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Department of Energy
Washington, DC 20585

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The Honorable John T. Conway
Chairman
Defense Nuclear Facilities Safety Board
625 Indiana Avenue, NW Suite 700
Washington, DC 20004

Dear Mr. Chairman:

Enclosed is the final version of the Department of Energy's (DOE) standard DOE-SAFT-0067, *Criteria for Packaging and Storing Uranium-233-Bearing Materials*. It represents the deliverable for Commitment 3 of the Department's Implementation Plan addressing the Defense Nuclear Facilities Safety Board's Recommendation 97-1 concerning the safe storage of U-233. The Department's 97-1 Technical Team has worked closely with the Board staff over the last several months in developing this new standard. Board comments regarding the draft standard, forwarded by your letter of 10 June 1998, have been addressed by this version.

A technical basis document entitled *Assessment of U-233 Storage Safety Issues at Department of Energy Facilities* has been developed in conjunction with the standard to provide the rationale for the standard's requirements. Also, resolution to comments received from the Board and other technical reviewers across the DOE complex during development of the standard has been compiled in a comment resolution log. Both of these documents will be provided to your staff to help facilitate review of the standard.

With issuance of DOE-SAFT-0067 the Department will proceed with inspection and characterization activities for Uranium-233 material in inventory throughout the complex and take the necessary actions to assure safe storage conditions consistent with the commitments of the Recommendation 97-1 Implementation Plan.

If you have any questions, please contact me, or have your staff contact Hoyt Johnson of my staff at (202) 586-0191.

Sincerely,

David G. Huizenga
Acting Deputy Assistant Secretary for
Nuclear Material and Facility Stabilization
Office of Environmental Management

Enclosure

cc: M. Whitaker, S-3.1

This draft, September 1998, prepared by DP-45, has not been approved and is subject to modification.

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NOT MEASUREMENT SENSITIVE

DOE-STD-XXXX-YR
PROPOSED

DOE STANDARD

CRITERIA FOR PACKAGING AND STORING URANIUM-233-BEARING MATERIALS

DEPARTMENT OF ENERGY • UNITED STATES OF AMERICA •

U.S. Department of Energy
Washington, D.C. 20585

AREA SAFT

FOREWORD

This Standard establishes the criteria for the safe packaging and storage of Uranium-233(^{233}U)-bearing materials and aims to obviate subsequent repackaging during their storage or from their existing storage facilities until their respective dispositions are identified. Materials conforming to these criteria should be contained and stored safely for a nominal 50 years (pending disposition). Periodic inspections of ^{233}U packages shall be conducted in order to confirm the storage lifetime objectives covered by this Standard. The justifications and bases for the criteria are given in Appendix A. This Department of Energy (DOE) Standard is approved for use by all DOE components and their contractors.

The Department of Energy (DOE) was producing special nuclear materials (SNM) in their purest forms for weapons production and reactor fuel fabrication during the Cold War period. Typically the SNM, which includes plutonium (Pu), enriched uranium-235 (^{235}U) or ^{233}U, were either in the forms of metals or relatively pure oxides. These SNM materials were also the most "attractive" from a safeguards perspective because they could most readily be used to fabricate nuclear weapons.

The DOE mission has been refocused in the past few years to emphasize weapons dismantlement, safe fissile materials storage and disposition of excess SNM to Departmental needs, while preserving a reduced stockpile. Aside from weapons dismantlement and production activities, significant quantities of Departmental fissile materials, also exist in a variety of chemical forms from fuel cycle programs and from other nuclear research and development (R&D) projects. These materials shall be safely stored in the interim until their ultimate dispositions are identified. Coincidentally, safeguards and nonproliferation concerns should be integrated into these storage criteria. Safe storage of these reactive materials is the current end-point for the SNM inventories prior to disposition.

Existing Departmental storage facilities at ORNL and INEEL will be used for near-term storage of the ^{233}U materials until such time as new or upgraded storage systems become available, the material is dispositioned, or transferred for reuse. Building 3019 at ORNL has been the National Repository for separated ^{233}U materials since 1962. It has most of the existing separated inventory in a variety of packages and diverse chemical and physical forms. The Idaho Chemical Processing Plant (ICPP) at INEEL has held the major ^{233}U inventory in fabricated forms of unirradiated nuclear fuel assemblies, rods, and sintered pellets since the early 1980s.

The major elements for the safe storage of separated ^{233}U are preventing criticality, containing radioactive materials, protecting personnel from penetrating radiation, and safeguarding this special nuclear material. The storage facility plays a primary role in addressing all of these safety elements except containment. The facility plays a principal backup role (i.e., defense in depth) in confining radioactive contaminants during upset conditions. Material stabilization, consolidation, access limitation, low maintenance storage and reliability in verification of the inventory are the Department's present goals for the ^{233}U-bearing materials.

The existing materials should not be repackaged if the existing container(s) pose no safety hazards. However, if repackaging is required, a standardized package, which considers the disposition mode, is the preferred option, while ensuring overall safety. An integrated approach that considers the packaging in combination with specified control measures is also acceptable.

DOE technical standards do not by themselves establish mandatory requirements. However, all or part of the provisions in a technical standard can become requirements under the following circumstances:

(a) they are explicitly stated to be requirements in a DOE requirements document; or

(b) the organization makes a commitment to meet a standard in a contract or in a plan or program required by a DOE requirements document.

Throughout this Standard, the word "shall" is used to denote actions that must be performed if this Standard is to be met. If the provisions in this technical Standard are made mandatory through one of the two ways discussed above, then the "shall" statements become requirements.

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1. INTRODUCTION

1.1 Purpose and Scope

This Standard provides criteria for safely packaging and storing ^{233}U-bearing solid materials for a nominal 50 years without subsequent repackaging. Periodic inspections of ^{233}U packages shall be conducted in order to confirm the storage lifetime objectives covered by this Standard. This Standard does **not** apply to packaging for liquids, wastes, spent fuels, irradiated targets, in-process materials, or small quantities involved in research and development studies. Furthermore, this Standard does **not** apply to packaging for uranium with isotopic content less than 1 wt % ^{233}U or to packaging for uranium-bearing materials contaminated with plutonium in amounts greater than 2 % (on a weight basis relative to ^{233}U content).

A majority of the ^{233}U in inventory consists of mixtures of ^{233}U and ^{232}U or mixtures whose properties are dominated by the ^{233}U and ^{232}U content. These materials have substantially different radioactive and nuclear characteristics than the other two special nuclear materials (SNMs), ^{235}U and Pu (note that ^{232}U is not a SNM). For example, the ^{232}U decay chain produces ^{208}Tl, which emits a 2.6 MeV gamma-ray. This highly energetic gamma-ray and the high alpha activity associated with ^{232}U necessitate facility safety characteristics such as shielding in addition to material and packaging considerations for safe storage. Therefore, guidance for facility features addressing the unique properties of ^{233}U and ^{232}U is provided in this Standard.

Bases for the criteria in this Standard are provided in Appendix A and are organized to correspond, section-by-section, with the Standard. Users of this Standard are advised to consult and assure adherence with other applicable directives while implementing these criteria. It is the responsibility of the organization in custody of the material to provide safe conditions for handling and storing the material.

