storage package continues to meet its design criteria.

a. General. The surveillance program must evaluate appropriate attributes of stored packages to determine whether the packages can continue to be stored safely. Surveillance must also validate the package design life.

b. As Low As Reasonably Achievable (ALARA). The surveillance program must be structured to minimize the overall risk to the facility workers and maintain radiation doses ALARA during the performance of surveillance activities. At a minimum, the following concepts should be considered:

(1) coordinating surveillance activities with MC&A measurements and inspections;

(2) coordinating surveillance activities with package movements;

(3) using MC&A and routine radiological survey data in the surveillance program;

(4) performing surveillance on packages as they are being opened for material use; and

(5) conducting remote surveillance (e.g., camera, load cell, etc.) for items generating high radiation fields.

c. Objectives and Techniques. The objective of the surveillance program is to identify indications of package degradation early to remediate the degraded package and to identify similar packages and materials that may need remediation. Surveillance techniques must be specified to provide early indications of package degradation which includes seal failure or loss of venting capability (if present). Any signs of degradation should be used for comparison with similar packages and containers. At a minimum, the following techniques must be considered:

(1) visual inspection of the container for indications of corrosion or pressurization including examining the container for signs of degradation prior to routine handling of the container or opening for material use;

(2) weight measurement for indications of mass change of the storage package which could indicate loss of package seal resulting in—

(a) possible oxidation and expansion of metal contents; and

(b) absorption of moisture which could increase corrosion of the package;

(3) contamination surveys which could indicate loss of container seal;

(4) testing of vent filters for plugging;

(5) radiography which could indicate pressurization or degradation of inner containers; and

(6) opening package for examination of interior contents and seals.

d. Frequency. Surveillance frequencies must be specified for each package design and content combination. At a minimum, the frequency should be based on the potential failure mechanism, failure consequence, and package design life. Statistical sampling of packages for surveillance may be used for large, uniform populations of packages and/or contents.

e. Procedures. Surveillance procedures must specify the surveillance techniques to be used and must have defined acceptance criteria. Procedures must be established to address initial response to packages that fail the acceptance criteria.

f. Evaluation. Surveillance data must be evaluated at least annually. Results of the surveillance program must be used to improve packaging design and modify the surveillance program, when appropriate. Sites should consider sharing data with other sites.

4. DOCUMENTATION. Field elements must ensure that documentation of the nuclear material storage package design and surveillance is maintained.

a. Records Retention. Packaging and surveillance records must be maintained in accordance with DOE O 243.1, *Records Management Program*..

b. Content Elements.

(1) Material Information. Records must include, at a minimum, available information on the following material characteristics:

(a) description of the chemical and physical form;

(b) best available isotopic content (and effective date of analysis[4]); and

(c) weight.

(2) Package Information. At a minimum, the records must include identification of the following package characteristics:

(a) date of packaging for each container;

(b) baseline package gross weight;

(c) unique identification number associated with each package; and

(d) configuration—quantity and type of containers in a package (this is not required for packages that existed before the Manual was issued; however, it is a recommended good practice).

(3) Surveillance Information. At a minimum, the records must include the following surveillance and inspection data:

(a) unique identification number associated with each package;

(b) surveillance and radioactive survey results and dates;

(c) dates, location, and results of inspections; and

(d) name and site qualifications of individuals performing inspections.

(4) Technical Basis Information. At a minimum, records must include information pertaining to the technical basis for packaging and storing applicable nuclear materials, including a description of how the applicable stored material characteristics and packaging design criteria are satisfied, supported by test results and other evidence, as appropriate; threshold calculations for the packaged material; and surveillance and monitoring information.

c. Database. A database of relevant information about stored materials and packages including material information, packaging information, and surveillance information for each storage package must be maintained. An electronic database should be utilized to simplify scheduling of surveillance and repackaging of

[4] The effective date of analysis should be included if it is used to address impacts of changes in isotopic content on packages over their lifetime.

packages and evaluation of surveillance data. The database may consist of several files, which in themselves may be databases, some of which may be classified. For completeness, the database should be coordinated and generally compatible with the MC&A data bases.

CONTRACTOR REQUIREMENTS DOCUMENT

The contractor is responsible for complying with the requirements of this Contractor Requirements Document (CRD) and flowing down CRD requirements to subcontractors at any tier to the extent necessary to ensure contractor compliance.

Contractors are responsible for developing technical bases in accordance with the requirements of this CRD for packaging system and for submitting the proposed packaging system to the responsible field element manager for review and approval.

CHAPTER I. SCOPE OF MATERIALS

1. Contractors must ensure that nuclear materials that are stored outside engineered contamination barriers are packaged in accordance with the requirements described in Chapter II of this CRD. The nuclear materials of concern in this CRD are those whose composition and quantity create the potential for an airborne contamination hazard that could result in a facility worker receiving an internal radiation dose in excess of 5 rem CEDE. Nuclear materials of this type (i.e., that could become an airborne hazard upon package failure) with a total quantity in a storage package exceeding the A_2 thresholds established in 49 CFR § 173.435, *Table of A_1 and A_2 values for radionuclides*, are subject to the specific container requirements of this CRD. A detailed description of the methodology for determining the type and quantities of materials is contained in Attachment 3 of DOE M 441.1-1.

2. The following materials are not subject to material packaging requirements of this CRD because other DOE, national or international standards provide appropriate material containment requirements:

   a. gases;

   b. materials stored in packaging meeting criteria described in DOE-STD-3013, DOE-STD-3028, or DOE-HDBK-1129;

   c. materials designated as waste, which are transferred to appropriate waste containers in accordance with DOE O 435.1, *Radioactive Waste Management*, and all applicable facility specific requirements;

   d. fully clad nuclear reactor fuels;

   e. nuclear material packaged for shipment in approved shipping containers in compliance with DOT, DOE O 460.1B, *Packaging and Transportation Safety* (or successor document), or DOE O 461.1A, *Packaging and Transfer or Transportation of Materials of National Security Interest* (or successor document) requirements;

   f. sealed radioactive sources that meet any of the following testing specifications;

      - DOT Special Form criteria per 49 CFR § 173.469;
      - NRC Special Form criteria 10 CFR § 71.75;
      - ANSI N43.6/ISO 2919 Annex E Special Form criteria; or
      - ANSI N43.6/ISO 2919 Class 4, Class 5 or Class 6 performance criteria for temperature, impact, and puncture.

g. material meeting the special form criteria in 49 CFR § 173.403, *Definitions* and 49 CFR § 173.469, *Tests for special form Class 7 (radioactive) materials*;

h. encapsulated (i.e., sealed or welded configurations) weapons components and heat source components. Welded payload containers (e.g., EP-61s and Russian Product Cans) used to ship nuclear material in DOE/DOT approved shipping casks (e.g., 9516 and 5320 shipping casks). Fully encapsulated materials or components (i.e., sealed or welded configurations) that are subject to more restrictive requirements than are included in this CRD such as those: 1) fabricated to American Society of Mechanical Engineers (ASME) NQA-1, *Quality Assurance Requirements for Nuclear Facility Applications* or *Weapon Quality Policy (QC-1)* and 2) subject to rigorous inspection and surveillance protocols;

i. natural uranium (NU) and depleted uranium (DU); and

j. fixed contaminated or activated tools and equipment.

Specific packaging criteria of this CRD are not applicable to material packaged for short durations in bagged-out convenience containers or other appropriate containers while being transferred from one approved engineered contamination barrier to another or to the final package configuration (if performed in accordance with approved radiological controls).

Although a specific time limit for this short duration storage is not provided in this CRD, it is expected that the time would be on the order of hours or days and not weeks and that the hazards of the storage will be identified and evaluated and controls described and implemented. No specific time is given because specific situations may dictate what an appropriate time is. In all cases, however, contractor management is responsible for ensuring appropriate controls are in place to protect the workers.

