Packaging Design Criteria for the Type B Drum

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Date Published
September 1995

Prepared for the U.S. Department of Energy
Assistant Secretary for Environmental Management

Westinghouse
Hanford Company Richland, Washington

Management and Operations Contractor for the
U.S. Department of Energy under Contract DE-AC06-87RL10930

Approved for Public Release

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ANSI	American National Standards Institute
ASME	American Society of Mechanical Engineers
DOE	U.S. Department of Energy
ICV	inner containment vessel
NRC	Nuclear Regulatory Commission
OCV	outer containment vessel
TRU	transuranic
WIPP	Waste Isolation Pilot Plant

PACKAGING DESIGN CRITERIA FOR THE TYPE B DRUM

1.0 INTRODUCTION

1.1 BACKGROUND

The Type B Drum package is a transportation cask capable of shipping a single 55-gal (208 L) drum of transuranic (TRU) waste. The Type B Drum is smaller than existing certified packages, such as the TRUPACT-II cask, but will allow payloads with higher thermal and gas generation rates, thus providing greater operational flexibility. The Type B Drum package has double containment so that plutonium contents and other radioactive material may be transported in Type B quantities. Conceptual designs of unshielded and shielded versions of the Type B Drum were completed in *Report on the Conceptual Design of the Unshielded Type B Drum Packaging* and *Report on the Conceptual Design of the Shielded Type B Drum Packaging* (WEC 1994a, WEC 1994b), which demonstrated the Type B Drum to be a viable packaging system.

A Type B package containment system must withstand the normal conditions of transport and the hypothetical accident conditions, which include a 9-m (30-ft) drop onto an unyielding surface and a 1-m (3-ft) drop onto a 15-cm (6-in.) diameter pin, and a fire and immersion scenarios.

1.2 PURPOSE AND SCOPE

The purpose and scope of this Packaging Design Criteria includes the following:

- Describe the Type B Drum and its proposed operation
- Define the payload proposed for the Type B Drum
- Establish the design requirements and safety analysis methodology for the Type B Drum.

1.3 JUSTIFICATION

The report, *Backlog Residues at the DOE Rocky Flats Plant: Residue IDC Descriptions*, Revision 1 (RFP 1993), states that Rocky Flats Environmental Technology Site currently possesses approximately 808 m³ (28,543 cu ft) of plutonium residue, most of which can be shipped inside of Type B Drum. Residue is defined as plutonium-bearing material, which historically contained sufficient quantities of plutonium to warrant processing to recover plutonium. However, since operations at Rocky Flats have been terminated, this

residue is now considered to be waste that will eventually be disposed. None of the plutonium residue that is currently stored at Rocky Flats can be shipped inside of existing packaging (such as the TRUPACT-II). In addition, there is a consent decree between the Colorado Department of Health and the U.S. Department of Energy (DOE) to remove all residue from Rocky Flats by January 1, 1999. The residue will have to be shipped to another DOE facility to be placed into a form suitable for disposal at the Waste Isolation Pilot Plant (WIPP). At present, no packaging exists that can ship this residue material on public highways, in accordance with U.S. Department of Transportation or Nuclear Regulatory Commission (NRC) requirements.

The DOE Office of Fissile Material Disposition is considering poisoning excess weapons-grade plutonium with gadolinium, vitrifying it, and placing the resulting ceramic pellets in drums for transport to its final disposal site. The Type B Drum will be able to safely transport greater quantities of ceramic pellets than any other existing packaging or packaging under development.

TRU waste will be shipped to WIPP or the Yucca Mountain Geologic Waste Repository in the TRUPACT-II transportation cask. TRUPACT-II is a Type B container that has been issued Certificate of Compliance Number USA/9218/B(U)F by the NRC, indicating compliance with the regulations of 10 CFR 71, "Packaging and Transportation of Radioactive Materials," *Code of Federal Regulations*, as amended. TRUPACT-II is a double-contained package that can transport up to 14 drums or 2 metal standard waste boxes per shipment. The use of TRUPACT-II is limited by worst-case analytic assumptions of gas generation, which impose a decay heat limitation that is lower than the package would otherwise require. Testing can be used instead to demonstrate that the actual gas generation rate of a given drum or standard waste box is sufficiently low to permit the raising of the heat limit for that container. Alternatively, a robust, small package for a single drum can provide a higher heat load (and a higher gas generation rate). Therefore, one of the purposes of this project is to develop a smaller, single drum package to supplement the TRUPACT-II package.

2.0 CONTENTS

The contents of the Type B Drum will be the residues at Rocky Flats, plutonium ceramic pellets, or TRU waste contents similar to the TRUPACT-II.