1.2 Equivalency

This Standard allows using systems, methods, material forms, or devices that are functionally equivalent or superior in the place of those prescribed herein if demonstrated by technical documentation.

2. DEFINITIONS

Terms and acronyms applicable to this Standard and to the criteria bases are listed and defined in Appendix B.

3. REFERENCES

Specific DOE and other Federal agency regulations and other documents used in developing this Standard and the bases for the Standard are listed in Appendix C.

4. MATERIAL AND PACKAGING CRITERIA

The following criteria are established to control potential hazards to workers, the public and the environment for packaging and safely storing separated ^{233}U-bearing materials. Technical bases for the criteria are provided in Appendix A. Besides conforming with these safe storage criteria, the reader should review other specific DOE directives which address SNM issues, e.g., orders on materials control and accountability (MC&A), radiation protection controls, criticality and transportation.

Some of the following sections are specific to the material form. The table below provides a mapping of material form to the applicable sections.

Table 1. Roadmap of Sections 4 and 5.

Material Form	Material Specific Sections
Metals	4.1.1, 4.2.1, 4.2.2, 4.2.3
Oxide Powders	4.1.2, 4.2.1, 4.2.2, 4.2.3, 4.3.2b
Monoliths	4.1.3, 4.2.1, 4.2.3, 4.2.5, 4.3.2b, 5.2
Ceramics	4.1.4, 4.2.6, 4.3.2b
All	4.2.4, 4.3.1, 4.3.2a, 4.4, 4.5, 4.6, 5.1, 5.3, 5.4

4.1 Material Criteria

Storable ^{233}U-bearing solid forms include metals, alloys, oxide powders, oxide monoliths, and ceramic oxide pellets.

4.1.1 Metals and Alloys. Metal and alloy pieces shall have a specific surface area of less than 50 cm^2/g. Particles and metal pieces larger than 8 mesh (2.38 mm) meet this criterion. Metal pieces with a specific surface area greater than 50 cm^2/g, thin foils, and turnings shall be thermally stabilized to oxides for storage. Thermal stabilization shall be at a temperature of at least 650 °C (1200 °F) for at least 6 hours in air. Loose oxide on outer surfaces of metal pieces shall be removed prior to packaging metals for storage.

4.1.2 Separated Oxide Powders. Stored materials may include oxide powders of ^{233}U and mixed uranium isotopes. These materials shall be thermally stabilized by heating to a nominal 650 °C (1200 °F) or hotter for a nominal 6 hours or longer to remove moisture and to convert residual salts to oxides.

4.1.3 Oxide Monoliths. Oxide monoliths are large, brick-like pieces of oxide, typically U_3O_8, which have been calcined in a denitration process and baked at a nominal 800 °C (1470 °F) or hotter for a nominal three hours or longer to remove moisture and convert residual salts to oxides.

4.1.4 Ceramic Oxides. Ceramic oxide pellets are high-fired ceramic matrices formed by sintering at greater than 1750 °C (3180 °F) in air for at least 12 hours.

4.2 Packaging for Storage Criteria

Packaging provides a principal barrier for isolating stored material from the environment. As such, it should be designed to maintain mechanical integrity, including closure, during anticipated handling and storage operations. General issues surrounding the package relate to material of construction, internal package atmosphere, identification and closure. The storage package for metals and powders shall consist of a minimum of two nested, leaktight containers to isolate the stored materials from the environment and to prevent the release of contamination. This two-container system is also acceptable for monoliths and ceramic oxides. However, the storage system for monoliths may consist of a minimum of one container combined with facility features described in Section 5.2.1. The storage system for ceramics may consist of containers described in Section 4.2.6. Sections 4.2.1, 4.2.2, 4.2.3, and 4.2.5 do not apply to ceramic material. Sections 4.2.2 and 4.2.6 do not apply to oxide monoliths.

4.2.1 **<u>General Requirements.</u>** Required containers used in packaging:

a. Shall be fabricated of materials that are resistant to corrosion due to contact with the material and the anticipated storage environment. It is recognized that stainless steel, aluminum, zirconium alloys, and nickel-based alloys are considered resistant to corrosion in most applications. No plastics are allowed in direct contact with the material.

b. Shall have permanent (e.g., etched, engraved, or stamped) identification markings.

c. Shall be leaktight as defined by ANSI N14.5-1997 at the time of closure for newly repackaged material or shall meet Section 4.2.3b for existing containers.

d. Should be designed and constructed to facilitate non-destructive assay (NDA) requirements for MC&A.

e. Should have structural properties meeting acceptance criteria that satisfies anticipated package storage conditions and handling accidents.

4.2.2 **<u>Inner Container.</u>** The inner container, if required:

a. Shall be sized to fit into an outer container (with clearance for optional welding, if applicable).

b. Shall conform to the limits specified in 10 CFR 835 (for transuranics) for removable contamination of the exterior surface, at the time of repackaging.

4.2.3 **<u>Outer Container.</u>** The following apply to the outer container:

a. Shall be sized to fit into the storage configuration. A maximum container height may be specified but should be related to physical handling operations and compatibility with transport casks.

b. Shall conform to the limits specified in 10 CFR 835 (for transuranics) for removable contamination of the exterior surface.

4.2.4 **<u>Optional Container(s).</u>** Additional optional containers, sometimes referred to as "material" or "convenience" containers, may be used. If the optional container is in direct contact with the material, the requirements of Sections 4.2.1a shall also be met. Sections 4.2.1b and 4.2.1d are considered as good practice for optional containers. Sections 4.2.1c and 4.2.1e are not required.

4.2.5 **<u>Oxide Monoliths.</u>** For oxide monolith materials, which are non-dispersible and of a non-respirable size, the primary barrier to confinement is provided by a container(s) that meets the provisions of Sections 4.2.1 and 4.2.3. The secondary confinement barrier shall be provided by a second container or by the facility as described in Section 5.2.

4.2.6 Ceramic Fuel Materials. For ceramic fuel materials, the primary level of containment is the robust, high-fired ceramic matrix of the fuel pellet. The secondary containment shall be provided by a container closed either by a screwed-on lid on a 2R container inside a 6M drum or a bolted-on lid stored in a storage vault. The following apply to the storage containers:

a. Shall be fabricated of or coated with materials that are resistant to corrosion in the anticipated storage environment.

b. Shall have permanent (e.g. etched, engraved, or stamped) identification markings.

c. Should be designed and constructed to facilitate NDA requirements for MC&A.

d. Should have structural properties meeting acceptance criteria that satisfies anticipated package storage conditions and handling accidents.

4.3 Contained Materials

4.3.1. Quantities

a. Criticality limits shall be addressed through nuclear criticality safety evaluations as specified by DOE O 420.1. (See Section 5.1)

b. The mass of fissile material per storage container shall not exceed (a) 5.4 kg (11.9 lb.) for metal and 9.1 kg (20 lb.) for oxides (including powders, monoliths, and ceramics) or (b) the limits specified in site-specific nuclear criticality safety programs, policies, and procedures. If Pu is present, this limit must be addressed on a case by case basis.