CHAPTER II. NUCLEAR MATERIAL PACKAGING REQUIREMENTS[5]

1. STORED MATERIAL CHARACTERISTICS. Contractors must ensure that the chemical, radiological, and physical characteristics of the stored material are evaluated for the lifetime of the storage of the material and are appropriate for the material package including the following:

   a. Explosion Sensitive and/or Flammable Materials must be evaluated to determine if safe storage can be achieved or stabilization is necessary

   b. Gas Generation rates and gas composition must be evaluated and measures must be taken to minimize the formation or accumulation of gases inside the storage package with particular attention paid to limiting flammable gases. Minimization measures may include placing limitations on contents of containers, stabilizing materials, or venting and filtering containers.

   c. Incompatible Materials whose interaction could lead to failure of a containment barrier must not be packaged together (e.g., oxidizers and nitrated ion exchange resins).

   d. Physical and Chemical Form of material must be evaluated including its corrosivity and potential for oxidative expansion to ensure proper packaging. For example, a Pu metal (because of the high potential for rapid and complete oxidation) should not be stored in a vented container while a Pu oxide powder could be depending on specific activity and particle size.

   e. Moisture Content must be evaluated to determine if safe storage can be achieved or if stabilization is necessary. Stabilization must be considered for materials that can absorb/adsorb significant quantities of moisture when in contact with air. Moisture content amount must not violate the requirements in item b or c by interacting with materials being stored to induce corrosion or to increase the potential for flammable mixtures or over-pressure.

   f. Pyrophoricity must be evaluated to determine if safe storage can be achieved or if stabilization is necessary.

   g. Radioactive Decay Heat must be evaluated to ensure no unacceptable thermal degradation occurs. Package designers must include a maximum heat load in the design specifications.

   h. Radiation Fields must be evaluated to ensure they will not cause failure of a containment barrier or other containers included in the storage package. Plastic should not be in direct contact with alpha emitting materials. Package designers must include radiation fields resulting from radioactive decay of the stored

[5] This CRD does not address criticality safety requirements that must be addressed per DOE O 420.1B, *Facility Safety*.

material including daughter products that might have worse radiation fields than the originally stored material. Consideration should also be given to the radiation fields of contiguous containers in a storage array.

i. Solution composition and its effect on the selection of packaging type, storage duration, and surveillance must be evaluated. Special consideration must be given to gas generation and venting during storage life.

2. PACKAGING DESIGN CRITERIA AND PERFORMANCE OBJECTIVES. Contactors must ensure that concerns with corrosion, radiolytic and thermal degradation, oxidative expansion, pressurization, incompatible materials, and usage (handling) that may result in container failure are addressed as part of the package design. Contactors must ensure that nuclear material storage packages meet the following design criteria and performance objectives[6, 7].

a. Corrosion Resistance. The container, including filter vent and seals, must be constructed entirely of materials that are resistant to corrosion and chemical degradation from the materials being stored and generated gases as well as the ambient storage environment.

b. Thermal Degradation Resistance. The container, including filter vent and seals, must be designed so that heat generation of the contents does not challenge the integrity of the container for the design life of the container.

c. Radiation Resistance. The container, including filter vent and seals, must be designed so that radiation from stored material and the storage environment does not challenge the integrity of the container for the container's design life.

d. Oxidative expansion accommodation. The container must be designed to accommodate the maximum volume increase and potential effects on the container from the oxidative expansion of stored material that may occur for the container's design life.

e. Pressurization. Containers must be designed to withstand pressure due to gas generation, material oxidation, volume expansion, or release of volatiles during the design storage period. Measures should be taken to minimize the formation or accumulation of gases inside the storage package. Such measures include placing limitations on the contents of containers and permitted length of storage time, or providing mechanisms in the storage package design, such as venting.

[6] Note: Multiple nested containers are a good practice to provide added assurance that nuclear material will not be released from a package during normal handling or potential drops. The criteria and performance objectives in this section are focused on the container credited for confinement of the nuclear material and its capabilities to provide an adequate contamination barrier; however, most of the criteria and performance objectives will also be appropriate for any other containers in the package and should be considered.

[7] Note: DOE sites may find it cost effective to utilize other site container designs. However, each site must ensure the container is appropriate for its specific storage conditions (material types, storage height, environmental condition, etc.).

f. Incompatible and Pyrophoric Materials. Incompatible materials must not be stored together. Furthermore, pyrophoric materials must be containerized to prevent interaction with oxidative environments using techniques such as inert environments (gas or liquid blanket), double hermetic seals, encapsulation, etc., to prevent a pyrophoric reaction. Sites are encouraged to stabilize pyrophoric materials prior to storage (refer to DOE-HDBK-1081, *Primer on Spontaneous Heating and Pyrophoricity*).

g. Filter Performance. Filters must be capable of venting the maximum credible gas flow rate. Filters must be compatible with the material being stored including any product of reaction between the environment and the material (e.g., salts adsorbing moisture and corroding the can).

h. Design Life. The design life of the materials used in the container assembly as fabricated must be calculated or tested and the container must be examined under a regular documented maintenance and surveillance program. The impact of organic or other materials, such as silicone gaskets, that are subject to degradation must be accounted for in these calculations and in maintenance and surveillance plans. The container must meet design objectives such as the design release rate and design qualification release rate for the design life of the container. Container designs incorporating filters require useful-life determinations and performance verification measurements at the rated filtration efficiency.

i. Container Closure. Storage containers must be securely closed in a way that precludes accidental opening or breaching during normal operational conditions and/or postulated drops.

j. Design Release Rate Performance Objective. The package must have a design release rate that will maintain the potential internal exposure to workers as low as reasonable achievable (ALARA) during normal storage or handling of the package. Attachment 4 of DOE M 441.1-1provides an acceptable design release rate value as well as details on the basis for release rate and appropriate testing methods.

k. Design Qualification Release Rate Performance Objective. The package must have a post drop design qualification release rate that will prevent the exposure of workers to greater than 5 rem CEDE. The drop test must be from the maximum working or storage height but not less than four feet. Attachment 4 of DOE M 441.1-1provides an acceptable design qualification release rate value as well as additional details on the basis for this release rate and the appropriate testing methods.

l. Non-Destructive Examination. The package configuration should allow for non-destructive contents verification, inspection, and surveillance such as by radiography and weighing.

m. Quality Assurance. Packages must be designed, tested, and procured in accordance with the quality assurance requirements of 10 CFR Part 830 and DOE O 414.1C, *Quality Assurance*.

n. Labeling. Each storage container or package of radioactive material must have a unique permanent identification marking or bear a durable, clearly visible label for identification and documentation purposes. Labeling must meet the requirements of 10 CFR § 835.605. Where practical and appropriate, combine radiological, criticality safety and MC&A data into a single label.

3. PACKAGING SURVEILLANCE PROGRAM. Contractors must ensure that a surveillance program is established and implemented to ensure the nuclear material storage package continues to meet its design criteria.

4. General. The surveillance program must evaluate appropriate attributes of stored packages to determine whether the packages can continue to be stored safely. Surveillance must also validate the package design life.