The residues at Rocky Flats, defined as plutonium bearing materials, have historically contained enough plutonium to warrant processing the materials to recover the plutonium. These residues came from production processes including component manufacture, laboratory and research development, and the plutonium recovery process itself. Table 1 shows the types of residues, the chemicals involved, the physical form, and the concentration of each. Detailed criticality, shielding, and gas generation analysis of each residue category will be required before they can be shipped within the Type B Drum, but it is expected that most residue material will be acceptable.

Table 1. Summary of Rocky Flats Residues. (2 sheets)

Residue group types	Chemicals description	Physical form	Concentration
Oxides	High levels of americium & other tracer elements	Fine powder (1 to 25 microns)	Upon request from Rocky Flats
Fluorides	Plutonium tetrafluoride - high neutron emitter	Powder form - pink cake	Upon request from Rocky Flats
Ash	Carbon, silica, Al ₂ O ₃ , CaO, Fe ₂ O ₃ , Na ₂ O	PVC, polyethylene, paper, liquid, rubber, filters with carbon, metal, wood, fine particulates	1.8 - 7% Pu/bulk wt. ($\approx$ 93% of bulk material has assay of 7% Pu)
Salts	Sodium chloride, magnesium chloride, potassium chloride, zinc chloride, calcium chloride, plutonium chloride, calcium metal	Dry, fused salts in the form of chunks	0.5 - 80% Pu/bulk wt. ($\approx$ 0.2% of bulk material has assay of 80% Pu; 84% of bulk material has assay of 2.3 - 6.5% Pu)
Pyrochemical Metals	Calcium metal, calcium-gallium	Salt	6.5 - 10.5% Pu/bulk wt. ($\approx$ 90% of bulk material has assay of 6.1% Pu)
Sand, Slag, and Crucible	Magnesium oxide, calcium fluoride, calcium metal, uncoalesced plutonium metal, pyrotechnic initiator, plutonium fluoride	Coarse pieces, pulverized material, chunks of crucible, sand	0.6 - 44.4% Pu/bulk wt. ($\approx$ 98% of bulk material has assay of 0.6 - 5.2% Pu)
Heels	High concentrations of carbon, aluminum magnesium oxide	Fine particulate	1.8 - 3.0% Pu/bulk wt. ($\approx$ 99.6% of bulk material has assay of 3% Pu)
Combustibles		Paper wipes, plastics, personal protective equipment, rags, rubber, teflon, PVC	0.5% Pu/bulk wt.

Table 1. Summary of Rocky Flats Residues. (2 sheets)

Residue group types	Chemicals description	Physical form	Concentration
Filters		Glass fibers and corrugated aluminum foil, wood, steel	1.0 - 4.3% Pu/bulk wt. ($\approx$ 64% of bulk material has assay of 1% Pu)
Metal	Stainless steel, aluminum, copper, iron, tantalum, tungsten, platinum, lead	Tools, piping, pieces of equipment	0.2 - 0.9% Pu/bulk wt. ($\approx$ 33% of bulk material has assay of 0.9% Pu)
Glass	Lead, barium	Glassware, ceramics, leaded glass	0.8 - 2.3% Pu/bulk wt. ($\approx$ 95% of bulk material has assay of 0.8% Pu)
Graphite	Graphite, calcium fluoride, calcium, magnesium	Pure graphite pieces, fine particulate	0.1 - 7.8% Pu/bulk wt. ($\approx$ 5% of bulk material has assay of 7.8% Pu)
Firebrick	High density alumina ceramic, actinide oxide	Bricks	0.7 - 4.7% Pu/bulk wt. ($\approx$ 90% of bulk material has assay of 0.7 - 1.2% Pu)
Resins	Acid and plutonium compounds, styrene-divinylbenzene copolymers,	Beads, fines	1.4% Pu/bulk wt. ($\approx$ 1 kg of bulk material has assay of 10% Pu)
Sludge	Actinide concentrations	Damp mass (paste), dried and may contain fines	3.4 - 7.6% Pu/bulk wt. ($\approx$ 85% of bulk material has assay of 3.4 - 3.9% Pu)
Dirt/Blacktop	One drum of blacktop	Blacktop, concrete, dirt, sand	0.1% Pu/bulk wt.
Ceramic Crucibles	Magnesium oxide, pyrochemical salts, aluminum silicate	Intact crucibles to broken chunks	1.7 - 2.7% Pu/bulk wt. ($\approx$ 18% of bulk material has assay of 2.7% Pu; rest is 1.7% Pu)

The plutonium ceramic pellets stem from the Fissile Materials Disposition Program. This program plans to produce 1.0% plutonium-loaded ceramic pellets containing gadolinium for neutron poisoning. The pellets will have a 2.5 cm (1.0 in) diameter, have a density of 4.5 g/cm³, weigh 34.32 g (0.0076 lb), and contain 0.3 g of plutonium. The Fissile Materials Disposition Program prefers 55-gal drums fully loaded with pellets, which translates to 16,100 pellets per drum with a total pellet weight of 555 kg (1,221 lb) and a total plutonium weight of 5.55 kg (12.21 lb). The Fissile Materials Disposition Program will accept fewer pellets per 55-gal drum, if that reduction is required to meet shipping requirements. Detailed criticality calculations will be required before the maximum pellet loading per Type B Drum and fissile classification can be established.