4.3.2. Internal Atmosphere

a. The package shall contain a non-corrosive atmosphere (e.g., nitrogen or inert gas for metals and oxides; oxides also may be packaged in ambient air).

b. The maximum anticipated internal pressure of any required container shall be less than the maximum allowable working pressure determined by proof tests as described in Section VIII-Section 1 Part UG-101 of the ASME Boiler & Pressure Vessel Code. The maximum anticipated internal pressure shall be determined by measurement, data from relevant experiments, or by use of Equation A-1 in Appendix A.

4.4 Inspection and Surveillance for Safety

Inspection and surveillance procedures shall be site-specific and should identify:

a. Prerequisites;

b. Acceptance criteria;

c. Specific instructions to ensure that items not meeting acceptance criteria are addressed in accordance with approved procedures and DOE reporting requirements; and

d. Frequency for surveillance for safety.

4.4.1 **Documentation of inspection and surveillance methods.** Formal methods and responsibilities shall be documented and maintained for independent review and evaluation.

4.4.2 **Surveillance Plan.** The surveillance plan shall include all packages and should include provisions for:

a. Initial baseline package inspection after an appropriate initial delay interval after repackaging;

b. Surveillance frequency, sample population, and package selection should be established by a statistical approach;

c. Integrating safety (e.g., ALARA, evaluation of indications of container deformation) and MC&A requirements (DOE 5633.3B).

4.4.3 **Surveillance Parameters.** Each sampled package:

a. Shall be inspected for an indication of internal pressure build-up and evaluated as per Section 4.3.2b.

b. Shall be inspected for transferable contamination on the outer container and evaluated per 10 CFR 835 Appendix D (for transuranics).

c. Shall be inspected (e.g., by radiography, by weight change of metals) for signs of changes in material form within the container and evaluated versus previous inspections.

d. Shall be inspected for signs of leakage and/or degradation of the container and evaluated versus previous inspections.

4.4.4 **Evaluation of Surveillance Data.**

a. Parameters obtained during surveillance inspections shall be compared against previous measurements to detect changes.

b. If at any time a deleterious change in the material or the container is noted, a safety evaluation shall be performed. This evaluation shall include, as appropriate, 1) evaluation of the detected change(s), 2) assessment of the potential consequences, 3) options for repackaging or overpacking the container, and 4) consideration for inspecting other packages that are similar, based on factors such as contents, origin, and date of closure.

4.5 Documentation

4.5.1 **Database.** An electronic database shall be maintained to serve as a source of relevant information about the stored materials and packages. If database information is classified, the database shall be subject to the requirements of DOE M 5639.6A-1. To assure consistency between databases, this database should be integrated with the MC&A database or electronically linked and coordinated with the MC&A database.

4.5.2 **Database Requirements.** The database should include:

a. Identification of the following material characteristics:
   1) Chemical composition.
   2) Physical form (e.g., ^{233}U metal, oxide powder, monolith, or ceramic).
   3) Elemental mass.
   4) Fissile isotope fraction (or mass) and ^{232}U fraction (in ppm).
   5) Source of stored material (facility that prepared the material in its current form).
   6) Specific processing condition(s).
   7) Moisture content
   8) Production date
   9) Other information relevant to the contents (e.g., major impurities, radiation level).

b. Identification of the following package characteristics:
   1) Type of fill gas on closing.
   2) Package configuration - number of inner containers in package.
   3) Date of packaging.
   4) Initial radiation field [gamma and neutron radiation levels at contact and 30 cm (12 in)].
   5) Baseline package weight and outer dimensions.

c. Record of the inspections performed, names of individuals performing inspections, and dates of inspections. Historical records on packages shall be maintained for the life of the packages.

d. Location(s) of stored materials.

4.6 Quality Assurance/Control Requirements

4.6.1 Personnel participating directly and with key responsibilities in essential processes and procedures shall be trained and qualified as appropriate to their assigned responsibilities.

4.6.2 Materials used in the fabrication and sealing of repackaging containers shall satisfy specifications necessary to comply with the requirements of this Standard.

4.6.3 Procedures and processes that are essential for assuring compliance with these criteria shall be subject to Quality Assurance (QA) per 10 CFR 830.120 and DOE O 414.1, and controlled by Quality Control (QC) Procedures.

4.6.4 Essential procedures and processes covered by QA and QC requirements shall include (but will not be limited to):

a. Thermal stabilization procedure;

b. Sealing (e.g., welding) procedure used in container fabrication and closure;

c. Package surveillance procedure(s);

d. Database recording procedure and characterization parameters addressed in Section 4.5.2; and

e. Assaying of container contents for MC&A and criticality safety requirements.

5. STORAGE FACILITY FEATURES

A facility used for the storage of ^{233}U should address the unique characteristics of the material and include nuclear criticality safety, confinement of radioactive materials, radiation shielding, and safeguarding SNM.

5.1 Nuclear Criticality Safety

Storage and handling of ^{233}U-bearing materials shall conform to the criticality safety requirements of DOE O 420.1. Criticality safety evaluations shall document that storage and handling activities shall remain subcritical during all normal and credible abnormal events. Criticality safety evaluations shall be performed for operations (under normal conditions) within any facility containing ^{233}U in excess of the limits specified in DOE O 420.1 or as specified in site-specific nuclear criticality safety program policies and procedures.

Special care should be exercised in validating calculation methods supporting criticality safety evaluations because of the paucity of data in the intermediate energy regime which may be important for some ^{233}U-bearing matrices under specified operational conditions.

5.2 Confinement of Contamination

The material form, material containers, or containment vessels serve as the principal barrier for confinement of contamination. Depending on the material storage system, the facility itself may serve as another confinement barrier. The combination of the material storage system and the storage facility represents a defense-in-depth safety confinement system.

5.2.1 **Facility Confinement.** The facility where ^{233}U-bearing material is stored may provide a physical barrier to the release of contamination if the material is in a non-respirable form. The integrity of the storage facility shall be maintainable through normal operations, anticipated operational occurrences, and any design basis accidents (DBAs) the barrier is required to withstand. The particular DBAs the storage facility is required to withstand shall be determined on a case-by-case basis. The DBAs to be considered include external events, including severe natural phenomena and man-made events, and internal events (e.g., container overpressurization). The adequacy of these confinement systems to effectively perform their required functions shall be demonstrated by the safety analysis. Requirements governing the safety analysis process include the applicable portions of DOE Orders 420.1, 5480.21, 5480.22, and 5480.23. The need for ventilation systems for confinement purposes shall be based on the results of the safety analysis.

5.3 Radiation Shielding

Owing to the presence of ^{232}U in ^{233}U inventories, radiation shielding is required to attenuate the 2.6 MeV photon emitted by the ^{232}U daughter, ^{208}Tl. Depending on the material form and material storage system used, the facility itself may serve as a radiation shield. The regulations pertaining to occupational radiation protection as specified in 10 CFR 835, shall be met.

5.4 SNM Safeguards

Uranium-233 is a weapons-usable material due to its fissile properties and its ability to be produced in sufficient quantities for manufacturing nuclear weapons. This material shall be protected from unauthorized access and unauthorized use. Safeguards measures shall meet the requirements of DOE O 470.1, DOE O 471.2A, DOE O 472.1B, DOE 5632.7A, and DOE 5633.3B.

APPENDIX A
TECHINCAL BASES FOR
URANIUM-233 PACKAGING AND STORAGE CRITERIA

This Appendix provides the bases for the criteria presented in this document. The section numbers in this Appendix correspond to the sections in the body of the Standard.