5. As Low As Reasonably Achievable (ALARA). The surveillance program must be structured to minimize the overall risk to the facility workers and maintain radiation doses ALARA during the performance of surveillance activities. At a minimum, the following concepts should be considered:

(1) coordinating surveillance activities with MC&A measurements and inspections;

(2) coordinating surveillance activities with package movements;

(3) using MC&A and routine radiological survey data in the surveillance program;

(4) performing surveillance on packages as they are being opened for material use; and

(5) conducting remote surveillance (e.g., camera, load cell, etc.) for items generating high radiation fields.

b. Objectives and Techniques. The objective of the surveillance program is to identify indications of package degradation early to remediate the degraded package and to identify similar packages and materials that may need remediation. Surveillance techniques must be specified to provide early indications of package degradation which includes seal failure or loss of venting capability (if present). Any signs of degradation should be used for comparison with similar packages and containers. At a minimum, the following techniques must be considered:

(1) visual inspection of the container for indications of corrosion or pressurization including examining the container for signs of degradation prior to routine handling of the container or opening for material use;

(2) weight measurement for indications of mass change of the storage package which could indicate loss of package seal resulting in—

(a) possible oxidation and expansion of metal contents; and

(b) absorption of moisture which could increase corrosion of the package;

(3) contamination surveys which could indicate loss of container seal;

(4) testing of vent filters for plugging;

(5) radiography which could indicate pressurization or degradation of inner containers; and

(6) opening package for examination of interior contents and seals.

c. Frequency. Surveillance frequencies must be specified for each package design and content combination. At a minimum, the frequency should be based on the potential failure mechanism, failure consequence, and package design life. Statistical sampling of packages for surveillance may be used for large, uniform populations of packages and/or contents.

d. Procedures. Surveillance procedures must specify the surveillance techniques to be used and must have defined acceptance criteria. Procedures must be established to address initial response to packages that fail the acceptance criteria.

e. Evaluation. Surveillance data must be evaluated at least annually. Results of the surveillance program must be used to improve packaging design and modify the surveillance program, when appropriate. Sites should consider sharing data with other sites.

6. DOCUMENTATION. Contractors must ensure that documentation of the nuclear material storage package design and surveillance is maintained.

a. Records Retention. Packaging and surveillance records must be maintained in accordance with DOE O 243.1, *Records Management Program*..

b. Content Elements.

(1) Material Information. Records must include, at a minimum, available information on the following material characteristics:

(a) description of the chemical and physical form;

(b) best available isotopic content (and effective date of analysis[8]); and

(c) weight.

(2) Package Information. At a minimum, the records must include identification of the following package characteristics:

(a) date of packaging for each container;

(b) baseline package gross weight;

(c) unique identification number associated with each package; and

(d) configuration—quantity and type of containers in a package (this is not required for packages that existed before the Manual was issued; however, it is a recommended good practice).

(3) Surveillance Information. At a minimum, the records must include the following surveillance and inspection data:

(a) unique identification number associated with each package;

(b) surveillance and radioactive survey results and dates;

(c) dates, location, and results of inspections; and

(d) name and site qualifications of individuals performing inspections.

(4) Technical Basis Information. At a minimum, records must include information pertaining to the technical basis for packaging and storing applicable nuclear materials, including a description of how the applicable stored material characteristics and packaging design criteria are satisfied, supported by test results and other evidence, as appropriate; threshold calculations for the packaged material; and surveillance and monitoring information.

c. Database. A database of relevant information about stored materials and packages including material information, packaging information, and surveillance information for each storage package must be maintained. An electronic database should be utilized to simplify scheduling of surveillance and repackaging of packages and evaluation of surveillance data. The database may consist of several

[8] The effective date of analysis should be included if it is used to address impacts of changes in isotopic content on packages over their lifetime.

files, which in themselves may be databases, some of which may be classified. For completeness, the database should be coordinated and generally compatible with the MC&A data bases.

REFERENCES

1. DOE TECHNICAL STANDARDS, HANDBOOKS, ORDERS, MANUALS, AND POLICIES.

a. DOE-HDBK-1081-94, *Primer on Spontaneous Heating and Pyrophoricity*, December 1994.

b. DOE-HDBK-1129-2007, *Tritium Handling and Safe Storage*, March 2007.

c. DOE-STD-3013-2004, *Stabilization, Packaging, and Storage of Plutonium Bearing Materials*, April 2004.

d. DOE-STD-3028-2000, *Criteria for Packaging and Storing Uranium-233-Bearing Materials*, July 2000.

e. DOE O 414.1C, *Quality Assurance*, dated 6-17-05.

f. DOE O 420.1B, *Facility Safety*, dated 12-22-05.

g. DOE O 435.1 Chg 1, *Radioactive Waste Management*, dated 7-9-99.

h. DOE O 440.1B, *Worker Protection Program For DOE (Including The National Nuclear Security Administration) Federal Employees*, dated 5-17-07.

i. DOE P 441.1, *Department of Energy Radiological Health and Safety Policy*, dated 4-26-96.

j. DOE P 450.4, *Safety Management System Policy*, dated 10-15-96.

k. DOE G 460.1-1, *Implementation Guide for use with DOE O 460.1A Packaging and Transportation Safety*, dated 6-5-97.

l. DOE O 460.1B, *Packaging and Transportation Safety*, dated 4-4-03.

m. DOE O 460.2A, *Departmental Materials Transportation and Packaging Management*, dated 12-22-04.

n. DOE O 461.1A, *Packaging and Transfer or Transportation of Materials of National Security Interest*, dated 4-26-06.

o. DOE M 470.4-7, *Safeguards and Security Program References*, dated 8-26-05.

p. DOE O 5400.5 Chg 2, *Radiation Protection of the Public and the Environment*, dated 1-7-93.

q. DOE O 5660.1B, *Management of Nuclear Materials*, dated 5-26-94.

r. DOE O 243.1, *Records Management Program,* dated 2-3-06.

s. *Criteria for Interim Storage of Plutonium Bearing Materials*, issued by a memo to field from DOE Secretary Curtis, January 25, 1996.

t. DOE HDBK 3010-94, Change Notice 1, *Airborne Release Fractions/Rates and Respirable Fractions for Non-Reactor Nuclear Facilities*, March 2000.

u. *The Use of Teflon® Components in National Nuclear Security Administration Nuclear Facilities,* issue by memo to the field from E. Beckner, Deputy Administrator for Defense Programs, May 20, 2004.

2. REGULATIONS AND GOVERNMENT DOCUMENTS.

a. 40 CFR 191.02, *Spent Nuclear Fuel.*

b. 10 CFR Part 71, *Packaging and Transportation of Radioactive Material.*

c. 10 CFR Part 830, *Nuclear Safety Management*.

d. 10 CFR Part 835, *Occupational Radiation Protection*.

e. 10 CFR Part 851, *Worker Safety and Health Program.*

f. 49 CFR Part 173, *Shippers—General Requirements for Shipments and Packagings*.

g. Executive Order 12344, *Naval Nuclear Propulsion Program*, 47 Federal Register 4979, February 1, 1982.

h. NUREG/CR-6487, Containment Analysis for Type B Packages used to Transport Various Contents. U.S. Nuclear Regulatory Commission, November 1996.

3. OTHER REFERENCES.

a. ANSI N14.5-1997, *Radioactive Materials – Leakage Tests on Packages for Shipment*, February 1998.

b. ANSI N43.6-1977, *Sealed Radioactive Sources, Classification*, August 1998.

c. ISO 2919, *Radioactive Protection - Sealed Radioactive Sources—General Requirements and Classification*, February 1999.

d. Safety Guide No. TS-G-1.1 (ST-2), Appendix 1, *Advisory Material for the IAEA Regulations for the Safe Transport of Radioactive Material*, 2002.

e. American Society of Mechanical Engineers (ASME) NQA-1, *Quality Assurance Requirements for Nuclear Facility Applications.*

f. DOE/NNSA Weapons Quality Policy *(QC-1)*, (Rev10), 2004.

METHOD FOR DETERMINING TYPES AND QUANTITY OF MATERIAL SUBJECT TO SPECIFIC PACKAGING DESIGN REQUIREMENTS

This attachment describes the method that must be used for determining the types and quantities of material in a storage package that are likely to result in an internal exposure to workers above 5 rem CEDE if not properly packaged and therefore are subject to the specific packaging design requirements of this Manual. This method is based upon and utilizes data on the amount of nuclear material that, if released in an accident, could result in exceeding annual limits of intake as defined in DOT requirements. These quantities (for non-special form material) are identified as A_2 quantities.

