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19 July, 2001

Mr. Dave Tiktinsky
Package Certification Section
Spent Fuel Project Office
US Nuclear Regulatory Commission
11555 Rockville Pike
One White Flint
Rockville, MD 20852

Dear Mr. Tiktinsky:

As a result of re-testing the Model 702 to demonstrate compliance with Normal and Accident Conditions of Transport, it has been determined that no change to the design is needed. We therefore request approval of the Model 702 as a Type B(U)-85 transport container in accordance with 10 CFR 71 and IAEA Safety Series No. TS-R-1. Please find the enclosed copies of the Safety Analysis Report for your review. If you need additional information, please contact me at 781-272-2000 ext. 241.

Sincerely,

Lori Podolak

Lori Podolak, CHP
Product Licensing Specialist
Regulatory Affairs Department

C. Rompton	19 July 01
Regulatory Approval	Date
[signature]	19 Jul 01
Engineering Approval	Date
C. Rompton	19 Jul 01
QA Approval	Date

Enclosures: Revision 4 to SAR
List of Affected Pages
Comparision Document (1992 SAR to Revision 4)

NMSS01 Public

List of Affected Pages	
Revision 4, 19 July, 2001	Revision in entirety. This revision supercedes previously submitted SAR's for the 702.

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The sections of the 1992 and 2001 SARs were not compared line-by-line since, in many instances, this was not possible. Instead, a comparison of ideas, (usually paragraph headings) or key points, were used to summarize differences.

Due to the different format used in 1992, paragraph numbers and headings of the old SAR do not always coincide with the currently accepted paragraph number/heading standard. To try to make this document easier to understand, the following list uses the 2001 SAR paragraph numbers and headings for SAR comparison.

Extra sections in the 1992 SAR have not been considered (i.e. Section 2.5.1, Load Resistance) since they appear to be covered through a test, or a different section.

Section 1 - GENERAL INFORMATION

1.1 Introduction

The 2001 SAR specifies that the package can be used for Type B quantities of Ir-192, Co-60, Se-75, Yb-169, and Cs-137 in special form instead of limiting it to Ir-192 in special form. It also states the 702 meets the requirements of 49 CFR 173 and the latest version of the IAEA Regulations for the Safe Transport of Radioactive Material (TS-R-1).

1.2 Transport Package Description

1.2.1 Description of the Model 702 Transport Package

The 2001 SAR has added reference to a descriptive drawing and split-up the component descriptions into subheadings. The following paragraph changes to the 2001 SAR include;

- Addition of the height of the cask,
- Removing the dimensions of the cooling fins and cask base plate (now contained in the descriptive drawing),
- Removing the thickness of the lid and cask liner,
- Adding reference to the neoprene gasket,
- Changed reference to skid metal from hot rolled steel to carbon steel,
- Removing specifics of the cage's frame and perforated steel cover,
- Removing reference to the aluminum plates for shipping labels,
- Removing reference to seal wire and tamper proof seals, and
- Removing reference to the casks smooth finish for decontamination and the outer packages inability to retain water.
- Called out material for cage bolts as stainless steel (not specified previously)

1.2.2 Operational Features

The 2001 SAR has made the following changes;

- Removed reference to special form source material.
- Added that there is no locking assembly.

1.3 Contents of Packaging

This used to be section 1.2.3 in the 1992 SAR (section 1.3 used to be a listing of drawings in the 1992 SAR) which limited contents to special form Ir-192. The 2001 SAR specifies that the package can be used for Ir-192, Co-60, Se-75, Yb-169, and Cs-137 in special form. In addition, "Curies" has now been defined as output Curies per ANSI N432 and 10 CFR 34.20.

1.4 Containment Boundary

1.4.1 Containment Vessel

This section has been added in the 2001 SAR.

1.5 Drawings

This use to be section 1.3 in the 1992 SAR. The new drawings have been updated to a computer format. A detailed comparison of the drawing changes between R70290 Rev K and 70290 Rev D is contained in Appendix A of this comparison document.

Section 2 - STRUCTURAL EVALUATION

2.1 Structural Design

2.1.1 Overview

This section was called, "Discussion" in the 1992 SAR. Instead of repeating what is in Section 1, it is now referenced.

2.1.2 Design Criteria

This section has remained the same except for updating the references to IAEA TS-R-1.

2.2 Weight and Center of Gravity

In the 1993 revision of the SAR, the maximum package weight was changed to 410 pounds.

The 2001 SAR has:

- Removed the breakdown of the component weights.
- Lowered the device weight from 440 pounds to 410 pounds.
- Though not specifically stated, the 410 pounds includes the weight of the tungsten shield slug used during testing.

2.3 Mechanical Properties of Materials

The 2001 SAR has extended the material property list to contain more data and references. Some values vary from previous quotes due to the use of different references.

2.4 General Standards for All Packages

2.4.1 Minimum Package Size

This is a new Section to the 2001 SAR.

2.4.2 Tamperproof Feature

This is a new Section to the 2001 SAR.

2.4.3 Positive Closure

This used to be section 2.4.2 in the 1992 SAR. The 2001 SAR has added reference to the special form capsule.

2.4.4 Chemical and Galvanic Reactions

This used to be section 2.4.1 in the 1992 SAR. The 2001 SAR has removed the reference of the evaluation of steel-uranium interfaces tests related to the formation of a eutectic as copper separators are used at all steel-uranium interfaces.

2.5 Lifting and Tie-down Standards for All Packages

2.5.1 Lifting Devices

The 1992 SAR (section 2.4.3) treated the base plate (skid) of the 702 as a simple beam, and used slightly different values for its material properties. The 2001 SAR used the same formula, but broke the Section Modulus into its components. Due to differences in the referenced or calculated Section Modulus, a larger maximum stress value was attained in the 2001 SAR.

2.5.2 Tie-down Devices

This was section 2.4.4 in the 1992 SAR. Both 1992 and 2001 SARs state the model 702 has no tie-down system.

2.6 Normal Conditions of Transport

2.6.1 Heat

The 2001 SAR still uses this value as a conservative estimate for gamma heating, but includes the isotopes Ir-192, Co-60, Se-75, Yb-169, and Cs-137.

In the 2001 SAR the heat balance is in this section instead of in Section 3.

2.6.2 Cold

The 2001 SAR changes include;

- Addition of reference to the brittle nature of carbon steel components at low temperatures.
- Addition of reference to successful completion of Type B tests below - 40°F.
- Removal of reference to gasket failure scenario which relies on capsule integrity to meet section requirements.

2.6.3 Reduced External Pressure

The 1992 SAR (revised 1996) relied on actual capsules leak tests performed during production.

The original 1992 SAR calculated lid bolt stresses.

The 2001 SAR, through reference to section 3.5.2, calculates lid bolt stress along with justification of the effect of losing the gasket and its effect on the source capsule.

2.6.4 Increased External Pressure

This section in the 1992 SAR was covered in paragraph 2.5.2.

The 1992 SAR verifies capsule integrity by calculating collapse pressure.

The 2001 SAR verifies capsule integrity by calculating collapse pressure and justifies the Model 702 will maintain its integrity.

2.6.5 Vibration

This section in the 1992 SAR was covered in paragraph 2.6:4. The only change between the 1992 and 2001 SARs is that additional years have passed to support the conclusion that there has never been a failure due to vibration.

2.6.6 Water Spray

This section in the 1992 SAR was covered in paragraph 2.6.5. The 1992 and 2001 SARs are the same, with minor changes in wording.

2.6.7 Free Drop

This section in the 1992 SAR was covered in paragraph 2.6.6. The 1992 SAR relies on the 9m drop results to support its conclusion while the 2001 SAR performed the 4-foot drop test.

2.6.8 Corner drop

This section in the 1992 SAR was covered in paragraph 2.6.7. The 1992 and 2001 SARs are the same, with minor changes in wording.

2.6.9 Compression

The 1992 SAR used a 1,850 pound stacking load while the 2001 SAR used a 2,138 pound load.

A revision to the 1992 SAR (1996 revision) calculated the effects of a 2200 pound load using a simple beam model.

The 2001 SAR also justifies compliance with the second stacking critera in 10 CFR, 49 CFR and IAEA.

2.6.10 Penetration

This section in the 1992 SAR was covered in paragraph 2.6.8. This section has basically remained the same, but now gives no dimensions for damage as in the 1992 SAR.

2.6.11 Summary

This is a new section in the 2001 SAR. It basically states that the 702 passed the Normal Conditions of Transport requirements.

2.7 Hypothetical Accident Conditions of Transport

The old SAR did one 30 foot drop with a 400 pound test specimen. The new SAR performed 3 drops to a maximum weight (410 pound, which is now mentioned in Section 2.2) package to account for the additional weight of the tungsten insert (also mentioned in Section 2.2).

2.7.1 Free Drop

The 2001 SAR changes include:

- Three specimens were dropped instead of one.
- The test specimens were chilled below - 40°F.
- The test specimens were dropped onto a unyielding steel plate instead of pavement.
- Addition of reasons why the drop attitude was chosen.

2.7.2 Puncture

The 2001 SAR changes include:

- Two specimens were dropped instead of one. (The third drop orientation was bounded by the other two specimens tested for puncture.
- The test specimens were chilled below - 40°F.
- Addition of reasons why the drop attitude was chosen.

2.7.3 Crush

This is a new section in the 2001 SAR. This section is not applicable to the 702 based on the package weight.