TRU waste containers fall into one of two categories based on their hydrogen gas generation potential: Analytic category waste or test category waste. In the *Safety Analysis Report for the TRUPACT-II Shipping Package, Revision 5* (Vectra 1994), theoretical worst-case calculations were performed to determine which waste containers could be shown to meet the limits on hydrogen concentration and could, therefore, be shipped without the need for testing. These theoretical worst-case calculations use bounding G values, which are a measure of the amount of hydrogen that can be generated by radiolysis of the waste materials. The waste containers that can be shipped without the need for testing comprise the analytical category. Because the primary mechanism for hydrogen gas generation is radiolysis, the limit on the hydrogen concentration for the analytic category is met by imposing a limit on the decay heat (or wattage) of the contents of the payload containers. A derivative limit on radiation source (alpha) is also thus imposed because alphas are the primary source of heat. The radioactive material content of the drum is thus limited for gas generation purposes, as well as for nuclear criticality and shielding purposes.

Decay heat limits for the waste containers are summarized in Tables 6-1, 6-2, and 6-3 of the *TRUPACT-II Content Codes (TRUCON)* (WIPP 1989) document. TRU waste materials may be classified into four waste types based on their chemical and physical characteristics as follows:

- I — Solidified Inorganics
- II — Solid Inorganics
- III — Solid Organics
- IV — Solidified Organics

Waste containers that exceed applicable decay heat limits belong in the test category, because they must be tested to determine the actual rate of gas generation and hydrogen concentration before shipment. Because the decay heat calculations for the analytic category are based on theoretical worst-case assumptions, it is probable that a significant number of containers of test category waste may be shippable after testing. In addition, a bounding G value has not been established that belong to Waste Type IV, or Solidified Organics. All of the waste containers in this waste type belong to the test category, because an upper bound for their gas generation potential has not been established.

The large capacity (14 drums, stacked in 2 levels of 7 each, or 2 standard waste boxes) of the TRUPACT-II transport cask causes heat that is generated within the containers to build up and produce higher temperatures than would occur if the containers were individually transported. The surface-to-volume ratio of a smaller package designed to transport a single TRU drum would be greater numerically than TRUPACT-II's ratio, and produce a better cooling effect. This would reduce the contribution to the gas generation caused by thermolysis. The interior space of the Type B Drum package can also be increased relative to the drum volume to produce a dilution effect greater than that of TRUPACT-II. These effects reduce the packing efficiency of Type B Drum relative to TRUPACT-II, but allow a higher heat and gas generation rate limit. In addition, the size and weight of the TRUPACT-II exceed the capabilities of some facilities, and a smaller package can be handled in any facility.

Package contents limits will be maximized without compromising facility access. The number of Type B Drums that may be shipped on a single legal weight truck will be derived from Type B Drum size and weight (i.e., the number of packages which may be transported simultaneously is not a specification).

The following are the package limits:

- Drum size — 55-Gal drum
- Drum weight — not to exceed 555 kg (1,221 lb) for 55-Gal drum
- Drum dimensions — 55-Gal Drum, 61 cm diameter (24 in.) by 89 cm height (35 in.)
- Fissile material — to be determined by detailed analysis
- Flammable organics — not to exceed 500 ppm in the headspace of a 55-gal drum
- Free liquids — not to exceed 1% by volume
- Prohibited materials — explosives, corrosives, nonradioactive pyrophorics, and pressurized containers.

3.0 FACILITY OPERATIONS

3.1 ORIGINATING FACILITY

The originating facility will vary from within the DOE sites. The primary application of this package will be from users at the following sites.

- Rocky Flats Environmental Technology Site for shipment of plutonium residue material.
- Vitrification plant that produces ceramic plutonium pellets.
- Facilities that slowly accumulate small quantities of radioactive materials over a long period of time, such as laboratories.
- Generating, processing, or storage facilities making shipments of Type B waste.
- Waste retrieval project sites where further handling of the recovered drum may be prohibited and/or the characterization of the contents is uncertain.
- Sites where handling/emergency response teams require an overpack for a damaged or leaking drum.

3.2 RECEIVING FACILITY

As noted in the following, the receiving facility will vary depending upon the location and purpose of the site.