1. <u>TYPES OF MATERIAL</u>.

The types of material for which the specific packaging criteria of this Manual apply are those for which a hazard analysis for a breached package would identify the potential for a significant internal radiation exposure. Table 1, *Threshold Quantities for Common DOE Isotopes*, provides a list of nuclear materials most prevalent in the DOE complex, where a hazard analysis for a breached package would identify an internal radiation exposure scenario as more limiting than an external radiation exposure scenario. Table 1 is not intended to be all-inclusive of the nuclear materials to be considered within the scope of this Manual. Threshold quantities for materials not listed in Table 1 should be evaluated individually using the methodology discussed below.

Some specific material forms and packaging (listed in Chapter II of this Manual) are not subject to the specific packaging criteria of this Manual. The rationale is that the material is either: stored in a DOE, DOT or NRC appropriate package for protection of workers and the public or packaged in a manner such that dispersion during handling is not possible, or has special requirements for protection of workers that are beyond those specified in this Manual (e.g., gases).

2. <u>QUANTITIES OF MATERIAL</u>.

Nuclear materials that are of the type described above and where the total activity exceeds the A_2 thresholds in 49 CFR § 173.435, *Table of A_1 and A_2 values for radionuclides*[9], are subject to the specific container requirements of this Manual[10].

The A_2 thresholds are utilized in 49 CFR § 173.435 to identify requirements for packaging of material for transport on public roadways. For mixtures of isotopes, sites should use a methodology consistent with that in 49 CFR § 173.433, *Requirements for determining basic radionuclide values, and for the listing of radionuclides on shipping*

[9] A_2 Thresholds in 49 CFR §173.435 correspond to the maximum amount of dispersible material that can be shipped via Type A packages (which have much less stringent testing criteria as compared to Type B packages). The values are based on not exposing workers to greater than 5 rem dose if the package were to fail (International Atomic Energy Agency [IAEA] Safety Guide TS-G-1.1 [ST-2] reports that inhalation from releases from packages would be on the order of 10^{-6} of the packaged material).

[10] The limits apply to the maximum amount of material in a package. Where multiple containers are included in an outer container, the total amount in the package is the amount to compare to the limit.

papers and labels, for determining whether the mixtures of isotopes are subject to the specific container requirements in this Manual. Section 3 below provides details for performing the threshold calculation.

Table 1 DOE M 441.1 Threshold Quantities for Common DOE Isotopes**

Isotopes	A_2 (Ci)	Specific Activity (Ci/g)	A_2 Quantity (g)
U-232	$2.7x10^{-2}$	$2.2x10^{1}$	$1.2x10^{-3}$
U-233	$1.6x10^{-1}$	$9.7x10^{-3}$	$1.6x10^{1}$
U-234	$1.6x10^{-1}$	$6.2x10^{-3}$	$2.6x10^{1}$
U-235* [a]	Unlimited	$2.2x10^{-6}$	Unlimited
Uranium enriched < 20% U-235	Unlimited	varies with enrichment See 49 CFR 173.434	Unlimited
Uranium enriched > 20% U-235	**	varies with enrichment See 49 CFR 173.434	
U-236	$1.6x10^{-1}$	$6.5x10^{-5}$	$2.5x10^{3}$
U-238*	Unlimited	$3.4x10^{-7}$	Unlimited
Pu-238	$2.7x10^{-2}$	$1.7x10^{1}$	$1.6x10^{-3}$
Pu-239	$2.7x10^{-2}$	$6.2x10^{-2}$	$4.4x10^{-1}$
Pu-240	$2.7x10^{-2}$	$2.3x10^{-1}$	$1.2x10^{-1}$
Pu-241	1.6	$1x10^{2}$	$1.6x10^{-2}$
Pu-242	$2.7x10^{-2}$	$3.9x10^{-3}$	6.9
Th-228	$2.7x10^{-2}$	$8.2x10^{2}$	$3.3x10^{-5}$
Th-229	$1.4x10^{-2}$	$2.1x10^{-1}$	$6.7x10^{-2}$
Th-232*	Unlimited	$1.1x10^{-7}$	Unlimited
Np-237	$5.4x10^{-2}$	$7.1x10^{-4}$	$7.6x10^{1}$
Am-241	$2.7x10^{-2}$	3.4	$7.9x10^{-3}$
Am-243	$2.7x10^{-2}$	$2x10^{-1}$	$1.4x10^{-1}$
Bk-249	8.1	$1.6x10^{3}$	$5.1x10^{-3}$
Cm-244	$5.4x10^{-2}$	$8.1x10^{1}$	$6.7x10^{-4}$
Cm-246	$2.7x10^{-2}$	$3.1x10^{-1}$	$7.7x10^{-2}$
Cf-252	$8.1x10^{-2}$	$5.4x10^{2}$	$1.5x10^{-4}$

* The quantities for U-235, U-238, and Th-232 require an intake of more than 10 mg to result in the threshold dose. Standards established by the International Atomic Energy Agency (IAEA) Safety Guide No. TS-G-1.1 assume an individual will inhale no more than 10 mg. Therefore, the Manual packaging requirements do not apply to these isotopes. However, for uranium isotopes, nonradiological effects, such as chemical toxicity, may be limiting and require evaluation per 10 CFR Part 851 and DOE O 440.1B.

** Gram values are based on 49 CFR §173.435. Isotopic mixtures vary and must be calculated. Refer to 49 CFR §173.433.

[a] These isotopes have A_2 values that considered the contributions from progeny with less than 10 day half-life.

Notes on Table 1:

- Threshold calculations of any dispersible material containing a mixture of radionuclides must be determined using a sum-of-fractions calculation. An example is described in Section 4 below.
- Table 1 is not all inclusive of all isotopes that meet the criteria of inhalation dose exceeding the external dose. Sites must evaluate the storage of uncommon isotopes to ensure that the specific packaging requirements of this Manual (i.e., potential for inhalation dose exceeding 5 rem CEDE upon package failure) are met.

3. METHODOLOGY FOR PERFORMING THRESHOLD CALCULATIONS.

Threshold calculations can be used to determine whether a material is in or out of scope of this Manual. Threshold calculations must use one of the following methodologies.

a. The quantity of material to be packaged must be compared against the A_2 values in Table 1. When comparing against Table 1 quantities, nuclides that are parents of decay chains with daughters with > 10 day half lives must be considered as mixtures with the longer lived daughters, and the mixture equation in 49 CFR 173.433(d) must be applied. For example, uranium enriched greater than 20% must be treated as a mixture of parent nuclides with all daughters with half lives greater than 10 days. If the identities of the radionuclides in a mixture are in doubt, the lowest A_2 values with the total quantity of material must be used for the mixture.

b. Threshold calculations of any dispersible material containing a mixture of radionuclides must be determined using a sum-of-fractions calculation. An example is described in Section 4 below. This follows the methodology of 49 CFR 173.433.

c. Materials in solid form do not have to be included in the threshold calculation. Material considered to be solid form must meet the following criteria:

(1) Solid forms are greater than 100 µm aerodynamic equivalent diameter (AED) at initial packaging.[11.]

(2) Solid forms maintain AED greater than 100 µm after a post drop event.

(3) Quantities of material less than 100 µm formed during storage due to corrosion, etc. or upon material disruption (container drop) must be included in the threshold calculation.

[11] The 100 µm AED is a factor of 10 greater than the respirable particle size (10 µm AED) and was chosen to be conservative.

d. In determining whether material is solid form, calculations must consider reactions that could generate powders (i.e. oxidation, decay heat, and physical degradation) over the life time of the storage conditions. For example, a container that has a large metallic object with very little (less than an A_2 quantity) of powder may not be required to meet the specific container requirements of this Manual if it can be further demonstrated that less than an A_2 quantity of fine material will result during the Design Life of the container due to reactions during storage or during a drop event.