2.7.4 Thermal

In the 1992 SAR this was section 2.7.3. The 1992 SAR relied on the melting point of the materials for justification. The 2001 SAR relies on recently performed thermal tests and Finite Element Analysis.

2.7.5 Immersion - Fissile Material

In the 1992 SAR this was section 2.7.4. In the 1992 SAR this section was labeled "Water Immersion" and was considered N/A. For the 2001 SAR this section is still N/A since the package is not used for transport of fissile materials.

2.7.6 Immersion - All Packages

In the 1992 SAR this was section 2.7.5. This was a new section for the 2001 SAR, but the same as section 2.5.2 of the 1992 SAR. It relies on a calculated value for the collapse pressure of the capsule.

2.7.7 Summary of Damage

The 1992 SAR had this in section 2.7.5, and gave a general statement that package passed the requirements of the Hypothetical Accident Condition.

(Note: Section 2.10 of the 1992 SAR contained test results and photographs of the drop and puncture tests)

The 2001 SAR gives a tabulated summary of damage.

2.8 Special Form

The 1992 SAR (1996 revision) implies that any special form capsule can be used. The 2001 SAR has added limits to key capsule dimensions.

2.9 Fuel Rods

This section has remained the same.

Section 3 - THERMAL EVALUATION

3.1 Description of Thermal Design Characteristics

This section is titled, "Discussion" in the 1992 SAR. This section has essentially remained the same.

3.2 Summary of Thermal Properties of Materials

The 2001 SAR changes include;

- A new table with additional material properties.
- The addition of tungsten.
- Removal of the minimum operating range of neoprene.
- Addition of references.

3.3 Technical Specifications of Components

This section has remained the same.

3.4 Thermal Evaluation for Normal Conditions of Transport

3.4.1 Thermal Model

The 1992 SAR used calculations and performed measurements to support the result. The 2001 SAR used only calculations.

3.4.2 Maximum Temperatures

The 2001 SAR has added a statement that there will be no loss of shielding or structural integrity.

3.4.3 Minimum Temperatures

The 1992 SAR used a subjective basis for its determination. The 2001 SAR used results from testing.

3.4.4 Maximum Internal Pressures

The 2001 SAR has added a few more words and references to specific SAR sections. Essentially the 1992 and 2001 SARs are the same, relying on calculated values.

3.4.5 Maximum Thermal Stresses

This section has remained the same.

3.4.6 Evaluation of Transport Package Performance for Normal Conditions of Transport

This section has remained the same.

3.5 Thermal Evaluation for Hypothetical Accident Conditions of Transport

3.5.1 Thermal Model

This section has remained the same.

3.5.2 Maximum Internal Pressure

The 1992 SAR had this in section 3.5.4. The calculations used to determine bolt stress has been modified slightly but the results are effectively equivalent to those obtained in the 1992 SAR.

3.5.3 Maximum Thermal Stresses

The 1992 SAR had this in section 3.5.5 and used a subjective basis for its determination. The 2001 SAR references a finite element analysis.

3.5.4 Evaluation of Transport Package Performance for Thermal Test

The 1992 SAR had this in section 3.5.5. The 2001 SAR has;

- Added information about depleted uranium response to high temperatures from other thermal tests.
- Added reference to the results of the finite element analysis.
- Removed reference to the calculated pressures.
- Added a sentence about how the high temperatures would relieve accumulated lid bolt stress.

3.6 Thermal Analysis Details

3.6.1 Surface Temperature Analysis

The 2001 SAR has;

- Added a sentence implying 86 Watts is a conservative value, and accounts for the five specified isotopes.

(Note: The value of 86 Watts is the approximate decay heat for 10,000 Curies of Ir-192)

Isotope	Device Capacity	Heat Generation (Watts)
Co-60	15 Curies	0.3
Cs-137	1,000 Curies	7
Ir-192	10,000 Curies	86
Se-75	10,000 Curies	51
Yb-169	10,000 Curies	54

3.6.2 Model 702 Series Type B(U) Source Capsule Thermal Analysis

The 1992 SAR based its evaluation on package heating effects due to 10,000 Curies of Ir-192 (Sections 3.6.2) and the increase in capsule stresses due to an increase in temperature to 800°C (Sections 3.6.3).

The 2001 SAR;

- Bases compliance with this requirement on the Finite Element Analysis as well as the special form test criteria of the source capsules.
- Removed reference that the capsule content is Ir-192.

Section 4 - CONTAINMENT

4.1 Containment Boundary

4.1.1 Containment Vessel

In 1992 SAR (revised 1996) removed the 849 source capsule as primary containment and replaced it with any Special Form capsule.

The 2001 SAR added the 702 as part of the containment.

4.1.2 Containment Penetrations

This section has remained the same.

4.1.3 Seals and Welds

The 1992 SAR references welds by an approved vender and leak testing of the 849 capsule.

The 2001 SAR references;
- Welding in accordance with the Quality Program and drawing specifications.
- Leak testing of the source per ISO 9978 (1992) or later revisions of this document.

4.1.4 Closure

This is a new section.

4.2 Requirements for Normal Conditions of Transport

4.2.1 Containment of Radioactive Material

The 1992 SAR references the Model 849 capsule. The 2001 SAR references special form capsules.

4.2.2 Pressurization of the Containment Vessel

This section has remained the same.

4.2.3 Containment Criterion

This is a new section in the 2001 SAR (formerly the Coolant Contamination section in the 1992 SAR), which basically states that this package will maintain containment during normal transport conditions.

4.3 Containment Requirements for Hypothetical Accident Conditions

4.3.1 Containment of Radioactive Material

This section is 4.3.2 (Release of Contents) in the 1992 SAR and has essentially remained the same in the 2001 SAR. The only differences are the sections that are referenced (i.e. The 1992 SAR references sections 2.7.1, 2.7.2, and 3.5. The 2001 SAR references sections 2.7 and 3.5.)

4.3.2 Pressurization of the Containment Vessel

This section has added reference to the cask cover bolt in meeting the requirements of this section.

4.3.3 Containment Criterion

This is a new section in the 2001 SAR stating 10 CFR 71.51(a)(1) is met.

4.4 Special Requirements

Not applicable. This includes sections 4.2.3, 4.2.4 and 4.3.1 in the 1992 SAR regarding coolant contamination.

Section 5 - SHIELDING EVALUATION

5.1 Design Features

The 1992 SAR gives a summary of maximum dose rates for 10,000 Curies of Ir-192. The 2001 SAR doesn't give dose rates until Section 5.4.

5.2 Source Specification

5.2.1 Gamma Source

The 2001 SAR references Table 1 in Section 1.3.

5.3 Model Specification

This section was "not applicable" in the 1992 SAR. The 2001 SAR references the use of Microshield verion 5.05 in obtaining loading capacities for the radionuclides other than Ir-192. These results were then confirmed by radiation measurement.

5.4 Shielding Evaluation

The 2001 SAR gives a tabular summary of the radiation profiles in this section while the 1992 SAR gives a radiation profile in section 5.5.1.

Section 6 - CRITICALITY EVALUATION

Not applicable.

Section 7 - Operating Procedure

The 2001 SAR has removed the "Preparation of a Package for Transport" and the "702 Operating Manual" sections as applicable details from the 1992 SAR have been incorporated into sections 7.1-7.3.

7.1 Procedure for Loading the Transport Package

The following changes have been made in the 2001 SAR as compared with the 1993 revision;

- Note: Removed the specific reference to 10,000 Curies of Ir-192.
- Step 1: Added a reference to the use of tungsten inserts when applicable to reduce and/or fix source locations within the cask.
- Step 2: Removed the expected dose rates for a loaded device.
- Step 3: Torque values have been slightly increased for the cover bolts.
- Step 5: The cask-to-skid plate bolts no longer specify carbon steel and stainless steel.
- Step 5: Removed the reference to 605 ±5 inch-pounds.

- Step 6: Removed the reference to the drawing.
- Steps 7 and 8 have been reversed.
- Steps 7 (formerly 8) no longer specifies how much of the rod should penetrate past the weldment.
- Steps 8 (formerly 7) has changed the torque value from 605 ±5 inch-pounds to 370 ±5 inch-pounds.
- Step 9: Added that the wipe test is to be conducted over a 300 cm^2 area.
- Step 9: Changed 0.001 μCi/100 cm^2 to 0.00001 μCi per cm^2.
- Step 10: Changed protective cage bolt torque values from 517 inch-pounds to 370 ±5 inch-pounds.
- Step 11: Changed drawing 70290 to drawing R70290. Changed indication for tamperproof seal to a single bolt instead of two at opposite sides of the cask.
- Step 12: Added the inspection requirement to assure skid sits firmly on the ground and to contact AEA/QSA for repair information.
- Added steps 13 though 16 which is equivalent to the "SHIPMENT OF RADIOACTIVE SOURCE" section in the old SAR.
- Refers to regulations in 10 CFR 171-178 instead of listing any.

7.2 Procedure for Unloading the Transport Package

The 1992 SAR referred back to the specific requirements specified in the users radioactive material license. The detail provided in the 2001 SAR incorporates the general requirements related to the package receipt.

7.3 Preparation of an Empty Transport Package for Transport

This was section 7.4 in the 1992 SAR. The 2001 SAR has:

- Removed the specific reference to 10,000 Curies of Ir-192.
- No longer refers to the loading procedure for securing the cover bolts.
- Refers to the regulations for preparation of a package for transportation (10 CFR 173) instead of listing the steps.