1. INTRODUCTION

1.1 Purpose and Scope

This Standard establishes the criteria for safely packaging and storing ^{233}U-bearing solid materials for a nominal 50 years. The bulk of this material is stored at ORNL and INEEL. Uranium-233-bearing solid forms include metals, alloys, oxide powders, cermets, ceramic oxide pellets, and oxide monoliths. This Standard does not apply to ^{233}U-bearing liquids, residues, wastes, spent fuels, irradiated targets, in-process materials or small quantities involved in R&D studies since these materials are either addressed by other storage programs or are not germane to the intended storage activity.

Much of the material covered by this Standard is nearly isotopically pure ^{233}U with small amounts of ^{232}U; isotopes of uranium that may be present (with their half-lives in parentheses), include $^{238}U(4.5 \times 10^9$ y), $^{236}U(2.4 \times 10^7$ y), $^{235}U(7.0 \times 10^8$ y), $^{234}U(2.4 \times 10^5$ y), $^{233}U(1.6 \times 10^5$ y), and ^{232}U(69 y). Uranium-233 and its associated isotope ^{232}U are man-made and present much more severe radiological hazards than any of the naturally occurring uranium isotopes. Therefore, an isotopic level of 1 wt % ^{233}U in total uranium represents the lower isotopic threshold since this is the ^{233}U isotopic concentration at which the inhalation hazard posed by ^{233}U (in terms of release limits from 10 CFR 20) exceeds that for uranium highly enriched in the ^{235}U isotope (Bereolos et al. 1998). Similarly, an upper plutonium contamination level was established at 2 wt % of the ^{233}U content because this is the concentration at which the inhalation hazard (from Radionuclide Concentration Guide in 10 CFR 20) posed by an isotopic blend for weapons-grade Pu exceeds that for currently stored ^{233}U with high levels of ^{232}U (~200 ppm).

1.2 Equivalency

The basis for equivalency shall be a technical justification for any departure from specific provisions of the Standard. This technical justification will be subject to oversight by the authorizing official.

2. DEFINITIONS

The terms and acronyms applicable to this Standard are adopted from relevant titles of the Code of Federal Regulations (CFR) and the Handbook of Acronyms, Abbreviations, Initialisms, Proper Names and Alphanumerics Encountered in Nuclear Safety Literature, March 1993.

3. REFERENCES

No Basis Required.

4. MATERIAL AND PACKAGING CRITERIA

4.1 Material Criteria

4.1.1 Metals and Alloys. Potentially pyrophoric metals are not acceptable storage forms because this could lead to fires and dispersal of the uranium. Metallic uranium in massive form presents little fire hazard, but it will burn if exposed to a severe, prolonged fire. By contrast, finely divided uranium metal powder is pyrophoric (L. Bretherick, *Hazards in the Chemical Laboratory*, 1986), and can ignite spontaneously, if confined in a container without liquid or without air movement. The presence of moisture in the gas phase over exposed chips increases this possibility (J. J. Burke, et al. *Physical Metallurgy of Uranium Alloys*, 1976). The flammability of uranium depends almost entirely on the specific surface area. Finely divided uranium metal ignites spontaneously upon exposure to air and burns rapidly to the oxide. For uranium foils and wires, the experimentally determined ignition temperatures are somewhat higher than for powders having the same specific surface area. The recommended upper limit of specific surface area is 50 cm^2/g, based on the analysis presented in Section 4.9 of the *Draft Hazard Analysis for Storage of* ^{233}U. This is considered a conservative value since the corresponding ignition temperature of about 255 °C is far above temperatures expected to be achieved during storage. Uranium metal pieces larger than sieve mesh size 8 (2.38 mm) are assured of having a specific surface of less than 50 cm^2/g and may be stored in tube vaults. Uranium metal of less than sieve mesh size 8, powders, thin foils, and turnings of uranium are more susceptible to ignition at temperatures below 255 °C. Therefore, these materials need to be converted to stabilized oxide prior to storage or stored in a sealed container with an inert atmosphere (ANL-6287).

Some loose removable oxides associated with metals may also be pyrophoric. An adherent oxide layer on stored metal is generally beneficial because it tends to retard further oxidation. However, as UO_2 (the first oxide produced), this coating may be pyrophoric. Therefore, prior to repackaging ^{233}U metal, readily removable loose oxide shall be removed from outer metal surfaces.

4.1.2 Separated Oxide Powders. Water and salts present in the oxide powders can cause corrosion of the container and reduce its integrity. Corrosion, or oxidation, of metal by water produces hydrogen gas, which could lead to pressurization of the container. Liquids are also subject to radiolysis that would result in increased pressure within the container. The complete radiolysis of one gram of water produces 1.87 liters of gas at standard temperature and pressure. Therefore, only uranium oxides that have been thermally stabilized to remove moisture and to convert residual salts are acceptable for storage without further stabilization. Processing of UO_2 at ORNL demonstrated that heating to 650 ± 25 °C hydrogen atmosphere zone for 6 ± 0.5 h is sufficient to bring the moisture content below 0.5 wt % (Parrott et al. 1979).

Materials that could lead to overpressurization of the inner container are not acceptable for storage and shall be thermally stabilized. Uranium oxide powders can have a high surface area depending on preparation conditions. All three predominant uranium oxide forms are acceptable for storage. The most desirable form is U_3O_8 because it potentially can adsorb less moisture per U atom than other oxides (UO_2, UO_3). The potential storage hazard concern associated with adsorbed moisture is the ultimate pressurization of a sealed oxide container over a prolonged period through any of several radiolytic and chemical processes. The adsorbed moisture also could be a potential problem for criticality if the associated moderation is not considered.

4.1.3 <u>Oxide Monoliths.</u> Oxide monoliths are more stable and physically more resistant to dispersion than oxide powders. Oxide monoliths have been formed at ORNL by a denitration technique (McGinnis, et al. 1986) that excludes enhanced fluidization, which would promote powder formation. These materials were calcined to an oxide and baked out at ~800 °C (1472 °F) for ~3 hours. Formation of the oxide monoliths under these conditions assures that there are essentially no fine particles available for dispersion and respiration upon a hypothetical container breach and that there are only minimal amounts of moisture or nitrates present. Elimination of moisture and undecomposed salts mitigates the formation of gases by radiolysis.

4.1.4 <u>Ceramic Oxides.</u> Ceramic mixed oxide pellets are very stable since the temperature reached during their formation is high enough (> 1750 °C) to ensure that there is no residual moisture or salt in the material. Prior processing operations and chemical compositions of ceramic ^{233}U mixed oxide pellets and sintered fuel result in more stable physical forms that provide inherent self-shielding, criticality constraints, and contamination controls.

The lack of fine materials in these products precludes them from being dispersible. The ceramic oxides are highly resistant to oxidation and require no further stabilization to be acceptable for storage [WAPD-TM-1244(L)].

The ^{233}U inventory at INEEL includes ceramic mixed oxide pellets, and unirradiated fuel rods composed of Zircaloy-clad ^{233}U-bearing ceramic pellets from a former fuel cycle program. The mixed oxide ceramics consist of an average 97 wt % thorium and 3 wt % ^{233}U oxides with less than 10 ppm ^{232}U.