- Interim storage facilities that are permitted to receive and store TRU wastes or plutonium residue.

Note: current laws do not allow the construction of interim storage facilities for TRU wastes.

- The WIPP is intended to receive a limited quantity of TRU wastes for permanent geologic disposal in a salt formation near Carlsbad, New Mexico.
- A geologic repository is under development at the Yucca Mountain site in New Mexico for the permanent geological disposal of spent fuel and TRU wastes in a volcanic tuff deposit.
- The Deep Borehole Disposal Facility is intended to receive vitrified ceramic plutonium pellets.

4.0 PACKAGING/TRANSPORT SYSTEM DESIGN CRITERIA

4.1 GENERAL

The Type B Drum consists of the following major components:

- Drum — 55-gal drum with contents
- Inner and outer containments (double containment)
- Impact limiter (foam or crushable material)
- Shielding (dependent upon maximum radiation level of contents).

4.2 TYPE B DRUM

4.2.1 General Description

The package will permit the shipment of single drums while providing a double-containment option. The package is to have interchangeable parts to accommodate single- and double-containment shipments.

4.2.2 Loading/Unloading

The Type B Drum will be loaded in facilities that do not possess extensive crane or handling capabilities. The package will be capable of being loaded vertically. The loaded Type B Drum must be capable of movement via forklift or crane.

4.2.3 Containment

The Type B Drum is a package for the shipment of transuranic materials including plutonium and americium. The package will provide double containment, with leak tight seals helium leak tested to 10^{-7} std-cm³/sec during factory acceptance and maintenance testing. Containment seals will be tested to a sensitivity equivalent to a helium leak rate of 10^{-3} std-cm³/sec before each shipment. Testing procedures will be in conformance with American National Standards Institute (ANSI) Standard N14.5, *Radioactive Materials Leakage Tests on Packages for Shipment* (ANSI 1987).

4.2.4 Thermal

The thermal limits of the Type B Drum will be maximized to provide the greatest operational flexibility possible. The conceptual design activities (WEC 1994a, 1994b) calculated that the Type B Drum could ship material that generates a minimum of 40 W.

4.2.5 Capacity

The capacity of the Type B Drum is a single 55-gal TRU drum.

4.2.6 Testing

Drop testing is required to demonstrate compliance with the 9-m (30-ft) free drop and pin puncture requirements of 10 CFR 71. Compliance with thermal, radiological, criticality safety, and other mechanical requirements of 10 CFR 71 will be demonstrated through analysis.

4.2.7 Metric Units

The design will be described with metric units and English equivalents. Items that are not commonly available in metric sizes may be based upon English units. English units may be used for stainless steel plate used to fabricate the Type B Drum package containment shells, with equivalent metric thicknesses also provided.

4.2.8 Materials

Outer and inner containment vessels will be fabricated from corrosion resistant austenitic stainless steel and conform to the American Society of Mechanical Engineers (ASME) *Boiler and Pressure Vessel Code*, Section III, Part D (ASME 1989). Materials will be compatible and will not cause galvanic corrosion.

4.3 SYSTEM DESCRIPTION

The configuration of the package system includes all items, tools, and processes required to perform the function of shipment of TRU drums.

4.3.1 System Components

The Type B Drum package is generally considered to be comprised of an inner containment and an outer containment, plus any shock absorbing outer packaging such as foam.

4.3.2 Shipping Configuration

The Type B Drum will be shipped vertically in a sole use truck.

4.3.3 Special Tools

Any special tools that must be used to load or unload the container are considered to be a part of the cask system. Special tools will be minimized.

4.3.4 Procedures

The procedures that are to be used to operate the package including loading, unloading, and decontamination must be provided in sufficient detail as to allow interfaces with facilities to be evaluated. Procedures for acceptance testing of newly fabricated components and maintenance are also required.

4.4 DESIGN SCOPE

The deliverable items for this project include the descriptions in Section 4.4.1.

4.4.1 Design of the Type B Drum Package

The design must be complete and evaluated to demonstrate compliance with the requirements of 10 CFR 71. The results of the evaluations are to be provided in the form of a safety analysis report for packaging.

4.5 DEFINITIONS

4.5.1 Transuranic

Transuranic materials consist of waste that contains isotopes of plutonium, americium, or other element heavier than uranium. Quantities in excess of 20 Ci of plutonium (the limit for Type A containers) must be transported in a Type B package.

4.5.2 Containment Vessel

The containment vessel is the structure that retains the contents of the package (payload) and prevents leakage of radioactive material at rates in excess of the requirements of 10 CFR 71.51. Double containment is provided by two independent vessels that do not share common structural components. The containment vessel(s) may require protection during the transportation phase to satisfy the requirements of 10 CFR 71.73.