Section 8 - ACCEPTANCE TESTS AND MAINTENANCE PROGRAM

8.1 Acceptance Test

8.1.1 Visual Inspection

The 2001 SAR has:

- Removed reference to inspection of package tolerances.
- Removed reference to source capsule visual inspection and leak tests.
- Removed reference to inspection of welds.
- Added reference to check that all fasteners are installed and secured.
- Added reference to check all labels and markings are present.

8.1.2 Structural and Pressure Tests

Not applicable to either SAR.

8.1.3 Leak Tests

The 2001 SAR has added a reference to ISO 9978 and stated that the capsules are leak tested when manufactured.

8.1.4 Component Tests

Not applicable to either SAR.

8.1.5 Tests for Shielding Integrity

The 2001 SAR removed the reference to a "small detector survey instrument".

8.1.6 Thermal Acceptance Tests

Not applicable to either SAR.

8.2 Maintenance Program

8.2.1 Structural and Pressure Tests

Not applicable to either SAR.

8.2.2 Leak Tests

The 2001 SAR has removed reference to a 6 month leak test, the 0.005 μCi limit, and NRC notification.

8.2.3 Subsystem Maintenance

The 2001 SAR has removed reference to a specific section of the SAR that lists things to check.

8.2.4 Valves, Rupture Discs and Gaskets on Containment Vessel

This section has remained the same.

8.2.5 Shielding

This section has remained the same.

8.2.6 Thermal

Not applicable to either SAR.

8.2.7 Miscellaneous

The 1992 SAR labeled this section as, "SECONDARY USERS", and contains the same information as the 2001 SAR.

APPENDIX A - Detailed Comparison of Drawing Changes Between R70290 Rev K and 70290 Rev D

Drawing Changes from the 1992 SAR for the 702
(SAR Revision 4) 6 Jul 01

R70290, Sheet 1 of 9

1 Torque values for the cover bolts was changed from 517 in lbs to 370 in lbs. This change was made to reflect actual torque values used for these bolts which is based on standard practice guidelines of torquing bolts to 75% of the bolt yield strength. Test plan specimens were torqued to the value listed on these drawings.
2 A notation was added to reference welding reference requirements for all sheets in drawing R70290.
3 Physical dimensions for thè 702 warning label are specified and the material thickness increased from 1/16" to 3/8" steel.
4 Steel type (304) for the cage plate specified.
5 A generic dimensional tolerance of 1/16" is added as well as specific tolerances for applicable dimensions.

R70290, Sheet 2 of 9

1 Material requirements for the hex head bolts, square nut, hex nut, lockwasher and threaded rods limited to stainless steel. (Old drawing allowed steel as an option for these items.)
2 Dimensional specifications for the threaded rods added.
3 Torque values for the cask hold down ring bolts was changed from 605 in lbs to 370 in lbs. This change was made to reflect actual torque values used for these bolts which is based on standard practice guidelines of torquing bolts to 75% of the bolt yield strength. Test plan specimens were torqued to the value listed on these drawings.
4 Torque values for the cask bolts references value for stainless steel only. Value for steel omitted as this material is no longer used on the 702.
5 A generic dimensional tolerance of 1/16" is added.

R70290, Sheet 3 of 9

1 Detailed description of the cask skid has been added giving dimensions not previously specified on the 1992 SAR drawings.
2 Additional detail on bottom foot location on the cask skid.
3 A 1/32" tolerance on skid cask plate added.
4 Additional dimensional details on the skid pads.
5 Material specification for the Danger Label added.
6 Change in material specification for the Warning Plate from unspecified aluminum thickness to 0.03 inch thick stainless steel.
7 Welding notations have been revised to reflect reference standard changes.
8 A generic dimensional tolerance of 1/16" is added as well as specific tolerances for applicable dimensions.
9 Call-out for the skid bottom feet has been slightly modified but old and new specifications are equivalent.

Drawing Changes from the 1992 SAR for the 702
(SAR Revision 4) 6 Jul 01

R70290, Sheet 4 of 9

1 Securing mechanism for the 702 Warning Label is now specified as four, 10-32 machine screws and nuts.
2 Under notations: Locations for tack welds on perforated steel plates is now specified.
3 Additional dimensional specifications for the cage, including tolerances, has been added.
4 Welding notations have been revised to reflect reference standard changes.
5 Clarification of description of frame weldment as 1/8" fillet or 1/8" butt weld as appropriate.
6 A generic dimensional tolerance of 1/16" is added as well as specific tolerances for applicable dimensions.

R70290, Sheet 5 of 9

1 Detailed description of the cask hold down ring has been added giving dimensions not previously specified on the 1992 SAR drawings.
2 Welding notations have been revised to reflect reference standard changes.
3 Added detail on material for top bracket and the hold down ring (previously referenced as "steel" now specified as "hot rolled carbon steel".
4 A generic dimensional tolerance of 1/16" is added as well as specific tolerances for applicable dimensions.

R70290, Sheet 6 of 9

1 Cask drawing now shows seal wire between two bolts.
2 Torque values for the cask lid bolts was changed from 153 in lbs to 236 in lbs. This change was made to reflect actual torque values used for these bolts which is based on standard practice guidelines of torquing bolts to 75% of the bolt yield strength. Test plan specimens were torqued to the value listed on these drawings.
3 Notation for marking of cask serial number added.
4 Material thickness of 3/8" for the lock washers and flat washers was added.
5 Steel grade for bolts as 304 stainless steel added.
6 Specifications for the cask eye bolt added and reference to specific manufacturer's product code/part number deleted.
7 A generic dimensional tolerance of 1/16" is added.

R70290, Sheet 7 of 9

1 Additional cask dimensions or fabrication details added including:
- Fin, depleted uranium shield and top plate chamfers
- Welding specifications for cask inner liner and cask assembly components.
- Dimensional values for inner cask liner and cask cavity
- Material thickness specifications for copper shims.
- Tolerance of ± 5 lbs on depleted uranium shield mass.

- Dimensional specifications for the six cover plate thread holes.
- Cask fin location specifications increased.

2 The 9.38 inch dimension for height of depleted uranium shield corrects an error in the previous drawings. This value was previously specified as 9.63 inches. All shields in previously manufactured 702's were 9.38 inches in height.

3 Added reference to the optional tungsten shielding nest for use within the cask cavity.

4 Welding notations have been revised to reflect reference standard changes.

5 A generic dimensional tolerance of 1/16" is added as well as specific tolerances for applicable dimensions.

R70290, Sheet 8 of 9

1 Additional cask lid dimensions or fabrication details added including:
- Specifications for bolt holes including location details.
- Welding specifications for lid components.
- Dimensional values for lid components.
- Material thickness specifications for copper shims.
- Specifications for eye bolt thread hole in lid.
- Outer diameter for the lid spacer.
- Added mass of the depleted uranium shielding in the lid.

2 Welding notations have been revised to reflect reference standard changes.

3 A generic dimensional tolerance of 0.03 inches is added.

R70290, Sheet 9 of 9

1 New drawing depicting the inner cavity tungsten nest. This nest is optional for use as added shielding for sources contained within the cask and its dimensions may vary to locate and accommodate source capsules within the cask cavity. The maximum physical dimensions for this nest (and the configuration used during the tests specified in 10 CFR 71.73) are shown on the drawing.

Safety Analysis Report

AEA Technology / QSA Inc.

Model 702
Type B(U) - 85
Transport Package

July 2001

Revision 4

Regulatory Approval	Date
Engineering Approval	Date
QA Approval	Date

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AEA Technology QSA, Inc.
Burlington, MA

Safety Analysis Report

AEA Technology / QSA Inc.

Model 702
Type B(U)
Transport Package

July 2001

Revision 4

AEA Technology QSA, Inc.
Burlington, MA

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Contents

List of Figures and Tables

Section 1 - GENERAL INFORMATION

1.1 Introduction

The Model 702 is designed as a transport package and storage container for Type B quantities of special form ^{192}Ir, ^{60}Co, ^{75}Se, ^{169}Yb and ^{137}Cs radioactive material. It conforms to the Type B(U)-85 criteria for packaging in accordance 10 CFR 71, 49 CFR 173, and the IAEA Regulations for the Safe Transport of Radioactive Material (TS-R-1) which were in effect at the time of sign-off of this report.

1.2 Transport Package Description

The Model 702, shown in Figure 1, is constructed in accordance with descriptive drawing R70290 in Appendix A. Its general dimensions are 20 inches (508 mm) high, 21 inches (533 mm) long, and 19 inches (483 mm) wide, and has a maximum weight of 410 lb (186 kg).

1.2.1 Component Description

Figure 2, with the following paragraphs describes the major components of the transport package.

- Shipping Cask: The Special Form source is contained in a shipping cask. The outer shell of the shipping cask is a stainless steel cylinder, 7.5 inches (191 mm) in diameter, and approximately 11 inches (279 mm) tall. Welded to the shell are 24 cooling fins. Inside the outer shell is a depleted uranium (DU) shield. The DU shield has an inner stainless steel liner that is welded at the top to the outer shell. Copper separators are installed around all exposed surfaces of the DU to prevent any stainless steel-uranium interaction.

- Cask Cover Assembly: A cover assembly encloses the top portion of the shipping cask. The cover assembly includes a DU shield encased in a stainless steel shell. The cover assembly flange is anchored to the inner liner of the shipping cask with six 3/8-16 stainless steel bolts. A neoprene rubber gasket is used to seal the cover assembly. Copper separators are installed around all exposed surfaces of the DU to prevent any stainless steel-uranium interaction.