Pellets were fabricated by high pressure compaction of finely ground ^{233}U oxide with finely ground thorium oxide powders into cylindrical pellets. These pellets were sintered at temperatures in excess of 1750°C (3182°F) for at least 12 hours to form pellets that resist chemical and physical degradation. The densities of these pellets are approximately 98% of theoretical (>10.6 g/cm^3), effectively self-shielding emitted alpha and gamma radiation, inhibiting particulate dispersal, and serving as a containment for the incorporated ^{233}U oxide.

Finished, unirradiated fuel elements (Zircaloy-clad pellets) further enhances the safety and safeguards character of the ^{233}U-bearing processed material.

4.2 <u>Packaging for Storage Criteria</u>

4.2.1 <u>General Requirements</u>

a. Materials of construction shall be selected so that their resistance to corrosion ensures structural integrity for prolonged periods of storage. Corrosion of the container during storage is a potential problem for two primary reasons: (1) if the corrosion is significant, it could result in loss of strength of the container or permit loss of containment of the packaged material; and (2) the resulting hydrogen evolution (as a by-product of corrosion) could cause container pressurization and pose a fire or explosion hazard. The facility is responsible for ensuring that the selected material of construction is appropriate to the environment.

b. Permanent markings ensure the integrity of identification for material control. (DOE 5633.3B)

c. For new packages: the definition of leaktight is 1×10^{-7} ref·cm^3/s of air at an upstream pressure of 1 atm abs and a downstream pressure of 0.01 atm abs or less. This rate is equal to 4.09×10^{-12} gram-moles/s of dry air or helium and is equivalent to a helium volumetric leakage rate, under the same conditions, of approximately 2×10^{-7} cm^3/s (ANSI 1997).

For existing packages: Conforming to limits in 10 CFR 835 for removable contamination on the exterior surface is a sensitive and non-invasive means of ascertaining the current state of leaktightness for containers that have been in storage beyond some initial period (i.e., to detect infant mortalities). Other techniques include undesirable conditions (e.g., helium leakcheck pressurizes the container) or are inconclusive (e.g., radiography provides insufficient detail to detect features that would more readily appear as a contamination leak). Limits for ^{233}U are not specified in 10 CFR 835. The limits for transuranics are used because they are the most restrictive and have the most similar characteristics to ^{233}U.

d. Ease of performing NDA is desirable from an operational point of view. If material is repackaged, facilitating MC&A requirements shall be considered. Repackaging the material solely for purposes of enhancing MC&A is not mandatory because of ALARA considerations and prior MC&A survey history. ORNL has been granted a waiver to the accounting requirements of DOE O 5633.3B because of the hazards involved in handling of ^{233}U packages (DOE ORO 1998).

e. The storage container should be designed to maintain its physical integrity, including its seal, during anticipated handling and storage conditions.

4.2.2 <u>Inner Container.</u>

a. Two containers are needed to provide a defense-in-depth for ^{233}U metals and powders in prolonged storage. The inner container serves as the primary barrier isolating the stored dispersible material from the environment. Dimensional limits, based on the outer container design, are such that positive closure of the inner container is facilitated. The facility operator is responsible for ensuring compatibility with the outer container. At ORNL, the inner container should be no greater than 8.6 cm (3.375 in.) I.D. (Primm 1993) and sized to fit into the outer container.

b. External surfaces of the inner container shall be as free from removable contamination as practical at the time of repackaging. Exterior surface contamination may be evidence of potential leakage of radioactive materials (10 CFR 835). The inner container is only required to meet 10 CFR 835 removable contamination limits at the time of repackaging because confirmation of the inner container status requires destruction of the outer container after sealing. Limits for ^{233}U are not specified in 10 CFR 835. The limits for transuranics are used because they are the most restrictive and have the most similar characteristics to ^{233}U.

4.2.3 Outer Container.

a. The outer container is sized to fit into tube vaults and current shipping containers. Consideration of compatibility with transport casks will minimize future prepackaging and avoid unnecessary additional personnel exposure, operational risk and waste generation.

At ORNL, the dimensional requirements for the outer cylindrical container should be as follows:

1. Maximum outside diameter <11.0 cm (4.4 in).
2. Minimum external height >10.1 cm (4.0 in).

The minimum height ensures that the container will not tumble when placed into the tube vault.

b. External surfaces of the outer container shall be as free from removable contamination as practical. Exterior surface contamination may be evidence of potential leakage of radioactive materials. (10 CFR 835). Limits for ^{233}U are not specified in 10 CFR 835. The limits for transuranics are used because they are the most restrictive and have the most similar characteristics to ^{233}U.

4.2.4 Optional Container(s). To facilitate material handling, additional packaging layers may be used for convenience.

4.2.5 Oxide Monoliths. The resistance of these materials to dispersal of solid particulates and release of radon is considered sufficient.

4.2.6 Ceramic Fuel Materials. The ceramic fuel pellets provide the primary level of containment for the $^{233}U\text{-}ThO_2$ oxide, ceramic-based LWBR fuel materials stored at the INEEL. Additional levels of containment are provided by the physical packaging. The packaging at the RWMC consists of Zircaloy-clad fuel rods, stainless steel rods closed with an O-ring sealed plug, PVC bags of pellets, or polyethylene bottles of pellets. These units are placed inside a steel 2R container that has been coated with a rust resistant paint and closed with a lightly oiled pipe cap. The 2R containers are put into an epoxy-coated galvanized steel 6M drum closed with an epoxy-coated steel lid sealed with an elastomer seal ring. The 2R container is located in the center of the drum by layers of fiberboard packing. The drums are then packed inside a lead/steel shielded overpack which is then stored inside a steel building on a concrete pad. This combination of physical barriers presents an effective level of containment and radiation shielding for the ceramic pellets.

The LWBR fuel materials stored at the CPP-749 facility are in the form of Zircaloy clad fuel rods and O-ring sealed, stainless steel rods. These rods are stored inside a larger stainless steel pipe container that is also sealed with an O-ring. These shipping containers are then placed inside a steel-lined, below-grade storage vault, which has an elastomeric gasket-sealed lid. This system also provides an effective level of containment.

Thus, the INEEL material utilizes the robust ceramic pellet as its primary level of containment and the various layers of physical barriers as the secondary and further levels of containment and radiation shielding.

4.3 Contained Materials

4.3.1 Quantities

a. Criticality safety evaluations shall be obtained for the specific ^{233}U-bearing storage configurations for quantities in excess of the limits listed in ANSI/ANS-8.1 or the requirements specified in site specific nuclear criticality safety programs as applicable. The evaluations shall consider the presence of other fissile isotopes and other materials, such as low-Z materials, plastics, moisture, and geometry as required by ANSI/ANS-8.1.

b. When the mass limits on ^{233}U as listed in ANSI/ANS-8.1 are used, it should be noted that these limits are most restrictive limits for the prevalent fissile nuclides (i.e., ^{233}U, ^{235}U, ^{237}Np, and ^{241}Am) except for Pu. If Pu is present, further restrictions on the mass limit should be considered on a case by case basis.

