RADIOACTIVE MATERIAL TRANSPORTATION CONSIDERATIONS WITH RESPECT TO DOE 3013 STORAGE CONTAINERS

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ABSTRACT

This paper evaluates sealed hardware that meets the requirements of DOE-STD-3013, "Criteria for Preparing and packaging Plutonium Metals and Oxides for Long-Term Storage" [1] with respect to radioactive material (Type B quantity) transportation requirements. The Standard provides criteria for packaging of the plutonium materials for storage periods of at least 50 years. The standard requires the hardware to maintain integrity under both normal storage conditions and under anticipated handling conditions. To accomplish this, the standard requires that the plutonium be loaded in a minimum of two nested stainless steel sealed containers that are both tested for leak-tightness per ANSI N14.5. As such the 3013 hardware is robust.

While the 3013 STD may provide appropriate storage criteria, it is not intended to provide criteria for transporting the material under the requirements of the Department of Transportation (DOT). In this evaluation, it is assumed that the activity of plutonium exceeds A1 and/or A2 curies as defined in DOT 49 CFR 173.431 and therefore must be shipped as a Type B package meeting the Nuclear Regulatory Commission (NRC) requirements of 10 CFR 71. The evaluation considers Type B shipment of plutonium in the 3013 hardware within a certified package for such contents.

I. INTRODUCTION - Regulations

A "Type B package" means a Type B packaging that, together with its radioactive contents, (plutonium in this case) is designed to meet the performance specifications of 10 CFR 71. Benefits from shipping the 3013 hardware as a component in a Type B package will be evaluated for three regulatory cases. The cases consider the 3013 hardware and plutonium as 1) special form radioactive material, 2) a packaging containment vessel, and 3) a form exempt from plutonium double containment. Each case will be evaluated to the requirements listed in Table 1. A summary of overall packaging benefits will then be made.

Table 1: Transport Requirements 3013 Cases

3013 CASES	REQUIREMENTS
Special form	10 CFR 71.4, .75, RG 7.9 (2.8)
Containment vessel	71.31(c), .71, .51(a)(1), .51(a)(2), NUREG 3854, ANSI N14.5, RG 7.9 (3.4.4), RG 7.6
Exempt form	71.63(b), RG 7.8 (1.4)

II. 3013 HARDWARE

In order to evaluate the DOE 3013 Standard as a Type B package component the 3013 Standard must describe the radioactive material and the hardware in adequate detail. Since much of the standard contains performance criteria which encourages design and material selections it is not sufficiently detailed to meet the content description requirements of 10 CFR 71.31(a)(1), and the package description requirements of 71.33. More specifically the 3013 Standard does not provide the level of design detail, weld definition, and drawings required for transportation package safety documentation. This evaluation will therefore be based on the standard 3013 outer container hardware.

The level of container detail provided by the 3013 Standard is illustrated by the performance requirements and guidelines excerpted from the standard and listed below.

- Minimum design pressure of outer container shall be 699 psig (6.2.1 (5))
- ASME code or an alternative design code equal or superior to the intent of the ASME code shall be used for designing and manufacturing the outer storage container (for example ASME VIII with exceptions) (A.6.2.1(6))
- It is stated that it is unlikely that the container pressures will exceed 100 psig under normal storage for 50 years (A.6.2.1(6))
- Low carbon stainless steels such as 304L or 316L are recommended (A.6.2.2(1))
- Maximum plutonium-steel interface temperature in the 3013 would be 482^{o}F (A.6.3.2(2))
- Mechanisms to produce corrosion in the container are not likely to be significant under storage conditions (A.6.3.3(3))

The 3013 inner and outer vessel designs under consideration have been analyzed and tested under room temperature conditions. The testing consisted of 30 foot drop, hydro, and burst tests. The drop tests will be discussed later; the hydro tests were conducted at 1.5 times the design pressure and then helium leak tested. The vessels were successfully helium leak tested after the hydro test. The pressure at which the cans burst was well beyond the hydro test pressures. For the inner cans the minimum burst pressure was 1590 psia. For the outer cans the minimum burst pressure was 3935 psia.

III. SPECIAL FORM

The 3013 is evaluated in this section to determine if it can be qualified as special form radioactive material per 10 CFR 71.75. The packaging regulations give special consideration to radioactive material that by its physical form or encapsulation is non dispersible. Radioactive material that is either a single solid piece or is contained in a sealed capsule meeting the criteria of 10 CFR 71.75 is designated as “special form”. Special form materials historically are double encapsulated sealed welded capsules. Special form capsules must remain leak tight under the thermal and structural criteria of 10 CFR 71.75, which include a bare drop from 9 m and direct exposure to an 800^{o}C heat test. Once a capsule is qualified as special form radioactive material the following considerations would apply.

- Certification of special form materials is carried out by the U.S. Competent Authority (Department of Transportation (DOT))
- Containment is provided by the special form material in a Type B package,
- Special form material is not subjected to the plutonium double containment requirements of 10 CFR 71.63(b),
- Type B packages with special form material are not required to meet the dynamic crush test specified in 10 CFR 71.73(c)(2), and
- Curie limits for Type A package can be much higher for special form (A1) than normal form (A2). Pu 239 for example: A1 = 54.1 Ci, A2 = .0054 Ci.