- Skid: The skid consists primarily of 1/4 inch (6.4 mm) thick carbon steel, formed into a flat base with rolled "legs" on two sides of the skid. Plates of 1/4 inch (6.4 mm) and 1 inch (25 mm) thickness are welded to the formed skid to provide a mounting pedestal for the shipping cask. The shipping cask assembly is attached to the skid with four 1/2-13 bolts (stainless steel).

- Cask Hold Down Assembly: The shipping cask is further secured to the skid by a hold down assembly. The assembly consists of four 1/2-13 threaded stainless steel rods that are anchored to the skid through bottom "feet" that are welded to the skid. The other ends of the rods clamp down on a hold down ring that fits on top of the shipping cask and around the cask cover.

- Protective Cage: To further protect personnel handling the transport package, a carbon steel cage is placed over the cask. The protective cage assembly is a frame constructed of square tubing. Perforated steel is attached to the frame. The frame is attached to the skid with four 1/2-13 stainless steel bolts that attach to the skid at tapped holes.

1.2.2 Operational Features

There is no locking assembly on the Model 702 transport package. The source is secured in the shielded position by the cask cover assembly, which is attached to the shipping cask by six 3/8-16 x 7/8 inch long stainless steel bolts. Two of these bolts are seal wired with a tamper indicator seal. In addition, a seal wire is provided on one or more of the bolts that secure the protective cage to the skid.

1.3 Contents of Packaging

The Model 702 transport package is designed to transport special form capsules containing the isotopes listed in Table 1:

Table 1: Isotopes Permitted in the Model 702

Isotope	Output Activity[1]	Capsule Form[2]
Ir-192	10,000 Ci	Special Form
Cs-137	1,000 Ci	Special Form
Se-75	10,000 Ci	Special Form
Yb-169	10,000 Ci	Special Form
Co-60	15 Ci	Special Form

Typically the source capsules are inserted into the transport package's inner cavity and secured in-place by the cask cover assembly. During shipments, an optional tungsten insert may be used to provide additional shielding.

[1] Output Activity is defined as output Curies as required in ANSI N432 and 10 CFR 34.20.
[2] Special Form is defined in 10 CFR 71, 49 CFR 173, and IAEA TS-R-1.

1.4 Containment Boundary

1.4.1 Containment Vessel

The containment system for the Model 702 transport package is the radioactive source capsule referred to in Section 4.1 of this Safety Analysis Report. This source capsule is certified as special form radioactive material under 10 CFR Part 71, 49 CFR Part 173 and IAEA TS-R-1.

1.5 Drawings

A drawing of the Model 702 transport package is provided in Appendix A. A detailed description of drawing changes is also included in Appendix A.

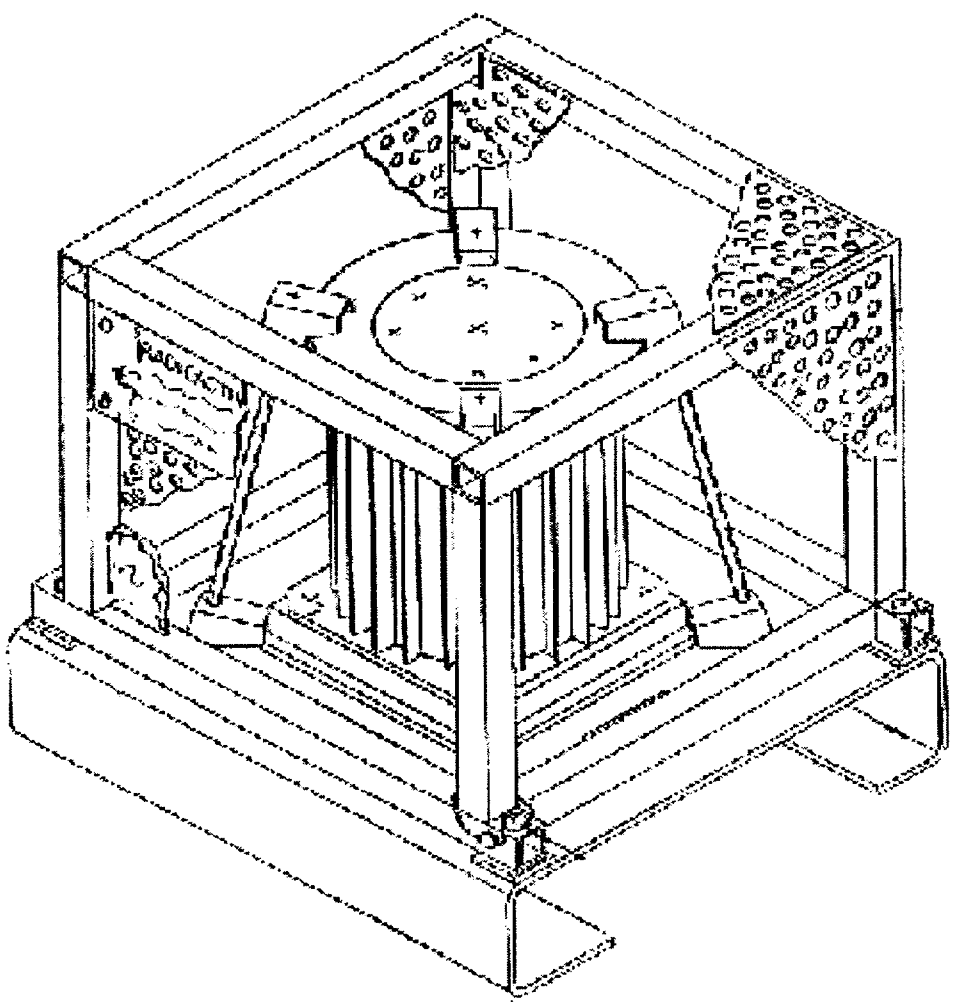

Figure 1: Isometric View of Model 702 Transport Package

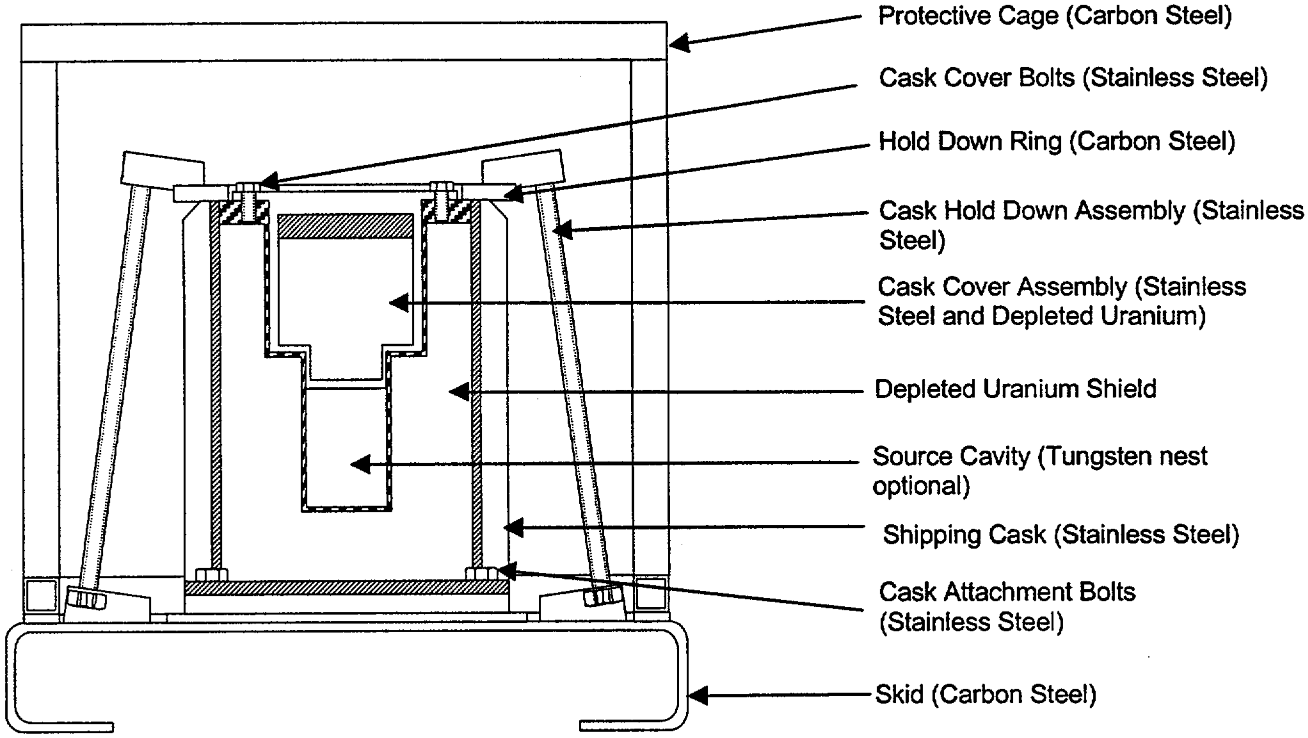

Figure 2: Section of Model 702 Transport Package

Section 2 - STRUCTURAL EVALUATION

This section identifies and describes the principal structural engineering design of the packaging, components, and systems important to safety and compliance with the performance requirements of 10 CFR Part 71.

2.1 Structural Design

2.1.1 Overview

The Model 702 transport package is described in Section 1.2.1, "Description of the Model 702 Transport Package."

2.1.2 Design Criteria

The Model 702 transport package is designed to comply with the requirements for Type B(U) packaging as prescribed by 10 CFR 71 and IAEA TS-R-1. All design criteria are evaluated by a straightforward application of the appropriate section of 10 CFR 71 or IAEA TS-R-1.