Double containment is required, consisting of an inner containment vessel (ICV) and an outer containment vessel (OCV). The inner package must be removable from the outer container after a worst-case, 9-m (30-ft) drop and pin puncture. Deformation of the ICV and OCV must not be sufficient to bind the containment vessels together so that excessive force is required to separate them after a 9-m (30-ft) drop and pin puncture.

4.5.3 Overpack

The containment vessels may be protected during the 9-m (30-ft) drop and pin puncture events by energy-absorbing materials. If such materials are employed, then their effect upon package heat transfer must be evaluated.

4.5.4 Gas Generation

Hydrogen gas is generated by radiolysis of water contained within the contents and by radiolysis or thermolysis of packing materials (e.g., plastic bags). The limit for hydrogen gas within the package is 5.0% by volume in a 60-day shipping period, as required by NRC Information Notice 85-72, *Conditions for Waste Shipping Subject to Hydrogen Gas Generation* (NRC 1984).

4.5.5 Design Life

The package will be designed for a 40-yr design life. All components of the package will be designed to a 40-yr design life or will be replaceable. The package will be capable of being decommissioned at the end of its useful life without using cleaning fluids, which contain hazardous materials that could generate a mixed waste.

5.0 DESIGN BASIS ENVIRONMENT AND CONDITIONS

5.1 NORMAL CONDITIONS OF TRANSPORT

Normal conditions of transport are described in 10 CFR 71.71. Specific information regarding the Type B Drum are provided in this section.

5.1.1 Ambient Thermal Conditions

The maximum ambient temperature for normal operation is 38 °C (100 °F), with full solar insolation. The exterior conditions, plus the 40 w generated by the waste contents of the package, will not result in excessive internal temperatures within the waste. Such excessive internal temperatures could result in a substantial contribution to gas generation through thermolysis. The minimum ambient temperature is -40 °C (-40 °F) for evaluation of seals, including the effects of still air and shade. The minimum ambient temperature for evaluation of structural performance is -29 °C (-20 °F). Minimum and maximum decay heat conditions will be selected to maximize the effect on the package. Active cooling may not be employed.

5.1.2 External/Internal Pressure

Package evaluations will consider an external pressure reduced to 24.5 kPa (3.5 psi) absolute and an external pressure increased to 140 kPa (20 psi) absolute. The maximum design internal pressure for the package will not exceed 689 kPa (100 psig).

5.1.3 Vibration

Package evaluation will consider vibration normally incident to truck traffic. The vibration standards are contained in ANSI Standard N14.23 *Design Basis for Resistance to Shock and Vibration of Radioactive Material Packages Greater than One Ton in Truck Transport* (ANSI 1994).

5.1.4 Water Spray

The package will be analyzed for the effects of water spray that simulates exposure to rainfall of approximately 5 cm (2 in.) per hour for one hour.

5.1.5 Free Drop

The effects of a normal operation free drop onto the package end, side, and corner will be considered. The drop will be onto a flat, unyielding horizontal surface and package orientation will be such that maximum damage occurs. The effects of the normal operation free drop may be evaluated through analysis or physical testing.

5.1.6 Compression

If the package weighs up to 5,000 kg (11,000 lb) loaded, it will be subject to a compression test simulating package stacking. The test will consist of the greater of either the equivalent of five times the package weight or the equivalent of 12.75 kPa (1.85 psi) multiplied by the projected area of the package. The load will be applied for 24 hours uniformly to the package top and bottom, in the orientation of transport.

5.1.7 Penetration

The package will be subject to the impact of the hemispherical end of a vertical steel cylinder of 3.2 cm (1.25 in.) diameter and 6 kg (13 lb) mass, dropped from the height of 1 m (40 in.) onto the exposed surface of the package that is expected to be most vulnerable to puncture. The long axis of the cylinder must be perpendicular to the surface of the package.

5.2 OTHER REGULATORY NORMAL CONDITION LOADS

5.2.1 Lifting Devices

If routine operations specify the use of conventional slings or chains for package lifting, then these items will have a minimum safety factor of 5 based on breaking strength.

If a specific lifting device is used for package handling then it will be designed to comply with ANSI N14.6, *Special Lifting Devices for Shipping Containers Weighing 10,000 Pounds (4,500 kg) or More* (ANSI 1993). The N14.6 requirements for critical loads

do not apply. The lifting requirements of NUREG/CR-0612, *Investigations of the Performance of Solidified High-Level Nuclear Waste Forms* (1979), will be applied to the structure of the lifting device to insure a factor of 6 on yield and 10 on ultimate strength.

5.2.2 Tie-Down Devices

Package tiedown devices will comply with 49 CFR 393, "Parts and Accessories Necessary for Safe Operation," *Code of Federal Regulations*, as amended. Cask tiedown attachment points will comply with 10 CFR 71.45.