4. EXAMPLE RESULTS OF A_2 CALCULATION FOR MIXTURE OF ISOTOPES.

The materials considered in this example are common plutonium containing materials. The nominal isotopic content is taken from DOE-STD-3013 for Weapon Grade, Fuel Grade, and Power Grade plutonium and from the Los Alamos National Laboratory (LANL) convention used in safety documentation for heat source plutonium (Pu-238 containing material). The isotopic compositions of the radionuclides are shown in Table 2.

Table 2. Isotopic Composition for Common Plutonium Containing Material.

Nuclide	A_2 (Ci)	Specific Activity (Ci/g)	Pure ^{239}Pu	Weapon Grade	Fuel Grade	Power Grade	Heat Source
^{238}Pu	0.027	17	0.00%	0.05%	0.1%	1.0%	89.3%
^{239}Pu	0.027	0.062	100.00%	93.50%	86.1%	63.0%	10.1%
^{240}Pu	0.027	0.23	0.00%	6.00%	12.0%	22.0%	0.6%
^{241}Pu	1.6	100	0.00%	0.40%	1.6%	12.0%	0.0%
^{242}Pu	0.027	0.0039	0.00%	0.05%	0.2%	3.0%	0.0%
^{241}Am	0.027	3.4	0.00%	0.00%	0.0%	0.0%	0.0%

The A_2 for a mixture is calculated using the sum as fractions:

$$A_2 = \frac{1}{\sum_i \frac{f(i)}{A_2(i)}}$$

Where f(i) is the releasable activity fraction of radionuclide i and $A_2(i)$ is the A_2 value for that isotope. Applied to the material compositions in Table 2, the A_2 values for the mixtures, which are expressed in terms of Curies and grams of oxide, are shown in Table 3 below.

Table 3. A_2 Values for Mixtures

Material	Pure ^{239}Pu	Weapon Grade	Fuel Grade	Power Grade	Heat Source
A_2 for mixture (Ci)	0.027	0.149	0.367	0.716	0.027
Total activity (Ci/g)	0.0547	0.4239	1.4989	10.8225	13.4014
A_2 for mixture (g)	0.4938	0.3518	0.2449	0.0662	0.0020

DETAILS OF BASIS FOR RELEASE RATE CRITERIA AND APPROPRIATE TESTING METHODOLOGY

This attachment provides the basis for the release rate criteria and testing methodology.

1. DESIGN RELEASE RATE.

The Manual requirement is: *The package must have a design release rate that will maintain the potential internal exposure to workers as low as reasonable achievable (ALARA) during normal storage or handling of the package.*

The design release rate is intended to protect workers from potential leakage of: (1) undisturbed material in storage packages, and (2) material disturbed during normal handling. It should account for changes in atmospheric pressure and minor buildup of pressure inside of the container and for the material becoming airborne (inside of the container) during normal handling (e.g., due to jostling or vibration during transport).

The objective is to have no release of particulate material during normal storage and handling conditions. A testable gas release rate that will meet this objective must be defined. One of the following testable release rates must be utilized.

a. Utilize ANSI N14.5-1997 criteria for leaktight.

ANSI N14.5-1997 defines leaktight as:

> "A degree of package containment that in a practical sense precludes any significant release of radioactive materials. This degree of containment is achieved by demonstration of a leakage rate less than or equal to 1×10^{-7} ref·cm^3/s, of air at an upstream pressure of 1 atmosphere (atm) absolute (abs) and a downstream pressure of 0.01 atm abs or less."

This is an appropriate value to utilize as a design release rate but may be unnecessarily conservative and overly restrictive for non-welded-shut containers used for storing nuclear material that must be periodically opened for material retrieval.

b. Utilize 10 CFR § 71.51 criteria for no loss of radioactive material

10 CFR § 71.51 specifies that for normal transport of radioactive material there should be no loss or dispersal of radioactive contents--as demonstrated to a sensitivity of 10^{-6} A_2 per hour. The translation of this particulate release rate (10^{6} A_2 per hour) to a gas release rate for testing the package is dependent upon the type and activity of the stored material. An example for making this translation is described in Attachment 5.

Both of these testable Design Release Rate criteria should prevent unacceptable contamination of storage areas from the release of radioactive material and meet the ALARA objective of this Manual.

2. DESIGN QUALIFICATION RELEASE RATE.

The Manual requirement for qualification of a design, is that *the container must have a post drop design qualification release rate that will prevent the exposure of workers to greater than 5 rem CEDE.*

An acceptable value for the design qualification release rate is less than $10^{-3} A_2$/event. This is a conservative value based upon a range of IAEA reported dispersion estimates as discussed further below. This value must be utilized except as allowed for in Attachment 6 for Uranium enriched to greater than 20% ^{235}U.

Note: the "event" is a drop of a storage container and the expected worker exposure time for the "event" should be very small (less than a minute) but for the purpose of this manual is taken as 10 minutes.

The basis for this value is that it is consistent with IAEA analysis utilized in establishing DOT shipping package requirements for Type B containers. IAEA Safety Guide TS-G-1.1 (ST-2), provides analytical results that indicate that 10^{-3} to 10^{-4} of material released from a package in an event may be inhaled by a person in the vicinity of the event (based upon consideration of a range of possible accident situations). Therefore, since inhalation of 10^{-6} A_2 of material equates to receiving a 5 rem internal dose, limiting the release material to 10^{-3} A_2 would not result in exceeding a 5 rem dose (10^{-3} A_2 released times 10^{-3} to 10^{-4} of the release material inhaled will be less than or equal to a total of 10^{-6} A_2 inhaled).

3. RELEASE RATE TESTING METHODOLOGY.

Testing to demonstrate that the container meets the design release rate is required. The testing requirements can be met by translating the material release rate into a He leak rate as described by Appendix B Section 15.27 of ANSI N14.5-1997 utilizing an appropriate oxide aerosol density and then performing a He leak rate test. Attachment 5 provides an example calculation.

For some low activity isotopes (such as enriched uranium) the value of A_2 is measured in kilograms and the corresponding material release rate would be greater than 1 milligram per hour. This magnitude of a material release rate is measurable by a mass measurement of the actual release from a container, but would not be measurable by a He leak rate test because the He leak rate would be too high (approximately 8 Ref. cm^3/s, where Ref. is the pressure at which the container normally operates). The appropriate test at high material release rates such as for uranium materials may be an actual loss of material from the container. A suitable testing surrogate for enriched uranium would be depleted uranium. For the purpose of the design release rate, the driving mechanism for causing the release of the material outside the container may be obtained by utilizing a shake table that simulates jostling of material during normal handling. Attachment 6 provides an alternative acceptable qualitative design release test criteria for the design release rate for enriched uranium.

Testing to demonstrate that the package design meets the post-drop design qualification test release rate may be performed by measuring the amount of surrogate material that is released from a package following a drop test (collecting the material for a period of 10 minutes following the drop test) or by measuring the release rate utilizing the ANSI N 14.5-1997 methodology. Attachment 5 provides further discussion on appropriate testing methods.

4. DROP TEST METHODOLOGY.

The drop test will consist of a free drop of the package through a maximum handling distance (at a minimum of 4 feet) onto a flat, essentially unyielding, horizontal surface, striking the surface in a position for which maximum damage is expected.