2.2 Weight and Center of Gravity

The transport package weighs up to 410 lb (186 kg). The shipping cask weighs approximately 260 lb (118 kg), including about 209 lb (95 kg) ± 5 lb (2.3 kg) of DU shielding. The center of gravity of the 702 transport package is approximately 2 inches (51 mm) above the bottom of the shipping cask.

2.3 Mechanical Properties of Materials

Table 2 lists the relevant mechanical properties (at ambient temperature) of the principal materials used in the Model 702 transport package. The sources referred to in the last column are listed after the table.

Table 2: Mechanical Properties of Principal Transport Package Materials

Material	Tensile Strength	Yield Strength	Source
Depleted Uranium	65 ksi	30 ksi	Reference #2
Copper	25 ksi	9 ksi	Reference #3, p. 224
Carbon Steel (nominal)	53 ksi	36 ksi	Reference #1, p. 205
Stainless Steel	75 ksi	30 ksi	Reference #1, p. 854
Tungsten	142 ksi	109 ksi	www.matweb.com

Resource references:

1. American Society for Metals. Metals Handbook, Volume 1, Tenth Edition. Ohio: Materials Park, 1990.

2. Lowenstein, Paul. *Industrial Uses of Depleted Uranium*. American Society for Metals. Metals Handbook, Volume 3, Ninth Edition.

3. American Society for Metals. Metals Handbook, Volume 2, Tenth Edition. Ohio: Materials Park, 1990.

2.4 General Standards for All Packages

2.4.1 Minimum Package Size

Reference:
- *USNRC, 10 CFR 71.43(a)*
- *USDOT, 49 CFR 173.412(b)*
- *IAEA TS-R-1, paragraph 634*

The transport package exceeds the minimum size requirements since it is 21 inches (533 mm) long, 19 inches (483 mm) wide, and 20 inches (508 mm) high.

2.4.2 Tamperproof Feature

Reference:
- *USNRC, 10 CFR 71.43(b)*
- *USDOT, 49 CFR 173.412(a)*
- *IAEA TS-R-1, paragraph 635*

The Model 702 shipping cask cover is secured with six 3/8-16 stainless steel bolts. Two of these bolts are seal wired with a tamper proof seal. The shipping cask is also enclosed in a protective cage which is bolted to the skid with four bolts (one at each corner). One or more of these bolts are seal wired.

2.4.3 Positive Closure

Reference:
- *USNRC, 10 CFR 71.43(c)*
- *USDOT, 49 CFR 173.412(d)*
- *IAEA TS-R-1, paragraph 639*

The radioactive material is sealed inside a special form capsule(s) placed inside the Model 702 shipping cask, then secured as described in paragraph 2.4.2. These features maintain positive closure of the transport package and containment of the radioactive material during transport.

2.4.4 Chemical and Galvanic Reactions

Reference:
- *USNRC, 10 CFR 71.43(d)*
- *USDOT, 49 CFR 173.410 (g)*
- *IAEA TS-R-1, paragraph 613*

The materials used in the construction of the Model 702 transport package are depleted uranium metal, steel (carbon and stainless), tungsten, and copper. To prevent the possible formation of a eutectic alloy from steel and depleted uranium during the Hypothetical Accident Conditions thermal scenario, defined by 10 CFR 71.73(c)(4), the copper is used as a separator for all steel-uranium interfaces. With this construction there will be no significant chemical or galvanic reaction between package components during normal or hypothetical accident conditions of transport.

2.5 Lifting and Tie-down Standards for All Packages

2.5.1 Lifting Devices

Reference:
- *USNRC, 10 CFR 71.45(a)*
- *USDOT, 49 CFR 173.410 (b)*
- *IAEA TS-R-1, paragraphs 607 and 608*

The Model 702 is designed to be lifted by the skid using a fork lift. For this analysis, the skid is assumed to be a flat, rectangular plate 21 inches (533 mm) long, 19 inches (483 mm) wide, and 0.25 inches (6.4 mm) thick, simply supported along two sides, with a concentrated load at the centerline. The maximum stress on the skid is:

$$\sigma = PLc/4I$$

Where:

P	=	The weight of the transport package (410 lb)
L	=	The length of the skid between supports (19.125 inches)
c	=	Half the thickness of the skid (0.125 inches)
I	=	The bending moment of inertia of the skid (0.0273 inches^4)

Therefore, the stress generated in the skid is 8,975 psi. With a Safety Factor of 3 applied, the maximum stress in the skid is 26,927 psi. This is below the yield strength of the

carbon steel skid, 36,000 psi. Therefore, the lifting device is capable of supporting more than three times the weight of the transport package as required by 10 CFR 71.45(a).

2.5.2 Tie-down Devices

Reference:

- *USNRC, 10 CFR 71.45(b) (1) (2) (3)*
- *USDOT, 49 CFR 173.412 (i)*
- *IAEA TS-R-1, paragraph 636*

The Model 702 has no tie down attachments. The package can be blocked and braced according to standard transportation practices.

2.6 Normal Conditions of Transport

2.6.1 Heat

Reference:

- *USNRC, 10 CFR 71.71(c)(1)*
- *IAEA TS-R-1, paragraph 651 and 637*

The heat source for the Model 702 transport package is 10,000 Curies of Iridium-192, generating approximately 8.6 milliwatts per Curie. This implies up to 86 Watts of energy is absorbed by the package, resulting in a cask wall temperature of 115°F (Section 3.6.1). Accounting for solar heating effects (Section 2.6.1.1), the maximum temperature of the wall was calculated to be 156°F. Since each isotope loaded into the Model 702 (Section 1.3, Table 1) will be less than 10,000 Curies and generate less than 86 Watts as shown in Table 3, it can be assumed that no part of the package will be greater than 156°F or significantly effected by heating effects. In addition, the materials used in the 702 (e.g., stainless steel, tungsten, depleted uranium, carbon steel) will not be significantly affected by 70°C (158°F).

Table 3: Radionuclide Decay Energy

Radionuclide	Package Activity (Ci)	MeV/Decay	Watts/Package
Iridium-192	10,000	1.46	86
Co-60	15	2.82	0.3
Se-75	10,000	0.86	51
Yb-169	10,000	0.91	54
Cs-137	1,000	1.18	7

Resource references:

Table of Isotopes, Volumes I & II, Eighth Edition. John Wiley & Sons, Inc., 1996.

2.6.1.1 Engineering Analysis

This analysis determines the maximum surface temperature produced by solar heating of the transport package surface in accordance with 10 CFR 71.71(c)(1) and Table XI of IAEA TS-R-1

The model consists of taking a steady state heat balance over the surface of the transport package. In order to assure conservatism, the following assumptions are made:

- The transport package is assumed to undergo free convective heat transfer and radiative heat transfer from the top, bottom, and four sides.
- The inside transport package faces are considered perfectly insulated so there is no conduction into the transport package.
- The transport package is approximated as a rectangular box with dimensions the same as the protective cage, 18 inches (457 mm) long, 18 inches (457 mm) wide, and 15 inches (381 mm) high. No heat transfer is assumed to occur at the sides of the skid.
- The surfaces of the transport package are assumed to be solid, although the top and two sides of the cage have holes. The faces are considered to be sufficiently thin so that no temperature gradients exist in the faces.
- The decay heat load (86 Watts) is added to the solar heat input load (See assumptions in Section 3.6.1).
- The emissivity coefficient of the steel transport package is assumed to be 0.8.
- The absorptivity coefficient of the steel transport package is assumed to be 1.0.

The maximum surface temperature is computed using the steady state heat balance relationship; heat input (Q_{in}) equals heat output (Q_{out}).

$$Q_{in} = Q_{out}$$

Heat Input:

The solar heat input is the combined solar heating of the top horizontal surface and four vertical side surfaces. The insolation data, provided in 10 CFR 71.71(c)(1), is found below in Table 2.

Table 2: Insolation Data

Surface	Insolation for a 12 hour period ($g\text{-}cal/cm^2$ or W/m^2)
Horizontal base	None
Other horizontal flat surfaces	800
Non-horizontal flat surfaces	200
Curved surfaces	400

Top surface heat input: $Q_{IT} = 800\ W/m^2 \times 0.209\ m^2 = 167\ W$

Side surface heat input: $Q_{IS} = 200\ W/m^2 \times 0.697\ m^2 = 139\ W$

Decay heat input: $Q_{DT} = 86\ W$

Absorptivity coefficient: $\forall = 1.0$

The total heat input is the sum of the solar heat input multiplied by the absorptive constant ($\forall$) for the material plus the decay heat input.

Total heat input: $Q_{IN} = \forall\ (Q_{IT} + Q_{IS}) + Q_{DT} = 392\ W$

Heat Output:

The total heat output is the sum of the radiation and convection heat transfer (Reference: Fundamentals of Heat and Mass Transfer, F. P. Incropera, 4th Edition, 1996, p. 9-10).