The Type B Drum package will be evaluated for the effects of tiedown loading and transport loading transmitted to the package through the tiedown system.

5.3 OTHER NORMAL LOADING CONDITIONS

5.3.1 Handling Loads

The design of the Type B Drum packaging will account for all loads associated with the handling during inner containment vessel processing, package assembly for shipment, and placement and removal from the transport vehicle. Handling loads will also include any pressure or mechanical loads that might be associated with the placement and removal of the Type B Drum contents (i.e., the 55-gal drum or 114 L [30-gal] drum.)

5.3.2 Fabrication Loads

The analysis of the Type B Drum will account for any loads imposed on it during the course of fabrication either from handling or from the fabrication processes (e.g., welding or heat treatment).

5.3.3 Test Condition Loads

The analysis of the Type B Drum will account for any loads imposed on it during the course of acceptance testing. This will include load testing and pressure testing to values in excess of the expected maxima for normal transport conditions.

5.3.4 External Environmental Loads

The Type B Drum will be evaluated for the effects of external environmental loads such as corrosive materials, rod salt, rain, hail, road debris, exhaust, and any other expected conditions that might damage the package exterior.

5.4 HYPOTHETICAL ACCIDENT CONDITIONS

The hypothetical accident conditions are applied in sequence (9-m [30-ft] drop, 1-m [40 in.] puncture, fire, water immersion.) The effects of 9-m (30-ft) drops at different orientations (end, corner, side, and oblique) are to be considered individually (i.e., the effects of drops are not cumulative). The ambient air temperature before, during, and after the test must be within the range of -29 °C (-20 °F) to +38 °C (+100 °F) with the selected value the most unfavorable for the feature under consideration.

5.4.1 Nine-Meter Free Drop

The Type B Drum will be evaluated for a 9-m (30-ft) drop onto an essentially unyielding horizontal flat surface. Package orientation will be such that the maximum damage is imparted. Drop orientations analyzed will include end, corner, side, and oblique. The end containing the ICV and OCV closures will be evaluated, as well as the end which does not. Oblique orientations will be evaluated at 15° intervals, and the worst-case angular orientation determined. Physical drop testing will include closure end, closure end corner, side, and worst case oblique angles. The ICV and OCV will be capable of separation after the 9-m (30-ft) drop in any orientation.

5.4.2 One-Meter Puncture Drop

The Type B Drum will be evaluated for a 1-m (40-in.) free drop onto the upper end of a solid, vertical, mild steel bar mounted on an essentially unyielding horizontal surface. The bar will be 15 cm (6 in.) in diameter, with its top edge rounded to a radius of no more than 6 mm (.25 in.) and having a length great enough to cause maximum damage to the package but not less than 20 cm (8 in.). The long axis of the bar will be vertical. The ICV and OCV will be capable of separation after the puncture drop in any orientation.

5.4.3 Thermal

The Type B Drum will be evaluated for total exposure for not less than 30 minutes to a heat flux not less than that of a radiation environment of 800 °C (1475 °F), with an emissivity coefficient of at least 0.9. For purposes of calculation, the package emissivity will

be the greater of its actual value if exposed to a fire or a value of 0.8. Artificial cooling is not permitted and any combustible components must be allowed to extinguish naturally. Solar insolation may be disregarded before to, during, and following the fire.

5.4.4 Water Immersion

5.4.4.1 Immersion - Fissile Material. Water inleakage will be assumed for criticality safety calculations, and no immersion test is required.

5.4.4.2 Immersion - All Packages. This test will apply to the undamaged Type B Drum. The package will be evaluated for water pressure equivalent to immersion under a head of water at least 15-m (50-ft) deep for a period of not less than 8 hours. For test purposes, an external pressure of water of 147 kPa (21 psi) gauge is considered to meet these conditions.

5.5 INTERNATIONAL ATOMIC ENERGY AGENCY CONDITIONS

The Type B Drum will not be certified to International Atomic Energy Agency Safety Series 6 conditions; however, the deep submergence condition of Safety Series 6 will be applied.

5.5.1 Deep Submergence

The undamaged Type B Drum will be evaluated under the deep submergence conditions of International Atomic Energy Agency Safety Series 6 (i.e., 200-m [656-ft] depth). Inner containment integrity will be maintained under these conditions.

6.0 STRUCTURAL DESIGN CRITERIA

6.1 GENERAL

6.1.1 Material Properties

Metallic materials will be austenitic stainless steel except for bolting and other components where wear resistance and high strength are required. For such items, consideration will be given to fatigue, brittle fracture, and corrosion resistance. Materials that are part of the ICV or OCV containment boundary will be austenitic stainless steel which conforms to ASME *Boiler and Pressure Vessel Code* Sections II and III. All other materials will be to American Society for Testing and Materials specifications or equivalent.