4.3.2 Internal Atmosphere

a. Any non-corrosive atmosphere is acceptable for packaging solid materials. However, an inert or nitrogen atmosphere is needed for metals to ensure that metal surfaces are not oxidized - the form of which can be reactive. (J. J. Dawson, et al., 1956)

b. Sealed containers storing ^{233}U-bearing material must be able to withstand the anticipated buildup of pressure. The containers are exempt from the ASME Boiler and Pressure Code because of their diameter (ASME Section VIII-Division 2 Part AG-121). However, this Standard is incorporating, as good practice, applicable elements of the Code. Section VIII-Division 1 Section UG-101 provides methods for proof tests to determine the maximum allowable working pressure. The maximum allowable working pressure must be greater than any pressure increases caused by temperature increases, evolved gases, helium from alpha decay, and radon.

There are many ways to determine the internal pressure (e.g., lid deflection on a CEUSP can). In the absence of any measured pressure, the following equation bounds the internal pressure of a container

$$P = \left(\frac{T}{T_0}\right)\left[P_0 + A + B + C + D + E\right] \qquad \text{(Eq. A-1)}$$

where P is the pressure, T_0 is the package temperature at the time of sealing, T is the storage temperature, and P_0 is the pressure at the time of sealing. The terms A, B, C, D, and E are terms that give the contributions from various sources of pressure described as follows:

A. Radiolysis of water. Research on the radiolysis of water indicates that hydrogen and oxygen form a steady state pressure between 1 and 2 atmospheres under intense radiation fluxes (Allen et al. 1952, Hochanadel 1952, Allen 1961, Firestone 1957). Lower levels of radiation from decaying radioisotopes such as ^{232}U and ^{233}U should produce only a fraction of an atmosphere at steady state conditions. However, for a conservative determination, 2 atmospheres should be used.

B. Reaction with water. Only unstabilized UO_2 powder undergoes this reaction. Furthermore, any water that undergoes reaction will be unavailable for radiolysis, thus the value of term A could be reduced, or eliminated for the case of complete reaction. The maximum pressure generated from hydrogen accumulation, assuming complete reaction of all oxygen dissociated from water, is given by

$$B = \left(\frac{RT}{V_c - \frac{m}{\rho}} \right) \left(\frac{mX_{H2O}}{MW_{H2O}} \right) \quad \text{(Eq. A-2)}$$

where R is the gas constant, V_c is the volume of the container, m is the mass of UO_2, ρ is the density of the material, X_{H2O} is the moisture fraction, and MW_{H2O} is the molecular weight of water.

C. Radiolysis of plastic. There is evidence that only plastic in direct contact with bulk material undergoes radiolysis (Shaw and Freestone 1998). However, the conservative assumption is to assume all plastic decomposes. The maximum pressure generated is given by

$$C = \left(\frac{RT}{V_c - \frac{m}{\rho}} \right) \left(\frac{m_P X_{H2,P}}{MW_{H2}} \right) \quad \text{(Eq. A-3)}$$

where m_P is the mass of any plastic present in the material, $X_{H2,P}$ is the mass fraction of hydrogen in the plastic and MW_{H2} is the molecular weight of H_2.

D. Helium from alpha decay. The pressure from helium generated by 50 years of alpha decay is given by

$$D = \left(\frac{RT}{V_c - \frac{m}{\rho}} \right) \left(\frac{m\sum_i b_i X_i}{MW_{He}} \right) \quad \text{(Eq. A-4)}$$

where b_i is the fraction of the isotope i that is emitted as a helium ion through alpha decay over a fifty-year period, and X_i is the mass fraction of isotope i, and MW_{He} is the molecular weight of helium.

E. Radon. The longest-lived isotope of radon, ^{222}Rn, has a half-life of 3.8 days. Over a 50-year period, any Rn intermediate on a decay chain will reach a steady-state concentration that is insignificant when compared to the helium that is produced by alpha decay of other radionuclides in the same decay chain. Thus, the partial pressure contribution of all isotopes of Rn may be neglected.

4.4 **<u>Inspection and Surveillance for Safety</u>** Inspection and surveillance are to be non-intrusive, maintaining intact containers.

4.4.1 **<u>Documentation of Inspection and Surveillance Methods</u>** Inspection and surveillance methods must be documented to assure consistency. Delineation of responsibilities is needed to assure a consistent management approach and awareness of responsibilities.

4.4.2 **<u>Surveillance Plan</u>** The function of the inspection and surveillance program is to identify errors and flaws in the initial packaging as well as to detect package degradation and contents changes that might affect package integrity during storage. Therefore, all packages (repackaged and previously existing) must be part of the surveillance program.

a. Inspection of every container after repackaging, but prior to emplacement in the storage configuration, is expected to detect flaws in the initial repackaging. This initial inspection also should provide baseline information on the leak rate, package mass, verification of contents through NDA measurements, and any other information deemed desirable and attainable through non-intrusive measurements such as radiography. This inspection may be part of the quality program for verifying package integrity.

b. After the package is placed into the storage configuration, mechanical failures are random. Uniform changes in the storage package population, such as a gradual pressure generation in oxide containers, are also expected to occur during this period. Surveillance during this period should consist of statistical sampling to monitor the behavior of the population. The ultimate storage life of the packages is unknown and must be established using surveillance data.

c. No additional basis required.

4.4.3 **<u>Surveillance Parameters</u>** These parameters are indicators of the stability of the container and its contents.

4.4.4 **<u>Evaluation of Surveillance Data</u>** No additional basis required.

4.5 **<u>Documentation</u>**

4.5.1 **<u>Database</u>** An electronic database is specified because a manual database would be overly cumbersome. The architecture is not specified here so that maximum flexibility to interface with existing databases and files is maintained.

4.5.2 **<u>Database Requirements</u>**

a. These parameters allow as complete a characterization of the contents as is possible without undertaking additional characterization. It is recognized that some information may be redundant. The apparently redundant items permit better characterization when some of the data is missing.

b. Package data can meet a number of needs. For example, if a package exhibits unexpected behavior, these data can help identify other, similar packages than may require inspection. These data also facilitate disposition process planning.

c. No additional basis required.

d. No additional basis required.

4.6 Quality Assurance

The appropriate QA requirements are given in 10 CFR 830.120 and DOE O 414.1.

5. STORAGE FACILITY FEATURES

5.1 Nuclear Criticality Safety

A principal safety consideration for the safe storage of ^{233}U is eliminating the possibility of the material reaching a configuration that would result in criticality. Criticality avoidance is a prime priority in safety considerations in the design and operation of a ^{233}U storage facility. In addition to providing an array that is criticality safe, the packages and facility shall be engineered, constructed, controlled, and monitored to avoid the occurrence of accidental criticality for all credible natural phenomena events such as fires, flooding, earthquakes, and tornadoes. Because criticality safety is considered to be the dominant safety concern in the design and operation of a ^{233}U storage facility, the vault area should be designed with consideration of water sources such as fire sprinklers. Co-existing combustible materials should be minimized or eliminated from the facility in order to minimize the potential for fires and the need for fire suppression systems.

A majority of the ^{233}U in inventory consists of mixtures of ^{233}U and ^{232}U or mixtures whose properties are dominated by the ^{233}U and ^{232}U content. Uranium-233 has substantially different nuclear criticality properties than the other two SNMs, ^{235}U and Pu. Therefore, facilities designed for ^{235}U and Pu may not be acceptable for comparable activities involving ^{233}U from a nuclear criticality safety standpoint and shall be evaluated to meet the requirements for criticality safety specified in DOE O 420.1.