The requirements for special form and an indication of DOE 3013 compliance to the requirements are given in Table 2.

Table 2: Special Form Evaluation

SPECIAL FORM REQUIREMENTS AND TESTS (10 CFR 71.4 & 71.75)	YES	NO
Sealed Capsule	X	
No Dimension < 5 mm	X	
Impact (9 m drop)	X	
Percussion (3lbs. @ 1 m)	X	
Bending	N/A (L/W<10)	
Heat (to 800^{o}C & hold 10 min)		X

The 71.75 acceptance criteria for the above tests are 1) the test specimen not break or shatter when subject to the impact, percussion, or bending test, and 2) the specimen may not melt or disperse when subject to the heat test. After each test the leak tightness (1.3E-4 atm-cc/sec) or indispersibility of the specimen must be determined.

A. Impact Test

Bare outer vessels with a variety of inner vessels were drop tested (bottom edge down and top edge down) onto an unyielding surface from 9 m. Damage caused to the containers was minimal with some denting and deformation. In all cases the 3013 outer vessel remained leak tight.

B. Percussion Test

The percussion test will impart loads on the 3013 vessel that are much lower than those during the 9 m impact test. Crush tests were conducted on vessels that are similar, but considered much more severe than the percussion tests required by 10 CFR 71. The crush tests used a pair of vessels – one as the target and one as the released can. The released can was dropped into the target can, resting on an unyielding surface, from a height of 9 m. The outer vessels remained intact and leak tight after testing.

C. Bend Test

The bend test is not applicable since the L/W = 10”/4.9” = ~2. The criteria to subject a special form specimen to the bend test is that L/W > 10.

D. Heat Test

The heat test is the most challenging test for the 3013 hardware. The test requires that the 3013 with representative non radioactive contents be heated to 800^{o}C and held for 10 minutes. The 3013 will pass the non-melting criteria, however a non-dispersion argument supported by the ASME code can not be made for units fabricated from 316L stainless steel (ss). It is feasible that units fabricated from higher strength 316 ss with ASME welds would meet the criteria. The heat test likely challenges the 3013 hardware beyond acceptable limits when the initial gas pressure in the vessel is the bounding value provided in the 3103 standard.

IV. CONTAINMENT

The criteria for leakage from Type B package containment is defined in terms of radionuclide release in 10 CFR 71.51. Containment vessel design is further defined in NRC Reg. Guide 7.6, "Design Criteria for the Structural Analysis of shipping Cask Containment Vessels", and containment vessel fabrication criteria given in NUREG 3854, "Fabrication Criteria for Shipping Containers" [2, 3]. A summary of design and fabrication criteria based on the ASME code is given in Table 3.

Table 3: ASME Design and Fabrication Criteria vs. Package Category

PACKAGE CATEGORY/ FUNCTION	I	II	III
Containment Design [6]	Section III, Sub NB Or Section III, Div 3	Section III, Sub NC	Section III, Sub ND
Containment Fabrication [7]	Section III, Sub NB	Section III, Sub ND	Section VIII, Div 1

As demonstrated by the 3013 drop and burst testing results the units are robust and should be capable of meeting the containment release criteria of 10 CFR 71. However, the units do not meet the fabrication criteria of NUREG 3854 or the welding criteria of NUREG 3019. Hence, it is concluded that a successful argument could not be made for the 3013 as a level of Type B package containment. The containment criteria for the 3013 outer vessel is compared to Type B package containment criteria in Table 4A and Table 4B. Table 4A and Table 4B compares the 3013 with the ASME requirements of NUREG 3854.

Table 4A Comparison of General Requirements in ASME Code, Section III, Division 3 for Transportation and in DOE Standard for Storage

Category	ASME Code Requirements	DOE 3013 Standard	ASME Code Compliance of 3013 Package
General Requirements			
1) Design Basis	Design and operating loads, and load or stress limits (WA-2000)	Internal design pressure is defined in A.6.2.1; Testing criteria are defined in A.6.2.3.	Compliant
2) Responsibility and Duties	Responsibility and duties of design owner and packaging owner (WA-3000)	Not defined.	Compliant
3) Quality Assurance	Quality assurance program (WA-4000)	Quality assurance requirements are not specified.	NQA-1 or compliant
4) Authorized Inspection	Authorized inspection agency and its duties are defined (WA-5000).	Not defined	N/A
5) Certificates, Nameplates, Code Symbol Stamp and Data Reports	Specified in WA-8000	Not specified	N/A

Table 4B: Comparison of Class TP Requirements in ASME Code, Section III, Division 3 for Transportation and in DOE Standard for Storage