Nonmetallic material properties will be verified by test or certified by the manufacturer as being derived from tests. Phenolic foams will comply with DOE *Material and Equipment Specification*, SP-9, Revision 1, and Supplement.

6.1.2 Analytical Procedures

Structural analytical procedures for the containment vessels will follow NRC Regulatory Guides 7.6, *Design Criteria for the Structural Analysis of Shipping Cask Containment Vessels*, and 7.8, *Load Combinations for the Structural Analysis of Shipping Casks for Radioactive Material* (NRC 1978, 1989).

6.2 NORMAL LOAD CONDITIONS

6.2.1 Containment Boundary

Under the conditions defined in NRC Regulatory Guide 7.8, the inner and outer containment vessel containment boundaries will be analyzed following the guidance and criteria of NRC Regulatory Guide 7.6.

6.2.2 Balance of Packaging

The analysis methods applied to the balance of the packaging will follow sound engineering principles.

6.3 HYPOTHETICAL ACCIDENT CONDITIONS

6.3.1 Containment Boundary

Under the conditions defined in NRC Regulatory Guide 7.8, the inner and outer containment vessel containment boundaries will be analyzed following the guidance and criteria of NRC Regulatory Guide 7.6. The inner containment boundary will not yield or buckle under any of the structural hypothetical accident conditions. Containment lid joints will prevent the application of shear loads to closure bolts.

6.3.2 Balance of Packaging

Bolts will have a fine thread appropriate to the diameter of the bolt. Closure bolts will be installed with a lubricant to insure proper torquing. Hard washers may be inserted between the bolt head and the closure to prevent galling. Bolts will be recessed to prevent side loads from being applied under any structural accident condition.

6.4 EXPERIMENTAL STRESS ANALYSIS

Experimental stress analysis or testing is permitted as a reasonable substitute for analytical methods. This may apply to any component of the Type B Drum. Computational stress analysis is required for the 9-m (30-ft) drops to identify the worst-case oblique angle orientation.

7.0 NUCLEAR DESIGN CRITERIA

7.1 CRITICALITY SAFETY

The Type B Drum criticality safety classification will be determined from the details of the package design and the contents of the package when such information is available.

7.1.1 Normal Conditions

The Type B Drum package will be designed and analyzed in accordance with the requirements of NRC regulations in 10 CFR 71.55. For analysis purposes, subcritical will mean a reactivity, k_{eff} , of no more than 0.95 considering all calculational biases and uncertainties.

7.1.2 Hypothetical Accident Conditions

The Type B Drum package will be designed and analyzed in accordance with the requirements of NRC regulations in 10 CFR 71.55. For analysis purposes, subcritical will mean a reactivity, k_{eff} , of no more than 0.95 considering all calculational biases and uncertainties. The package will be considered to contain pure water at the optimum density for these calculations.

7.2 SHIELDING

7.2.1 Normal Conditions

Package shielding will ensure that the dose rate limits of 10 CFR 71.51 and 49 CFR 173 "Shippers-General Requirements for Shipments and Packaging," *Code of Federal Regulations*, Section 441, as amended, are not exceeded. The maximum surface dose rate upon any accessible surface of a loaded package will not exceed 200 mrem/hour. The maximum dose rate at 1 m from the package boundary will not exceed 10 mrem/hour. Dose rates will include neutron and gamma radiations, and secondary gamma radiation from neutron capture in shielding material.

7.2.2 Hypothetical Accident Conditions

Package shielding will ensure that the dose rate limits of 10 CFR 71.51 are not exceeded. The maximum dose rate at 1 m (3 ft) from the package (the surface of the Type B Drum) will not exceed 1,000 mrem/hour under hypothetical accident conditions. Dose rates will include neutron and gamma radiations and secondary gamma radiation from neutron capture in shielding material.

7.3 CONTAINMENT

7.3.1 Normal Conditions

The Type B Drum packaging will be designed such that there will be no loss of contents under the normal conditions of transport. Inner and outer containment seals will be leaktight.

7.3.2 Hypothetical Accident Conditions

The Type B Drum packaging will be designed such that there will be no loss of contents under the hypothetical accident conditions of transport. Inner and outer containment seals remain leaktight.

7.4 HEAT MANAGEMENT

7.4.1 Normal Conditions

The Type B Drum will be designed and the contents so limited as to satisfy the thermal conditions of 49 CFR 173.442 and the external surface temperature limits of 10 CFR 71.43(g). Both external and internal heat will be considered in the analysis.