5.2 Confinement of Contamination

The matrix of the material and/or the inner container provide the first barrier against spread of contamination; the outer container and the tube vaults provide additional barriers. The packaging should be designed to maintain mechanical integrity, including its seal, during normal handling. However, this package is not expected to provide protection against all perils such as major fires and earthquakes; design of the facility and of the storage array are expected to address these considerations.

5.2.1 Facility Confinement. No additional basis required.

5.3 Radiation Shielding

Uranium-233 with its associated sister isotope ^{232}U present much more severe external radiation hazards than any of the naturally occurring uranium isotopes. Massive biological shielding is required, where high concentrations of ^{232}U occur, to protect personnel from the 2.6 MeV gamma emission of ^{232}U daughter product ^{208}Tl. The occupational radiation exposure should be kept as low as reasonably achievable (ALARA) and radiation protection be provided as specified in 10 CFR 835, "Occupational Radiation Protection." Dose rates are dependent on the source (e.g., activity, geometry, and matrix), shielding, and source-to-detector configuration, so expected dose rates for actual conditions should be determined on a case-by-case basis.

Except for spontaneous fission, neutrons are not directly produced during the radioactive decay of any of the uranium isotopes or the sequential decays. However, alpha-neutron reactions, in which alpha particles react with low-Z isotopes such as ^{6}Li, ^{7}Li, ^{9}Be, ^{10}B, and ^{19}F, (and to a lesser extent ^{27}Al and ^{28}Si), generate neutrons. Depending on the material storage system used, the facility itself may serve as a shield.

5.4 <u>SNM Safeguards.</u> DOE requirements for safeguards are given in DOE O 470.1, DOE O 471.2A, DOE O 472.1B, DOE 5632.7A, and DOE 5633.3B.

APPENDIX B

GLOSSARY AND ACRONYMS

1. GLOSSARY

Acceptable - Conforming with safety requirements, directives, or regulations.

Accountability - That part of Safeguards and Materials Management that encompasses the management system and records and reports to account for source and special nuclear material to minimize the possibility of diversion and to detect diversion promptly should it occur. Accountability does not include physical protection.

ALARA (As low as reasonably achievable) - The implementation of good radiation-protection programs and practices which traditionally have been effective in keeping the average and individual exposures for monitored workers well below allowable limits.

Alloy - A substance composed of two or more metals united by being fused together and dissolving in each other when molten.

Approved - Acceptable to the "authority having jurisdiction."

Authority Having Jurisdiction - The organization, office, or individual responsible for approving equipment, installation, or procedure.

Barrier - A restraint that provides containment of stored material and protection from the environment.

Calcine, Calcining - The process of heating materials to remove combustible or volatile materials such as organic matter, salts, and moisture.

Ceramic - A class of inorganic, nonmetallic solids formed at high temperature (>1000°C) in manufacture or use.

Cladding - An outer metal jacket or can that surrounds and protects fuel pellets containing source and special nuclear material. Typical cladding materials are alloys of aluminum or zirconium and stainless steel.

Combustible - In the form used and under the conditions anticipated, will ignite, burn, support combustion, or release flammable vapors when subjected to fire or elevated temperature.

Container – A structurally closed barrier outside of which the concentration of hazardous materials is normally expected to be lower than allowable limits. A container is designed to remain closed and intact during all design basis accidents.

Contamination – The presence of residual radioactivity in excess of levels that are acceptable for release of a site, a facility, or a package.

Conversion - An operation for changing from one material form, use, or purpose to another.

Criterion – A quantitative or qualitative measure of what is acceptable or desirable for one or more factors (e.g., individual dose limit, subcritical mass limit, mechanical strength limit, etc.) for packaging and safe storage.

Criticality Safety Evaluation (CSE) - Document the parameters, limits, and controls required to ensure that the analyzed conditions are subcritical for normal and credible abnormal conditions. Reviews of operations to ascertain that limits and controls are being followed and that process conditions have not been altered such that the applicability of the nuclear criticality safety evaluation has been compromised. It is acceptable to DOE to follow DOE-STD-3007-93 (Guidelines for Preparing Criticality Safety Evaluations at Department of Energy non-Reactor Nuclear Facilities) when preparing Criticality Safety Evaluations (420.1).

Database - A large collection of data in a computer, organized so that it can be expanded, updated, and reviewed rapidly for various uses.

Dilution - In general the addition of inert material or solvent with the result that the concentration of the material of interest is reduced.

DOT-2R – Containers that meet the specifications of 49 CFR 178.360.

DOT-6M – Drums that hold DOT-2R containers and meet the specifications of 49 CFR 178.354.

Effective Neutron Multiplication Factor (k_{eff}) - The ratio of the total number of neutrons produced during a time interval (excluding neutrons produced by sources whose strengths are not a function of fission rate) to the total number of neutrons lost by absorption and leakage.

Enclosure - A physical structure that provides a barrier between the internally contaminated package and the worker, facility, and environment.

Engineered Safety Feature - Systems, components, or structures that prevent and/or mitigate the consequences of potential accidents including the bounding design basis accidents.

Handling Enclosure - A glove box line or similar equipment that isolates ^{233}U-bearing materials from the worker's environment while allowing the material to be handled or processed.

Hot Cell - A heavily shielded enclosure in which radioactive materials can be handled by persons using remote manipulators and for viewing the materials through shielded windows or periscopes.

Inert Gas - A non-reactive gas or combination of gases appropriate to the material being stored that will not support corrosion of the container or oxidation of its contents.

In-Line - Something located inside a material handling enclosure (e.g., glove box or "hot" storage vault). When material is stored "in-line," the enclosure provides one barrier for storage.

In-Process, In-Use Material - Material that is integral to the continuing manufacture or recycle operations of the nuclear weapons complex and may not be considered as excess material for storage.

Inventory – The total quantity of radioactive material at a site.

Irradiated Nuclear Material – Nuclear material that has been subject to nuclear irradiation in a reactor or accelerator and that consequently delivers an external radiation dose requiring special containment and handling.

Leaktight - 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 atm abs and a downstream pressure of 0.01 atm abs or less.

Low-Z Material – Elements of atomic number 9 or less.

Material Container - The container that is in contact with the uranium material being stored. If structurally adequate and sealed, the material container provides one barrier for containment and environmental protection.

Nondestructive Assay (NDA) - A procedure (e.g., calorimetric or radiometric measurement) for determining the amount of fissionable uranium in a container without physically sampling the material.

Nondestructive Examination (NDE) - A procedure (e.g., radiography) for examining the contents of a container without opening the container.

Nonproliferation Treaty - A Treaty (to prevent the spread of nuclear weapons) presented to the Eighteen-Nation Disarmament Committee in Geneva by the U. S. and USSR in identical texts on January 18, 1968. The Treaty entered into force March 5, 1970.

Nuclear Criticality Safety - The prevention or termination of inadvertent nuclear criticality and protection against injury or damage due to an accidental nuclear criticality.

Oxide Monolith – A large, brick-like piece of oxide, typically U_3O_8, which has been calcined in a denitration process and baked at greater than 800 °C (1472 °F) for at least three hours to remove moisture and convert residual salts to oxides.