Category	ASME Code Requirements	DOE 3013 Standard	ASME Code Compliance of

			3013 Package
Requirements for Class TP (Type B) Containment			
1) Material	Material selection, heat treatment and testing are defined in WB-2000	Requirements are defined in ASME Code, Section VIII.	Compliant
2) Design	Detailed stress and fatigue analyses required for design, normal operating and accident conditions; acceptable criteria and allowable weld types defined in WB-3000.	Detailed stress and fatigue analyses not required in ASME Code, Section VIII, Division 1. Only the required minimum wall thickness' calculated based on design pressures need be met.	Not compliant
3) Fabrication and Installation	Requirements for fabrication and installation are defined in WB-4000.	Requirements are specified in ASME Code, Section VIII. Pressure relief devices are required in accordance code.	Partially compliant. Pressure relief devices can not be installed because contents are radioactive materials. Meets code per definition of pressure system.
4) Examination	Requirements and procedures for non-destructive examination and post-weld heat treatment are defined in WB-5000.	Full radiographic examination are not required in ASME Code, Section VIII for Category C weld (at flat head)	Final weld not fully ASME compliant, everything else is compliant.
5) Testing	Requirements for hydrostatic and leakage tests are defined in WB-6000.	Testing requirements are defined in A.6.2.3.	Hydro test not performed on each vessel.

While the hardware is most probably capable of meeting the regulatory requirements of containment, it falls short of meeting the applicable national codes and standards. It is considered very unlikely that approval of a packaging design that does not meet the applicable codes and standards could be gained for a major shipping campaign. Table 5 lists the changes that would be required in order to bring the 3013 standard into compliance with the applicable national codes and standards.

Table 5: Changes Required to Bring 3013 Package into Compliance with ASME Code, Section III, Division 3 and 10 CFR 71

Category	ASME Code Requirements	Required Changes
Requirements for Class TP (Type B) Containment		
1) Material	Material selection, heat treatment and testing are defined in WB-2000	None
2) Design	Detailed stress and fatigue analyses are required for design, normal operating and accident conditions are required; methodology, acceptable criteria and allowable weld types are defined in WB-3000.	Perform detailed stress and fatigue analyses for both normal operating and hypothetical accident conditions in accordance with the methodology in WB-3000. The containment design adequacy for a 6-inch-diameter puncture bar and a 40-inch-drop must be justified by an analysis or a test.
3) Fabrication and Installation	Requirements for fabrication and installation are defined in WB-4000.	The adequacy of the weld joints should be justified by stress and fatigue analyses and nondestructive examinations.
4) Examination	Requirements and procedures for nondestructive examination and post-weld heat treatment are defined in WB-5000.	Perform nondestructive examination and post-weld heat treatment per WB-5000.
5) Testing	Requirements for hydrostatic and leakage tests are defined in WB-6000.	Perform a 40-in drop test by using a 6-in-diameter puncture bar.

V. DOUBLE CONTAINMENT EXEMPTION

Double containment is required for plutonium contents greater than 20 Ci (10 CFR 71.63). The performance requirements for the additional

inner container during Normal Conditions of Transport and Hypothetical Accident Conditions are identical to those for Type B containment vessels. The regulations detail three forms of plutonium which are exempt from the double containment requirement.

1. Reactor fuel elements
2. Metal or metal alloy
3. Vitrified high level waste contained in a sealed canister designed to maintain waste containment during handling activities associated with transport. The canister can be designed to ASME Boiler and Pressure vessel Code, Section VIII, 1995 ed. The design requirements in Section VIII Parts UG-46, UG-115 through UG-120, UG-125 through UG-136, UW-60, UW-65, UHA-60 and UHA-65 need not be satisfied. In addition the final closure weld need not be designed to Section VIII Parts UG-99 and UW-11.

The 3013 outer and inner vessel configuration has already been approved by DOE for 50 year storage. A credible justification could be made that the 3013 consists of engineered vessels with appropriate quality assurance to allow exemption from double containment. In fact, the 3013 vessels are more robust (structurally) than a typical reactor fuel element. This exemption option should be further considered, and the 3013 testing, design, and ASME code comparison could provide the basis for the justification.

This evaluation was performed several years ago. Since then a revision to 10 CFR 71 has been approved which will include relief of the double containment requirement for other solid forms of plutonium (i.e. oxides).

VI. CONCLUSIONS

Although the 3013 vessels are engineered and quite robust, as demonstrated by testing, they do not satisfy the radioactive material transportation requirements (Type B) for special form or as a containment vessel. The best approach to take credit for the robustness of the 3013 is to ask for an exemption from double containment. The revised 10 CFR 71 effectively eliminates the double containment requirement.

VII. ACKNOWLEDGMENTS

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VIII. REFERENCES

1. DOE-STD-3013-00, "Stabilization, Packaging, and Storage of Plutonium Bearing Materials", September, 2000.

2. US Nuclear Regulatory Commission, "Design Criteria for the Structural Analysis of Shipping Cask Containment Vessels", Regulatory Guide 7.6.

3. US Nuclear Regulatory Commission, "Fabrication Criteria for Shipping Containers", NUREG/CR-3854, March, 1995.