Consistent with DOE G 460.1-1, *Packaging and Transportation Safety,* the drop test should be performed as specified in 49 CFR § 173.465(c)(5) at a test facility capable of dropping a packaging onto a flat and horizontal surface of such mass and rigidity that any increase in its resistance to displacement or deformation upon impact by the specimen would not significantly increase the damage to the specimen. Each test facility should provide documentation describing its drop test apparatus and demonstrating that its target surface meets the mass and rigidity requirements of 49 CFR § 173.465(c)(5). The drop test procedure should document the means by which packages would be dropped, the manner in which a maximum-damage drop orientation would be determined for each package, the means by which the appropriate drop orientation and drop height would be ensured during testing, the pass/fail criteria for the drop tests, and records to be kept (including photographs and/or videotape) of the testing and results.

When performing the drop test the package configuration that represents the worst case storage conditions shall be tested (e.g., load in the container). Any package configuration that is designed to minimize the impact (including use of shock absorbing material) can be utilized if this represents the design package configuration.

Note: The intent of the design release rate and design qualification release rate requirements are to establish minimum criteria for leak tightness and structural integrity of containers. However, site specific conditions may warrant additional engineering, administrative, or personnel protection controls. For example, if there is the potential for dropping multiple containers or for puncturing containers with a fork lift, the contractor must evaluate the hazards and establish appropriate controls in accordance with Integrated Safety Management requirements

EXAMPLE CALCULATION OF DESIGN RELEASE RATE AND DESIGN QUALIFICATION RELEASE RATE

The following is an example of a calculation of design release rate and design qualification release rate. The example is for weapons grade Pu in an oxide form stored in a vented container[12]. The purpose of this section is to provide an example of how these calculations can be done. This example outlines the steps involved in performing these calculations in accordance with the ANSI N14.5-1997 methodology and provides additional background information useful in performing the calculation. The calculated release rate values in this example should not be utilized. Rather, facility and package specific calculations should be performed utilizing the appropriate facility/site engineering and quality control procedures.

Calculation Overview

Step 1: Determine the mass release rate criterion (i.e., convert $10^{-6} A_2$/hr to g/hr)

Step 2: Convert the mass release rate criterion to a volumetric release rate criterion (air and He gas)

Step 3: Determine driving pressure for release of material specific to the container and facility conditions

Step 4: Convert the He gas release rate criterion (for the facility conditions) to a test acceptance criteria specific to the He gas detector being utilized for the test.

Step 5: Calculate a post-drop test release rate (corresponding to $10^{-3} A_2$/event)

Step 1: Determine the mass release rate criterion

The design release rate criterion is 10^{-6} A_2 per hour.

Using the value for A_2 (.352 g) for weapons grade Pu oxide (taken from Table 3 in Attachment 3 of this Manual) this corresponds to:

$$10^{-6} A_2/\text{hr} = 10^{-6} (0.352\text{ g})/\text{hr} = 3.52 \times 10^{-7} \text{ g/hr } (1\text{ hr}/3600\text{ s})$$

$$= 9.8 \times 10^{-11} \text{ g/s}$$

Step 2: Convert to a volumetric release rate Criterion

In order to convert the mass release rate into a volumetric release rate, the density of the Pu oxide must be determined.

The oxide aerosol density used by ANSI N 14.5-1997 (Section B.15.27) is 9×10^{-6} g/cm^3 and

[12] This example is based upon calculations performed by Douglas K. (Kirk) Veirs in September 2007 to support testing of Hagen cans used to store Pu at Los Alamos National Laboratory (LANL). A test report that provides details of the calculations and test result is being developed and is expected to be issued in 2008.

represents the worst case of an agitated container intended to simulate vibrations present in normal transport. This is more conservative than the case for a quiescent package in storage or carefully handled by plutonium workers. An extensive literature review of experimental studies of aerosol actinide oxide densities achieved by flowing gas through a vibrating bed is summarized in NUREG/CR-6487, *Containment Analysis for Type B Packages used to Transport Various Contents*. The lines of best fit yielded densities of $1x10^{-8}$ g/cm^3 for a leak above the oxide bed and $6x10^{-8}$ g/cm^3 for a leak below the oxide bed.

For conservatism and simplicity this is rounded up to $1x10^{-7}$ g/cm^3 which is used as the oxide density in the fluid leaking from the container in this calculation.

Therefore, the volumetric gas (air) release rate at the pressure and temperature of the container is:

$$\frac{\text{Pu Mass Release Rate}}{\text{Pu Gas Concentration}} = \frac{9.8x10^{-11}\ g/s}{1x10^{-7}\ g/cm^3} = 9.8x10^{-4}\ \text{cm}^3\text{/s for Weapons Grade Pu oxide}$$

<u>Step 3:Determine driving pressure for release of material</u>

The driving pressure from the containers is a combination of pressure buildup in the container from radiolytic gas generation and changes in atmospheric pressure conditions. For this example, a filtered container is used.

Volume of gas generated by radiolysis:

$$\Delta V_g = \frac{G \cdot f_{H2O} \cdot TA \cdot R \cdot T}{P}$$

Where G = gas generation rate (from the DNFSB 94-1 Surveillance and Monitoring Program[13]) is equal to 300 nmol/s Watt for Pu.

f_{H2O} = fraction of water in contained material (.05 is assumed for this example)

TA = Total Activity of contained material in Watts (determined from total material in the container. For this example 3.78 Watts is used which is reasonable for a one quart container loaded with Pu)

R = Gas constant (8.314 kPa L/K mol)

T = Local temperature (assumed to be 55 ˚C [328 ˚K])

P = Local atmospheric pressure (assumed to be 100 kPa)

[13]LA-13261-PR, *94-1 Research and Development Project,* December 1996

$$\Delta V_g = \frac{\left(300x10^{-9}\,\frac{\text{mol}}{\text{s W}}\right)(0.05)(3.78\text{ W})\left(8.31\,\frac{\text{kPa L}}{\text{K mol}}\right)(328\text{ K})}{100\text{ kPa}} = 1.55x10^{-6}\,liter/s$$

$$\left(1.55x10^{-6}\,liter/s\right)\left(1000\,\frac{cm^3}{liter}\right) = 1.55x10^{-3}\,cm^3/s$$

This change in volume is converted to a pressure drop across the filter utilizing data on the filter flow capacity (for this case 200 ml/min at 1 inch water column differential pressure [.248 kPa]) assuming that the filter is 99 percent clogged. This flow per pressure drop is then:

$$F = \frac{(200\text{ ml/min})(1\text{ cm}^3/\text{ml})(1\text{ min }/60\text{ s})}{(0.248\text{ kPa})} = 13\,\frac{\text{cm}^3}{\text{s kPa}}$$

For a 99 percent clogged filter the flow is $F_{red} = F * 10^{-2}$

$$\Delta P_g = \frac{\Delta V_g}{F_{red}} = \frac{1.55x10^{-3}\,\frac{cm^3}{s}}{\left(13\,\frac{\text{cm}^3}{\text{s kPa}}\right)\left(10^{-2}\right)} = 0.012\,kPa$$

The driving pressure due to atmospheric pressure changes can be determined from records of maximum daily atmospheric pressure changes. For example, the maximum atmospheric pressure change in a day at LANL was 2 kPa. This could be directly used as the driving pressure for the release of material. Conversely a calculation of the volume that must be released through a filter vent can be determined and an assumption made on the time the pressure change occurs.