Packaging - The assembly of materials and components in compliance with storage/shipment requirements.

Process - To extract, separate, purify, or fabricate a material by physical, chemical, or mechanical means.

Pyrophoric - Capable of igniting spontaneously when exposed to air.

Quality Assurance (QA) - All planned and systematic actions necessary to provide adequate confidence that a structure, system, or component will perform satisfactorily in service.

Quality Control (QC) – The overall system of technical activities that measure the attributes and performance of a process, item, or service against defined standards to verify that they meet the stated requirements established by DOE. QC includes operational techniques and activities that are used to fulfill requirements for quality.

Removable Activity – Surface activity that can be readily removed and collected for measurement by wiping the surface with moderate pressure.

Residue - Process-generated uranium-bearing materials not classified as storable metal or stabilized oxide that contains a non-discardable quantity of uranium.

Safeguards - an integrated system of physical protection, material accounting, and material control measures designed to deter, prevent, detect, and respond to unauthorized possession, use, or sabotage of nuclear materials.

Sealed - Sealed means that a container has been closed (e.g., welded) and does not exceed the maximum permissible limits defined in ANSI N 14.5-1997.

Sealed Source – Any SNM that is encased in a capsule designed to prevent leakage or escape of the SNM.

Shall, Should and May - "Shall" denotes that something is required. "Should" denotes that something is recommended but is not required. "May" denotes that something is permitted but is neither a requirement nor a recommendation.

Significant Quantity of Fissionable Material – The minimum quantity of fissionable material for which control is required to maintain subcriticality under all normal and credible abnormal conditions.

Sinter – To form a homogeneous mass by heating compacted material without melting.

Site Safeguards and Security Plan – A plan developed at site level under direction of the cognizant field element manager that provides a description of site-wide protection programs and evaluations of risk associated with DOE design basis threat policy and identified facility targets.

Specific Surface Area - The ratio of the geometric surface area of a material to its mass in units of cm^2/g.

Standard Cubic Centimeter of Gas - The quantity (moles) of gas in one cubic centimeter of volume at 1 atmosphere pressure and 25°C (298 K).

Storage - Any method for safely maintaining items in a retrievable form for subsequent use or disposition.

Storage Facility - The building structure and other confinement systems that house storage packages.

Storage Package - A configuration of nested containers including package content.

Survey – A systematic evaluation and documentation of radiological measurements with a correctly calibrated instrument(s) that meets the sensitivity required by the objective of the evaluation.

Thermal Stabilization - A process that exposes a uranium-bearing material in air to an elevated temperature for the duration required to convert reactive constituents present to a stable oxide form and to remove adsorbed moisture and other volatile species.

Tube Vaults - Tubular storage devices (steel lined and encased in concrete) used for the storage of packages containing ^{233}U.

Unirradiated Material - Material that has not been subjected to the high-neutron-flux environment existing near the core of a nuclear reactor, or material irradiated in a reactor but with a radiation level equal to or less than 100 rad/h at 1 m unshielded or material that has been irradiated in a reactor but has been separated from fission products to permit reuse.

Waste – Uranium-233 containing material that meets three requirements: (1) there is no existing, planned, or proposed use; (2) the ^{233}U (a) has a concentration of <200 g ^{233}U/55-gal drum or (b) the enrichment level is <0.66 wt % ^{233}U in ^{238}U; and (3) the ^{233}U (a) has an approximately homogeneous concentration of <1 kg $^{233}U/m^3$ (equivalent to <200 g/55-gal drum) or (b) the enrichment level is <12 wt % ^{233}U in ^{238}U.

2. Acronyms

ALARA	As low as reasonably achievable
ANSI	American National Standards Institute
CFR	Code of Federal Regulations
DOE	U. S. Department of Energy
DOT	Department of Transportation
ICPP	Idaho Chemical Processing Plant
INEEL	Idaho National Engineering and Environmental Laboratory
MC&A	Material Control and Accountability
NDA	Nondestructive Assay
NDE	Nondestructive Examination
ORNL	Oak Ridge National Laboratory
ppm	Parts per million, or grams of designated material per megagram (metric ton) of net representative sample

psi	Pounds per square inch
Pu	Plutonium
Rn	Radon
SNM	Special nuclear materials
Th	Thorium
Tl	Thallium
U	Uranium
UO_2	Uranium Dioxide
UO_3	Uranium Trioxide
U_3O_8	Triuranium Octoxide

APPENDIX C

REFERENCES

REFERENCES

Specific DOE and other Federal agency regulations and other documents used in developing this Standard and the bases for the Standard are listed below.

1. Federal Regulations

The following Federal Regulations are referenced in this Standard:

10 CFR 20, Standards for Protection Against Radiation;

10 CFR 830.120, Nuclear Safety Management, Quality Assurance Requirements;

10 CFR 835, Occupational Radiation Protection, Surface Radioactivity Values;

29 CFR 1910, Occupational Safety and Health Standards;

40 CFR 61 Subpart H, National Emission Standards for Emissions of Radionuclides Other Than Radon From Department of Energy Facilities;

49 CFR 173, Shippers – General Requirements for Shipments and Packagings;

49 CFR 178.354, Specification 6M; metal packaging;

49 CFR 178.360, Specification 2R; inside containment vessel.

Copies of Federal Regulations are available from the Government Printing Office (GPO), Superintendent of Documents, Mail Stop: SSOP Washington, DC 20402-9329

2. Department of Energy Orders, Manuals and Reports

The following DOE Orders, Manuals and Reports are referenced in this Standard:

DOE O 231.1, Environment, Safety, and Health Reporting, November 7, 1996;

DOE M 231.1, Environment, Safety, and Health Reporting Manual, September 30, 1995;

DOE G 414.1-1, Assessment Guide for QA, August 1996;

DOE O 420.1, Facility Safety, October 13, 1995;

DOE O 425.1, Startup and Restart of Nuclear Facilities, October 26, 1995;

DOE O 430.1, Life Cycle Asset Management, October 26, 1995;

DOE O 470.1, Safeguards and Security Program, June 21, 1996;

DOE O 471.2A, Information Security Program, March 27, 1997;

DOE O 472.1B, Personnel Security Activities, March 24, 1997;

DOE 5400.1, General Environmental Protection Program, June 29, 1990;

DOE 5480.21, Unreviewed Safety Questions, December 1991;

DOE 5480.22, Technical Safety Requirements, January 23, 1996;

DOE 5480.23, Nuclear Safety Analysis Reports, March 1994;

DOE 5632.7A, Protective Force Program, February 13, 1995;

DOE 5633.3B, Control and Accountability of Nuclear Materials, September 1994;

DOE M 5639.6A-1, Manual of Security Requirements for the Classified Automated Information System Security Program, July 1994;

Copies of DOE Orders and reports are available from:

U.S. Department of Energy, AD-631/FORS, Washington, DC 20585, (202)586-9642

3. Non-Federal References.

The following non-government documents are referenced in this Standard.

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Department of Energy, Oak Ridge Operations Office. January 21, 1998. "Approval of Extension of Waiver of DOE Order 5633.3B Requirements for Physical Inventory in Material Balance Area (MBA) 070 (Deviation Request No. OSS-OR-95-009), letter to Dr. J.H. Swanks, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

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