Radiation heat transfer: $Q_R = B\ E\ A_{TS}\ \{(T_W + 273)^4 - (T_A + 273)^4\}$

Where:

B	=	$5.67 \times 10^{-8}\ W/m^2\ K^4$ (Stefan-Boltzmann Constant)
E	=	0.8 (Emissivity)
A_{TS}	=	$1.115\ m^2$ (top, bottom and side surface area)
T_W	=	The maximum surface temperature of the package (°C)
T_A	=	38°C (ambient temperature, per 10 CFR 71.71(c)(1))

Therefore:

$$Q_R = 5.06 \times 10^{-8}\{(T_W + 273)^4 - (311)^4\} \quad \text{(Equation 1)}$$

Top surface convection: $Q_T = H_T A_T (T_W - T_A)$ (Equation 2)

Where:

A_T	=	0.209 m^2 (the top surface area)
H_T	=	The free convection coefficient for a flat horizontal surface

For a heated plate facing up, the free convection coefficient for laminar flows is (Reference: Fundamentals of Heat and Mass Transfer, F. P. Incropera, 4th Edition, 1996, Ch. 9).

$$H_T = 0.54 [(g \beta (T_W - T_A) L^3) / (\nu \alpha)]^{1/4} (K / L)$$

Where:

g	=	9.8 m/s^2
β	=	0.00303 ($1/T_{avg}$ assuming that T_{avg} = 330°K)
L	=	0.114 m (Area / Perimeter)
ν	=	18.9 x 10^{-6} m^2/s
α	=	26.9 x 10^{-6} m^2/s
K	=	28.52 x 10^{-3} W/mK

Therefore:

$$H_T = 2.32 (T_W - 38)^{0.25}$$

Substituting into Equation 2:

$$Q_T = 0.485 (T_W - 38)^{1.25}$$ (Equation 3)

Side surface convection: $Q_S = H_S A_S (T_W - T_A)$ (Equation 4)

Where:

A_S	=	0.697 m^2 (the total surface area of sides)
H_S	=	The free convection coefficient for a flat vertical surface

For a vertical plate, the free convection coefficient for laminar flows is (Reference: Fundamentals of Heat and Mass Transfer, F. P. Incropera, 4th Edition, 1996, Ch. 9).

$$H_S = [0.68+0.67\{g\beta(T_W-T_A)L^3/\nu\alpha\}^{1/4}/\{1+(0.492/\nu/\alpha)^{9/16}\}^{4/9}](K/L)$$

Where:

L	=	0.104 m (Area / Perimeter)

Therefore:

$$H_S = 0.186 + 2.26\ (T_W - 38)^{0.25}$$

Substituting into Equation 4:

$$Q_S = 0.130\ (T_W - 38) + 1.58\ (T_W - 38)^{1.25} \qquad \text{(Equation 5)}$$

Bottom surface convection: $Q_B = H_B\ A_B\ (T_W - T_A)$ (Equation 6)

Where:

A_B = 0.209 m^2 (the bottom surface area)
H_B = The free convection coefficient for a flat horizontal surface

For a heated plate facing down, the free convection coefficient for laminar flows is (Reference: Fundamentals of Heat and Mass Transfer, F. P. Incropera, 4th Edition, 1996, Ch. 9).

$$H_B = 0.27\ [(g\ \beta\ (T_W - T_A)\ L^3) / (\nu\ \alpha)]^{1/4}\ (K / L)$$

Where:

L = 0.114 m (Area / Perimeter)

Therefore:

$$H_B = 1.16\ (T_W - 38)^{0.25}$$

Substituting into Equation 6:

$$Q_B = 0.242\ (T_W - 38)^{1.25} \qquad \text{(Equation 7)}$$

Total heat output: $Q_{OUT} = Q_R + Q_T + Q_S + Q_B$

Total heat input: $Q_{IN} = Q_R + Q_T + Q_S + Q_B = 392$ W

Substituting for Q_R from Equation 1, Q_T from Equation 3, Q_S from Equation 5, and Q_B from Equation 7:

$$392 \text{ Watts} = 5.06 \times 10^{-8}\ \{(T_W + 273)^4 - (311)^4\} + 0.485\ (T_W - 38)^{1.25} + 0.130\ (T_W - 38) + 1.58\ (T_W - 38)^{1.25} + 0.242\ (T_W - 38)^{1.25}$$

Iteration of this relationship yields a maximum wall temperature (T_W) of 69°C (156°F).

This temperature would not adversely affect the transport package during normal transport since the melting temperatures of all safety critical components are well above this temperature. It its therefore concluded that the Model 702 transport package will maintain its structural integrity and shielding effectiveness under the normal transport heat condition.

2.6.2 Cold

Reference:

- *USNRC, 10 CFR 71.71 (c)(2)*
- *IAEA TS-R-1, paragraph 637*

The carbon steel components of the Model 702 transport package are susceptible to brittle fracture at low temperature. The transport package, however, successfully met Type B(U)-85 Transport Tests requirements at temperatures below -40°C (-40°F), the minimum specified in the regulations. Thus, it is concluded that the Model 702 transport package will withstand the normal transport cold condition.

2.6.3 Reduced External Pressure

Reference:

- *USNRC, 10 CFR 71.71 (c)(3)*
- *USDOT, 49 CFR 173.412(f)*
- *IAEA TS-R-1, paragraph 643*

The Model 702 transport package includes a Neoprene gasket between the cask body and the cask cover. If the gasket remains intact, Section 3.5.2, "Maximum Internal Pressure" demonstrates that the cask cover bolts will withstand an external pressure reduction of at least 54 psi. If the gasket fails under this pressure, the Model 702 will no longer be a sealed unit. Thus, there will be no differential pressure acting on it. Therefore, the reduced external pressure requirements of 3.5 psi in 10 CFR, 3.6 psi in 49 CFR and 8.7 psi (60 kPa) in IAEA are met.

2.6.4 Increased External Pressure

Reference:

- *USNRC, 10 CFR 71.71(c)(4)*

If the Neoprene gasket remains intact, the package would be subjected to a differential pressure between the 2.26 inch (57.4 mm) diameter source cavity and the cask (7.5 inch (191 mm) outer diameter) of 5.3 psig. The cask will withstand this pressure without loss of structural integrity.

If the gasket fails under the required pressure increase of 20 psi, the Model 702 will no longer be a sealed unit and the pressure will be felt on the source capsule. Section 2.7.6 calculates the collapse pressure of the capsule to be 2,186 psi, satisfying this requirement.

2.6.5 Vibration

Reference:

- *USNRC, 10 CFR 71.71(c)(5)*
- *USDOT, 49 CFR 173.410(f)*
- *IAEA TS-R-1, paragraph 612*

In the 20 years that the Model 702 transport package has been in use, no transport packages have failed due to vibration. It is therefore concluded that the Model 702 will withstand vibration normally incident to transport.

2.6.6 Water Spray

Reference:

- *USNRC, 10 CFR 71.71(c)(6)*
- *USDOT, 49 CFR 173.465(b)*
- *IAEA TS-R-1, paragraph 721*

The Model 702 transport packages are constructed of water-resistant materials throughout. Therefore, the water spray test would not reduce the shielding effectiveness or structural integrity of the package.

2.6.7 Free Drop

Reference:

- *USNRC, 10 CFR 71.71(c)(7)*
- *USDOT, 49 CFR 173.465(c)*
- *IAEA TS-R-1, paragraph 722*

Test specimen TP81(A) was subjected to the 1.2 meter (4 foot) free drop in accordance with Test Plan 81 (Appendix B). The orientation of the 1.2 meter (4 foot) free drop was selected because of its potential to cause significant deformation of the carbon steel protective cage and to put significant loads on the cask hold down assembly. The specimen was dropped at about a 45° angle onto the top long edge of the protective cage. The test specimen temperature was less than -40°C (-40°F). Photographs of the drop orientation are provided in Appendix D of the Test Plan 81 Report (Appendix C).

There was damage to both the cage and the cask hold down assembly. Specifically, the cage perforated plate buckled on the sides, the top of the cage was displaced horizontally about 1/2 inch, and the hold down ring fractured and a 30 degree section of the ring

(along with one of the top brackets) broke off. However, the Model 702 shipping cask maintained its structural integrity and shielding effectiveness, and the cask remained secured to the skid, within the protective cage.

2.6.8 Corner drop

Reference:
- *USNRC, 10 CFR 71.71(c)(8)*
- *USDOT, 49 CFR 173.465(c)(3)*
- *IAEA TS-R-1, paragraph 722(b)*

This test is not applicable, as the transport package does not transport fissile material, nor is the exterior of the transport package made from either fiberboard or wood.

2.6.9 Compression

Reference:
- *USNRC, 10 CFR 71.71(c)(9)*
- *USDOT, 49 CFR 173.465(d)*
- *IAEA TS-R-1, paragraph 723*

The Test Plan 81 Report (Appendix C) documents that the Model 702 transport package maintained its structural integrity and shielding effectiveness under the Normal Conditions of Transport compression test. The TP81(A) test specimen was subjected to a compressive load of 2,138 lb (970 kg) for a period of 24 hours, which exceeds five times the maximum transport package weight of 410 lb (186 kg). This weight is also greater than 13 kPa (2 lb/in^2) multiplied by the surface area of the transport package. Following the test, no damage to the specimen was observed.

2.6.10 Penetration

Reference:
- *USNRC, 10 CFR 71.71(c)(10)*
- *USDOT, 49 CFR 173.465(e)*
- *IAEA TS-R-1, paragraph 724*

Test specimen TP81(A) was subjected to a penetration test, in accordance with Test Plan 81 (Appendix B). The TP81(A) test specimen was impacted by a penetration bar on the top center of the protective cage with the intention of puncturing the cage. Inspection following the test indicated that the bar hit as intended on the specimen, and dented and partially broke the perforated plate at the point of impact. There was no loss of structural integrity or reduction of shielding efficiency as a result of the impact.