For example (using the ideal gas law for the case of a 1 quart [.95 liter] container), assuming the pressure change occurred over a 2 hour time, the change in volume due to atmospheric pressure changes is:

$$\Delta V_a = \frac{\Delta P}{P}\cdot V = \frac{2kPa\,\frac{1}{2hr}}{100kPa}\cdot(.95liter)\left(\frac{1000cm^3}{liter}\right)\left(\frac{1hr}{3600s}\right) = 2.6x10^{-3}\,\frac{cm^3}{s}$$

This change in volume can be converted into a change in differential pressure from the atmospheric pressure change:

$$\Delta P_a = \frac{\Delta V_a}{F_{red}} = \frac{2.6x10^{-3}\,\frac{cm^3}{s}}{\left(13\,\frac{\mathrm{cm}^3}{\mathrm{s\ kPa}}\right)\left(10^{-2}\right)} = 0.02\,kPa$$

$$\Delta P_{total} = \Delta P_a + \Delta P_g = 0.02\,kPa + 0.012\,kPa = 0.032\,kPa$$

Therefore, for a 1 liter container, an appropriate differential pressure to conduct a leak rate test would be 0.032 kPa differential pressure. For larger containers with more material using the same filter, the differential pressure would increase to 1 to 2 kPa. For most storage conditions, a 2 kPa differential pressure would be conservative.

Step 4: Convert the He gas release rate criterion to a test acceptance criterion

A means for performing the release rate test is to pull a vacuum (exhausting to a He detector) on the outside of the container and introduce He into the container such that there is a 1 kPa differential pressure.

However, because the He leak detector measures the release rate in standard [std] atmosphere [atm] $cm^3\ sec^{-1}$ (= 101 kPa $cm^3\ sec^{-1}$), a conversion must be made to account for the density differences. Using the approach in ANSI N 14.5, the gas leak rate can be converted to a He leak rate at the maximum operating differential pressure. Using 1 kPa differential pressure for a container with Weapons Grade Pu oxide, the volumetric gas release rate determined in Step 2 can be converted to a He leak rate reported by a He leak detector in atm cm^3/s of He.

Several steps are involved in performing this calculation. First, the size of the leakage hole needs to be determined that corresponds to the air leakage rate (and conditions), then a He leak rate corresponding to testing conditions and the calculated leakage hole size.

The following conditions are used for the calculation of the hole size:

Pressure upstream = P_u = 102 kPa = 1.01 atm
Pressure downstream = P_d = 101 kPa = 1.00 atm
Average pressure = P_a = ½(P_u+P_d) = ½(1.01 + 1.00) = 1.005 atm
Measured Leak Rate = Lu = 9.8 x 10^{-4} cm^3/sec
Temperature = T = 298K
Gas = air
Gas Properties:
  Fluid Viscosity: μ = 0.0185 cP
  Molecular Weight: M = 29 g/gmol
Length of leakage pathway (assumption) = 0.1 cm

Calculate the hole diameter using ANSI N14.5 Equation B.3, B.4 and B.5 using the approach outlined in example B5:

Calculate Fc (coefficient of continuum flow conductance, ANSI N14.5 Eq B.3):

$$F_c = \frac{\left[2.49x10^6 D^4\right]}{a\mu}\frac{cm^3}{atm\ s} = \frac{\left[2.49x10^6 D^4\right]}{(0.1)(0.0185)}\frac{cm^3}{atm\ s} = 1.35x10^9 D^4 \frac{cm^3}{atm\ s}$$

Calculate Fm (coefficient of free molecular flow ANSI N14.5 Equation B.4):

$$F_m = \frac{\left[3.81x10^3 D^3\left(\frac{T}{M}\right)^{0.5}\right]}{aP_a}\frac{cm^3}{atm\ s} = \frac{\left[3.81x10^3 D^3\left(\frac{298}{29}\right)^{0.5}\right]}{(0.1)(1.005)}\frac{cm^3}{atm\ s} = 1.21x10^5 D^3 \frac{cm^3}{atm\ s}$$

Putting this information into ANSI N 14.5 Equation B.5 (where L_u is the upstream air leakage rate)

$$L_u = (F_c + F_m)(P_u - P_d)\left(\frac{P_a}{P_u}\right)\frac{cm^3}{s}$$

$$9.8x10^{-4}\frac{cm^3}{s} = \left(1.35x10^9 D^4 \frac{cm^3}{atm\ s} + 1.21x10^5 D^3 \frac{cm^3}{atm\ s}\right)(1.01atm - 1.00atm)\left(\frac{1.005atm}{1.01atm}\right)$$

Solve for D to get: D = 2.9 x10^{-3} cm.

Calculate the helium leak rate at the testing conditions:

The following conditions apply to this situation

Pressure upstream = P_u = 1 kPa (1 atm/101 kPa) = 0.01 atm
Pressure downstream = P_d = 0 atm
Temperature = T = 298K
D = 2.9 x 10^{-3} cm
Gas = Helium
Gas Properties:
  μ = 0.0198 cp
  M = 4 g/gmol

Calculate the leak rate:

$P_a = ½(P_u+P_d) = ½(0.01 + 0) = .005$ atm

Calculate Fc (ANSI N14.5 Eq B.3):

$$F_C = \frac{\left[2.49x10^6 D^4\right]}{a\mu}\frac{cm^3}{atm\ s} = \frac{\left[\left(2.49x10^6\right)\left(2.9x10^{-3}\right)^4\right]}{(1)(0.0198)}\frac{cm^3}{atm\ s} = 0.088\frac{cm^3}{atm\ s}$$

Calculate Fm (ANSI N14.5 Equation B.4):

$$F_m = \frac{\left[3.81x10^3 D^3\left(\frac{T}{M}\right)^{0.5}\right]}{aP_a}\frac{cm^3}{atm\ s} = \frac{\left[\left(3.81x10^3\right)\left(2.9x10^{-3}\right)^3\left(\frac{298}{4}\right)^{0.5}\right]}{(0.1)(0.005atm)}\frac{cm^3}{atm-s}$$

$$= 1.6\frac{cm^3}{atm\ s}$$

Putting this information into ANSI N 14.5 Equation B.5 (where L_u is the helium leak rate and Q is the mass flow rate detected by the He leak detector)

$$L_u = (F_c + F_m)(P_u - P_d)\left(\frac{P_a}{P_u}\right)\frac{cm^3}{s}$$

$$L_u = \left(0.088\frac{cm^3}{atm\ s} + 1.6\frac{cm^3}{atm\ s}\right)(0.01atm - 0.00atm)\left(\frac{.005atm}{.01atm}\right) = 8.4x10^{-3}\frac{cm^3}{s}$$

$$Q = L_u\ x\ P_u = 8.4x10^{-3}\frac{cm^3}{s}\ x\ 0.01\ atm = 8.4x10^{-5}\frac{atm\ cm^3}{s}$$

So the Helium Leak Rate Test Criteria will be $8.4x10^{-5}$ atm cm^3/s.

Note: Because the He detector is not being operated over a 1 atm pressure differential, the actual reading will be different that the leak rate. This is calculated by and adjustment using the upstream pressure.

Step 5: Establish a post-drop release test criterion

The design qualification release rate criterion ($10^{-3}A_2$ per event) can be measured as either as a material release amount after the drop (in a given period of time, e.g., 10 minutes) or a gas release rate after the drop. The measurement of material provides a better indication of the potential impact on a worker (because it accounts for the potential puff release that may occur) but may be impracticable because the release criterion is extremely small for certain high activity isotopes (e.g., .00035 grams of weapons grade Pu).

A simple go/no go test can be used on material that has an extremely small release criterion by loading the container with a luminescent surrogate material (e.g., fluorescence) and then looking for any release of material during and immediately following the drop test.

Alternatively, since a zero release criteria may be too restrictive, if very small amounts of surrogate material are released, an assessment of the post drop release rate can serve as an appropriate indicator of the ability of the container to meet the post drop release rate criterion.

Using the methods outlined in ANSI N 14.5-1997, for Weapons Grade Pu, a bubble test (with a criterion of no bubbles released) or a pressure drop test may be shown to suffice.

IMPLEMENTATION GUIDANCE
SPECIFIC TO STORAGE OF GREATER THAN 20% ENRICHED URANIUM ^{235}U (EU)

This attachment provides an acceptable approach for implementing some specific aspects of the Manual requirements for greater than 20% enriched uranium (EU) material containers. The reason for including this attachment is that, due to its low specific activity and other unique characteristics, implementation of some of the Manual requirements for EU can be performed in a qualitative rather than quantitative manner.