7.4.2 Accident Conditions

The Type B Drum will be evaluated under the hypothetical accident conditions of transport. There will be no loss of containment or contents nor any reduction in nuclear criticality safety as a result of the accident thermal conditions. Both external and internal heat will be considered in the analysis.

7.5 GAS GENERATION MITIGATION

For operational purposes, means to mitigate pressure and hydrogen (see Section 4.5.4) caused by gas generation within the package may be provided. The hydrogen getter 1,4-bis(phenylethynyl)benzene (DEB) should be considered for use. The Kansas City Division report *Getter Material Products Development: DEB Hydrogen Getter Gas Inhibition Analysis* (KCD 1995), demonstrates that the DEB hydrogen getter captures hydrogen gas and reduces overall pressure within packaging, even in the presence of known inhibitors. However, no credit will be taken for active gas mitigation features in the hypothetical accident scenarios.

8.0 PACKAGE SERVICE REQUIREMENTS

8.1 OPERATIONAL AND TRANSPORTATION INTERFACE REQUIREMENTS

The Type B Drum will be designed to interface with the loading and unloading conditions of DOE facilities. The Type B Drum transportation interfacing will consider the number of packages that may be shipped in a truck trailer where the gross vehicle weight is limited to 80,000 pounds (legal weight truck). Gross vehicle weight is the total weight of the loaded transporter in its over-the-road configuration.

Package interfacing with the transporter trailer will accommodate placement or removal by forklift or overhead crane. Tiedowns will be compatible with the structural members of the trailer.

8.2 IN-SERVICE INSPECTION/MAINTENANCE REQUIREMENTS

The design of the Type B Drum packaging will consider in-service inspection and maintenance.

8.2.1 Containment Vessels

Welds will be inspectable by radiographic testing. A means will be provided for pressure testing the inner and outer containments before each shipment and during annual maintenance and acceptance testing. The containment vessel closure seals will be replaceable. High wear components will be reasonably replaceable. Surface finish will be 64 rms or better. Consideration will be given to decontamination by avoiding rough welds, crevices, or other surface features which might trap radioactive particulates.

8.2.2 Balance of Package

All welds will be inspectable by appropriate means such as dye penetrant examination, ultrasonic testing, or visual inspection. A means will be provided to perform moisture measurements and drying operations, if needed, on the contained thermal insulation/ impact protection media. Seals for weather proofing and any high wear components will be reasonably replaceable. Surface finish will be 125 rms or better.

9.0 MANUFACTURING REQUIREMENTS

9.1 CONTAINMENT VESSELS

The inner and outer containment vessels will be manufactured in accordance with NUREG/CR-3854, *Fabrication Criteria for Shipping Containers* (1985), and NUREG/CR-3019, *Recommended Welding Criteria For Use in the Fabrication of Shipping Containers for Radioactive Materials* (1984), as applicable.

9.2 BALANCE OF PACKAGE

The balance of the package will be manufactured in accordance with NUREG/CR-3854 and NUREG/CR-3019, as applicable.

10.0 QUALITY ASSURANCE REQUIREMENTS

The Type B Drum will be designed, manufactured, and tested following a quality assurance plan that will be included in the safety analysis report for packaging for DOE approval. Requirements for such a quality assurance plan are contained 10 CFR 71, Subpart H.

11.0 REFERENCES

10 CFR 71, "Packaging and Transportation of Radioactive Materials," *Code of Federal Regulations*, as amended.

49 CFR 173, "Shippers-General Requirements for Shipments and Packaging," *Code of Federal Regulations*, as amended.

49 CFR 393, "Parts and Accessories Necessary for Safe Operation," *Code of Federal Regulations*, as amended, U.S. Department of Transportation, Washington, D.C.

ANSI N14.5, 1987, *Radioactive Materials Leakage Tests on Packages for Shipment*, American National Standards Institute, New York, New York.

ANSI N14.6, 1993, *Special Lifting Devices for Shipping Containers Weighing 10,000 Pounds (4500 kg) or More for Nuclear Materials*, American National Standards Institute, New York, New York.

ANSI N14.23, 1994, *Design Basis for Resistance to Shock and Vibration of Radioactive Material Packages Greater than One Ton in Truck Transport*, American National Standards Institute, New York, New York.

ASME, 1989, *Boiler and Pressure Vessel Code*, American Society of Mechanical Engineers, New York, New York.

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- WEC, 1994a, *Report on the Conceptual Design of the Unshielded Type B Drum Packaging*, Westinghouse Electric Corporation-Nuclear Technology Division, Pittsburgh, Pennsylvania.
- WEC, 1994b, *Report on the Conceptual Design of the Shielded Type B Drum Packaging*, Westinghouse Electric Corporation-Nuclear Technology Division, Pittsburgh, Pennsylvania.
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