2.6.11 Summary

Based on the above assessments and physical tests, it is concluded that the Model 702 transport package meets the Normal Conditions of Transport requirements. There was no loss or dispersal of the radioactive contents, no significant increase in radiation levels, and no decrease in the effectiveness of the transport package.

2.7 Hypothetical Accident Conditions of Transport

Sections 2.7.1 through 2.7.5 summarize evaluations and testing for the hypothetical accident conditions of transport tests. Section 2.7.6 summarizes the results of this testing.

Three test specimens were used to conduct the hypothetical accident tests. Each test specimen consisted of a separate cage/skid and hold down assembly. However, the same cask was used in all three test specimens. In addition, the cage/skid assembly subjected to the Normal Conditions of Transport Testing (Test Specimen TP81(A)), was also subjected to the Hypothetical Accident tests.

2.7.1 Free Drop

Reference:
- *USNRC, 10 CFR 71.73(c)(1)*
- *IAEA TS-R-1, paragraph 727(a)*

Three test specimens were subjected to the 9 meter (30 foot) free drop in accordance with Test Plan 81 (Appendix B). All tests were conducted with the test specimen temperatures at or below -40°C (-40°F). Three different orientations were used, as described below. Photographs of the drop orientations are provided in Appendix D of the Test Plan 81 Report (Appendix C).

- Horizontal Short-Side Down: The intent of the test was to apply the maximum moment to the hold down lower brackets and the cask-to-skid bolts, and to determine if (1) impact could cause buckling and/or brittle failure of the carbon steel protective cage structure, and (2) detachment of the cask from the skid could occur due to thread failure of the tapped holes in the skid and brittle failure of the hold down assembly lower brackets, which are welded to the skid. (Test Specimen TP81(C))

- Top Long Edge Down: The intent of the test was to determine if (1) impact could cause deformation of the carbon steel protective cage, and (2) detachment of the cask from the skid could occur due to thread failure of the tapped holes in the skid and brittle failure of the hold down assembly lower brackets, which are welded to the skid. (Test Specimen TP81(B))

- Vertical Top Down: The intent of the test was to apply the maximum tensile load to the cask cover bolts and inner liner weld and to determine if (1) the cask cover could separate from the shipping cask, (2) the impact could cause buckling and/or brittle failure of the carbon steel protective cage structure, and (3) detachment of the cask from the skid could occur due to thread failure of the tapped holes in the skid and brittle failure of the hold down assembly lower brackets, which are welded to the skid. (Test Specimen TP81(A))

The test results are summarized below:

- Test Specimen TP81(C) impacted as intended. Both legs of the skid fractured. All four cask-to-skid bolts sheared off and all four lower brackets of the hold down assembly fractured, which freed the cask and allowed the hold down ring to strike the impact surface. The hold down ring transferred the side impact load into the top edge (0.25 inch (6.4 mm) plate) of the cask cover. The top plate deflected slightly along a chord perpendicular to the impact point, and through the closest cask cover bolt hole. The deflection pried off the head of the closest bolt. The cask cover remained secured by the other 5 cask cover bolts, and the dummy sources remained secured within the cask.

- Test Specimen TP81(B) impacted as intended. The impact deflected the top of the cage frame horizontally about 4 inches. The perforated plates on both sides of the cage detached. The skid buckled slightly. Two of the four lower brackets (those opposite the impact edge) broke. Two of the four top brackets (those next to the impact edge) also failed. Frame welds on the top edge failed and the tube steel dented due to the impact from the two top brackets. The cask remained secured to the skid via the four cask-to-skid bolts. There was no damage to the cask, and the cask cover remained secured in place.

- Test Specimen TP81(A) impacted as intended. The skid fractured and the cask and square plate welded to the skid tore away from the rest of the skid. Three hold down ring brackets broke off (the fourth bracket had previously failed in the 1.2 meter drop test of specimen TP81(A)). The cask struck the impact surface, as evidenced by an impact mark on the head of one of the cask cover bolts. However, the cask cover remained securely in place.

2.7.2 Puncture

Reference:
- *USNRC, 10 CFR 71.73(c)(3)*
- *IAEA TS-R-1, paragraph 727(b)*

Following the 9 meter (30 foot) free drop, the test specimens were subjected to the puncture test, in accordance with Test Plan 81 (Appendix B). All drops were conducted

with the test specimens at or below -40°C (-40°F). The drop orientation for each test specimen was selected based on an assessment following the 9 meter (30 foot) drop tests of which orientation would impart the most damage to the specimen. Photographs of the drop orientations are provided in Appendix D of the Test Plan 81 Report (Appendix C).

- Test Specimen TP81(C): As noted above, in the 9 meter (30 foot) free drop of TP81(C), the cask broke free of the skid but was retained within the cage. For the puncture drop, the specimen was dropped in the same orientation as in the 9 meter (30 foot) drop, i.e., cage horizontal, short-side down. The puncture bar was intended to strike the cask cover through the perforated plate where the hold down ring had struck the impact surface in the 9 meter (30 foot) free drop.

- Test Specimen TP81(A): As noted above, in the 9 meter (30 foot) free drop of TP81(A), the cask and a portion of the skid broke free from the cage/skid assembly. For the puncture drop, the cask, bolted to the portion of the skid that remained, was dropped without the cage. The cask was dropped at a 15 to 20 degree angle off vertical, directly onto the puncture bar, to put the cask center of gravity over the bolt that had been dented during the 9 meter (30 foot) drop test.

- Test Specimen TP81(B): Since the cask remained secured to the skid in the 9 meter (30 foot) drop of Test Specimen TP81(B), and the same cask was used for all drop tests, the puncture tests performed on Test Specimens TP81(C) and TP81(A) are considered to bound any drop which could be performed on Test Specimen TP81(B). Accordingly, Test Specimen TP81(B) was not subjected to a separate puncture bar drop.

The test results are summarized below:

- Test Specimen TP81(C) impacted on its side, and the puncture billet impacted the side of the perforated plate, as intended. The impact caused further degradation of the skid and cage. One of the skid legs broke off, the puncture bar tore through the perforated plate at the point of impact, and the bottom tube of the cage frame broke. One of the cask cooling fins was slightly bent, but there was no additional damage to the cask or cask cover bolts.

- For Test Specimen TP81(A), the cask struck the puncture bar on the previously impacted cask cover bolt, as intended. The bolt was dented further, but remained secure. There was no additional damage to the cask or the other cask cover bolts.

2.7.3 Crush

Reference:
- *USNRC, 10 CFR 71.73(c)(2)*
- *IAEA TS-R-1, paragraph 727(c)*

Not applicable.

2.7.4 Thermal

Reference:
- *USNRC, 10 CFR 71.73(c)(4)*
- *IAEA TS-R-1, paragraph 728*

Because no damage occurred during the Hypothetical Accident Conditions of Transport Tests that could result in oxidation of the DU shield, thermal testing was not performed on any of the 702 test specimens. Specifically, the cask cover was secured to the cask and there were no openings in the cask that could result in oxidation of the DU shield.

A finite element analysis (FEA) was performed to evaluate the 702's performance under stress of the thermal test since the cask containment was not breached during the other destructive pre-testing. A copy of this FEA is included as Appendix D. Results of this analysis showed the ability of the 702 package to hold the depleted uranium shields in place around the source cavity and prevent the uranium from being exposed to a high temperature oxidizing environment. The 702 is determined to pass the requirements of the hypothetical accident thermal event.

2.7.5 Immersion - Fissile Material

Reference:
- *USNRC, 10 CFR 71.73 (c)(5)*
- *IAEA TS-R-1, paragraphs 731-733*

Not applicable.

2.7.6 Immersion - All Packages

Reference:
- *USNRC, 10 CFR 71.73 (c)(6)*
- *IAEA TS-R-1, paragraph 730*

If the Neoprene cask cover gasket remains intact, the package would be subjected to an increased external pressure of 21.7 psig (10 CFR) and 290 psi (IAEA). The cask will withstand this pressure without loss of structural integrity.

If the gasket fails, the cylindrical special form source (primary containment) will be vulnerable to collapse due to the required assumed pressure increases of 21.7 psig and 290 psi for the respective regulatory references. The source capsules are fabricated from Type 304 or 310 stainless steel. This analysis bounds any special form source capsule with a maximum inside diameter of 0.195 inch (4.95 mm) and a minimum wall thickness and weld penetration of 0.02 inch (0.508 mm). From Reference 1, the external collapsing pressure for a thin walled cylinder is:

$$P_{collapse} = (t / R)(\sigma_y / (1 + (4\sigma_y / E)(R / t)^2))$$

Where:

t	=	0.02 in (Weld Thickness)
R	=	0.195 in (Inside Radius)
σ_y	=	30,000 psi (Yield Strength) (Table 1)
E	=	28,000 ksi (Young's Modulus) (Reference 2)

From this relationship, the minimum collapsing pressure of the source capsule is 2,186 psi, which exceeds the required external pressure.

Resource references:

1. Young, Warren C. Roark's Formulas for Stress & Strain, Sixth Edition. McGraw-Hill: New York, 1989, p. 634.

2. Hibbeler, R.C. Mechanics of Materials. 2nd Edition, 1991.

2.7.7 Summary of Damage

Table 3 summarizes the results of the Normal Conditions of Transport and Hypothetical Accident testing performed on the Model 702, in the sequence that the tests were completed.

Table 3: Summary of Damages During Performance of TP81

Specimen	Test Performed	Test Results
TP81(A)	Compression test	No damage
	1 meter (40 inch) penetration bar on top, center of cage	Cage perforated plate dented in and partially broken. No other damage.