1. GUIDANCE FOR EU.

a. Guidance for Implementation of Requirement for Determining the Scope of Material (Sections 2 and 3 of Attachment 3).

In determining threshold quantities and whether material is within the scope of the manual, the following guideline applies:

Bulk EU metal (i.e., material in solid form as defined in Attachment 3, section 3.c.) can be excluded from the threshold calculation (not including EU chips, turnings, or fines that may potentially be oxidizable to respirable powders upon storage).

b. Guidance for Implementing the Requirements for Determining the Threshold Quantity (Section 2 and 3 of Attachment 3).

When determining the threshold quantity (A_2 value) for EU, dose conversion factors based on physical characteristics of the particular EU material, such as bloodstream absorption rate and particle size, should be utilized in accordance with DOE radiation protection requirements and associated guidance.

c. Guidance on Packaging Design Criteria and Performance Objectives (Chapter III, Section 2 of the Manual).

Item j, "Design Release Rate Performance Objective" can be met by meeting the "Container Closure" requirement, item i.

d. Guidance on Design Qualification Leak Rate.

The Manual requirement for qualification of a design is that *the container must have a post drop design qualification release rate that will prevent the exposure of workers to greater than 5 rem CEDE.*

Attachment 4 states that "an acceptable value for the design qualification release rate is less than $10^{-3}A_2$/event." This is a conservative value based upon a range of IAEA reported dispersion estimates. Because the A_2 for EU is on the order of 3000 grams, a qualitative acceptance criterion that the container top remains on the container and no major container failure, e.g., split seam, occurs following the drop test can be utilized for the design qualification release rate for EU.

2. TECHNICAL BASIS FOR GUIDANCE.

Enriched uranium consists of a mixture of several uranium isotopes. Most of the dose potential arises from the presence of ^{234}U that is co-enriched with ^{235}U due to the similar atomic masses. The DOT rules for uranium enriched to less than 20% ^{235}U are promulgated assuming that this low enrichment material does not have sufficient concentrations of ^{234}U to affect dose potential for transportation containers. Furthermore, enriched uranium has a significantly lower specific activity than weapons grade plutonium, for example (over 6000 times lower than WG ^{239}Pu) such that the A_2 quantity for uranium oxides is measured in kilograms rather than grams. This difference leads to significantly different confinement strategies and requirements. For example, releases that are large enough to cause worker exposures in excess of 5 rem are too large to effectively measure, simulate, or test using gasses.

Enriched uranium metal exhibits a low oxidation rate when in the bulk metal form and does not pose an inhalation risk even after years of storage. For example, an 18 kg hollow right circular uranium metal cylinder with an outer radius of 6.25 cm and an inner radius of 4.445 cm exposed to 100% relative humidity air would corrode/oxidize at a rate of 4.1 g/year. At this rate it would take over 730 years to generate one A_2 (3000g) of oxide. The oxidation rate drops to 0.226 g/year if the relative humidity is maintained below 90%. On the other hand, finely divided uranium metal chips, turnings, and/or fines produced as a result of machining, sawing or other means have a greater potential for oxidation due to the higher surface area to mass ratio and may over time further subdivide into particle sizes that may be respirable. The quantities of oxide packaged with bulk uranium metal should be evaluated to determine whether the threshold quantity could be exceeded.

ACRONYMS

AED	aerodynamic equivalent diameter
ALARA	as low as reasonable achievable
ANSI	American National Standards Institute
ASME	American Society of Mechanical Engineers
CRD	contractor requirements document
CEDE	committed effective dose equivalent
CFR	Code of Federal Regulations
DEAR	DOE Acquisition Regulation
DOE	Department of Energy
DOE-HDBK	Department of Energy Handbook
DOE M	Department of Energy Manual
DOE P	Department of Energy Policy
DOE-STD	Department of Energy Standard
DOT	Department of Transportation
DU	depleted uranium
EU	enriched uranium
IAEA	International Atomic Energy Agency
ISO	International Standards Organization
MC&A	material control and accountability
NNSA	National Nuclear Security Administration
NRC	Nuclear Regulatory Commission
NU	natural uranium
P.L.	Public Law

DEFINITIONS

Approved engineered contamination barrier. An enclosure which is designed with the intention of maintaining separation between nuclear materials and facility workers, and whose preventive function is a major contributor to worker safety as determined from safety analyses and approved by DOE. Examples are hot cells, glovebox lines, ventilation hoods, process vessels, and liquid transfer lines.

Clad nuclear reactor fuel. Plutonium or uranium enclosed in a metal casing and designed for use in a nuclear reactor to produce power.

Container. A can, drum, jar, box, or similar object of rigid construction intended to retain its shape under normal handling that is closed or sealed to contain nuclear materials. As used in this Manual the container is the primary containment/contamination barrier preventing the nuclear material from reaching the environment.

Design release rate test. One of two required release tests verifying that a packaging design will contain radioactive material for normal handling, packaging and storage conditions. The design release rate test, for this Manual, is defined as a pre-drop test release rate.

Design life. A period of time during which a component or product is expected by its designers to work within its specified parameters; i.e. the life expectancy of the package.

Design qualification release test. The design qualification release test, for this Manual, is defined as a post-drop test release rate.

Dispersible material. Material that is or could become a loose powder or fine particulate capable of causing a large contamination spread or potential for inhalation in the event of a container rupture. Examples include oxide-like materials, loose powdery salts, and ground materials (taken from Interim Safe Storage Criteria).

Encapsulated. Material or component that is contained in a sealed capsule that can be opened only by destroying the capsule. The encapsulation retains reasonable resistance against impact, temperature, and corrosive species in the intended environments for storage, transportation, use, and disposition.

Handling. Movement of the package as a result of picking up, transferring, or setting down except those covered under DOE O 460.1B, *Packaging and Transportation Safety*.

Leaktight. A degree of package containment that in a practical sense precludes any significant release of radioactive materials.

Material form. Describes material in broad terms as falling into one of three physical states: gas, liquid, or solid. Solid materials are further broken down into elemental metals and compounds.

Nuclear material. Nuclear Material means any material that is “Special Nuclear Material,” “byproduct material,” or “source material” as defined in the Atomic Energy Act of 1954, as amended. The definition of "nuclear material" as used for the purposes of this manual may differ from the definition of nuclear material used with other MC&A and materials management programs.

Packaging/packages. An assembly of one or more containers that meets a DOE Directive or Standard.

Packaging system. The assembly of packaging containers intended to retain nuclear material during interim storage (adapted from the definition of Containment System in 49 CFR §173.403).

Pyrophoric material. A pyrophoric material is a liquid or solid that, even in small quantities and without an external ignition source, can ignite within five (5) minutes after coming in contact with air when tested according to the United Nations Manual of Tests and Criteria (49 CFR § 173.124 (b)(1)).

Release rate. The quantity of material passing through a containment system boundary per unit of time.

Sealed radioactive sources. A radioactive source manufactured, obtained, or retained for the purpose of utilizing the emitted radiation. The sealed radioactive source consists of a known or estimated quantity of radioactive material contained within a sealed capsule, sealed between layers of non-radioactive material, or firmly fixed to a non-radioactive surface by electroplating or other means intended to prevent leakage or escape of the radioactive material (10 CFR § 835.2).

Spent nuclear fuel. Fuel that has been withdrawn from a nuclear reactor following irradiation, the constituent elements of which have not been separated by reprocessing (40 CFR §191.02, *Definitions*).

Stabilizing (Stabilization). Processing of material to change the chemical form such that the undesired characteristic is removed (e.g., explosiveness or gas generation).