Specimen	Test Performed	Test Results
	1.2 meter (4 foot) drop, top, long edge down	• Hold down ring, 30° section, and 1 bracket broken • Cage frame displaced about ¼ inch • Perforated plate buckled on sides • Skid cracked • Cask and cage still secured to skid
	Post-Drop Inspection	• Cask cover secure • No change in radiation profile
TP81(C)	9 meter (30 foot) drop, horizontal, short-side down	• Brittle fracture of both legs of skid • All 4 cask-to-skid bolts sheared off • All 4 lower brackets fractured, so cask was free within the cage • 1 of 6 cask cover bolts failed (bolt head pried off due to local buckling of cask cover) • Cask cover locally buckled near broken cover bolt • Perforated plate torn along impacted edge
	1 meter (40 inch) puncture, horizontal, short-side down (puncture bar positioned directly under tear in perforated plate)	• Broke off one leg of skid • Puncture bar tore through perforated plate • Bottom tube of cage frame broken • Slight bend on one cask fin
	Post-Drop Inspection	• Cask cover still secured by remaining 5 bolts
TP81(B)	9 meter (30 foot) drop, top, long edge down	• 3.75 inch to 4 inch deflection of cage frame • Perforated plate detached on both sides of cage • Some buckling of skid • 2 of 4 hold down ring brackets (next to impact edge) failed • 2 cage frame welds on top edge failed • Tube steel dented by impact from 2 hold down ring brackets • 2 of 4 hold down base brackets (opposite impact edge) broke
	1 meter (40 inch) puncture test not performed for this cage/skid because potential damage to cask was bounded by puncture tests using cask with cage/skid assemblies TP81(C) and TP81(A)	n/a

Specimen	Test Performed	Test Results
	Post-Drop Inspection	• Cask remained secured to skid via 4 cask-to-skid bolts • Cask cover remained secured
TP81(A)	9 meter (30 foot) drop, vertical, top down	• Brittle fracture of skid • Cask and square plate welded to skid tore away from rest of skid • 3 hold down ring brackets failed (4th had broken in 1.2 meter (4 foot) drop test) • Cask struck impact surface, which dented head of 1 cask cover bolt • Cask fin ends dented
	1 meter (40 inch) puncture, cask attached to portion of skid, dropped upside down, 10° to 15° off vertical onto dented cask cover bolt	Bolt was further dented, but remained secure.
	Post-Drop Inspection	• Cask remained secured (after 3rd 30 foot drop and 2 puncture tests) • Small change in radiation profile

The same shipping cask was used in all three test specimen. In the course of testing, the single cask was conservatively subjected to all the Normal Conditions of Transport Tests, three 9 meter (30 foot) drop tests, and two puncture tests without loss of structural integrity or shielding effectiveness.

Based on these results, it is concluded that the Model 702 transport package maintains structural integrity and shielding effectiveness during Hypothetical Accident Conditions and Normal Conditions of Transport.

2.8 Special Form

The Model 702 transport package is designed for use with a special form source capsule with an inside radius ≤ 0.195 inches and a wall thickness or weld penetration ≥ 0.02 inches. The source capsule must qualified as Special Form radioactive material.

2.9 Fuel Rods

Not applicable.

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Section 3 - THERMAL EVALUATION

3.1 Description of Thermal Design Characteristics

The Model 702 transport package is a completely passive thermal device having no mechanical cooling system or relief valves. All cooling of the transport package is through free convection and radiation. The maximum heat source is 10,000 Curies of Iridium-192. The corresponding decay heat generation rate is approximately 86 Watts (See Section 2.6.1, "Heat").

3.2 Summary of Thermal Properties of Materials

Table 4 lists the relevant thermal properties of the important materials in the transport package. The sources referred to in the last column are listed below the table.

Table 4: Thermal Properties of Principal Transport Package Materials

Material	Density (lb/in^3)	Melting/Combustion Temperature	Thermal Expansion	Source
Depleted Uranium	0.68	1,130°C (2,066°F)	8μin/in°F	Reference #1, p. 6-11 and Reference #2
Copper	0.32	1,082°C (1,980°F)	9.2μin/in°F	Reference #1, p. 6-7 and 6-11
Carbon Steel (nominal)	0.28	1,510°C (2,750°F)	6.3μin/in°F	Reference #1, p. 6-7 and 6-11
Stainless Steel-Type 304	0.29	1,427°C (2,600°F)	9.9μin/in°F	Reference #1, p. 6-11
Tungsten	0.70	3,370°C (6,098°F)	2.4μin/in°F	Reference #1, p. 6-51
Neoprene	0.044	120°C (248°F)	--	Reference #3, Table 3.1

Resource references:

1. Eugene A. Avallone and Theodore Baumeister III, *Mark's Standard Handbook for Mechanical Engineers, Tenth Edition,* New York: McGraw-Hill, 1996.

2. Lowenstein, Paul. *Industrial Uses of Depleted Uranium*. American Society for Metals. Metals Handbook, Volume 3, Ninth Edition.

3. Smith, L. P., The Language of Rubber: An Introduction to the Specification and Testing of Elastomers," Oxford: Butterworth-Heinemann, 1993.

3.3 Technical Specifications of Components

Not applicable.

3.4 Thermal Evaluation for Normal Conditions of Transport

3.4.1 Thermal Model

Three thermal conditions are evaluated. Two thermal conditions are evaluated using analytical models, and the third condition is evaluated by testing.

The heat analysis in Section 2.6.1.1, "Engineering Analysis" demonstrated that under the conditions described in 10 CFR 71.71(c)(1) the surface temperature of the transport container will be approximately 69°C (156°F). At this temperature, the neoprene gasket may begin to suffer a reduction in effectiveness. However, failure of the neoprene gasket will not result in a release of radioactive contents because the special from source capsules are the primary containment. The surface temperature analysis in Section 3.6.1, "Surface Temperature Analysis" will demonstrate that there will be no degradation of packaging or shielding effectiveness at the maximum ambient temperature of 38°C (100°F) specified in 10 CFR 71.43(g).

Testing of the Model 702 transport package under Test Plan 81 (Appendix B) demonstrated that there is no degradation of packaging or shielding effectiveness at the minimum temperature of -40°C (-40°F), specified in 10 CFR 71.71(c)(2) for cold condition evaluation.

3.4.2 Maximum Temperatures

The maximum temperatures encountered under Normal Conditions of Transport will have no adverse effect on the structural integrity or shielding efficiency of the transport package.

As shown in Section 3.6.1, "Surface Temperature Analysis" the maximum surface temperature does not exceed 46°C (115°F) with the transport package in the shade (i.e., no insolation effects) and at an ambient temperature of 38°C (100°F). The transport package meets the requirements of 10 CFR 71.43(g).

The maximum surface temperature when insolation effects are considered (and ambient temperature is 38°C) is 69°C (156°F), as described in Section 2.6.1.1, "Engineering Analysis."

A review of the thermal properties of the materials used in the construction of the Model 702 transport packages (Table 4) shows that there will be no reduction in structural integrity or loss of shielding of the transport package due to maximum Normal Conditions of Transport temperatures.

3.4.3 Minimum Temperatures

Test Plan 81 (Appendix B) tested the Model 702 transport package at or below -40°C (-40°F) to evaluate the possibility of brittle fracture of the carbon steel components during Normal Conditions of Transport. As shown in the Test Plan 81 Report (Appendix C), the transport package can withstand Normal Conditions of Transport at minimum temperature, while maintaining its structural integrity and shielding efficiency.

3.4.4 Maximum Internal Pressures

Normal operating conditions will generate negligible internal pressures within the transport package. Any pressure generated under Normal Conditions of Transport is bounded by the pressure generated during the Hypothetical Thermal Accident, which are shown to be acceptable in Section 3.5.2, "Maximum Internal Pressure."

Any pressure within the Special Form source during Normal Transport Conditions is bounded by the internal pressure seen during Hypothetical Accident Conditions which are shown in Section 3.6.2, "Model 702 Series Type B(U) Source Capsule Thermal Analysis" to result in no loss of structural integrity or containment.

3.4.5 Maximum Thermal Stresses

The maximum temperature of the transport package during normal transport (69°C, 156°F) is low enough to ensure that thermal gradients will not result in significant thermal stresses.

3.4.6 Evaluation of Transport Package Performance for Normal Conditions of Transport

The thermal conditions of normal transport will have no adverse effect on the structural integrity or shielding efficiency of the transport package. The applicable conditions of IAEA TS-R-1 for Type B(U) Packages have been shown to be satisfied by the Model 702.

3.5 Thermal Evaluation for Hypothetical Accident Conditions of Transport

3.5.1 Thermal Model

The Model 702, including the special form capsule, is assumed to reach the thermal test temperature of 800°C (1,472°F). At this temperature the Neoprene gasket will have

melted and charred. The resulting gases will have escaped the transport package through the space left by the melted gasket.

3.5.2 Maximum Internal Pressure

The Model 702 shipping cask is airtight when the Neoprene gasket is intact. Neoprene will melt and/or decompose well below 800°C, and any internal gases will vent to the atmosphere.

If the gasket does not melt, the maximum internal pressure can be found by assuming that the internal temperature will reach 800°C (1,472°F) under the thermal test conditions. Using the ideal gas law and requiring the air to occupy a constant volume, the internal air pressure could reach 54 psi.

The maximum stress would occur in the six 3/8-16 bolts securing the cask cover. The maximum stress is given by:

$$\sigma = F/A$$

Where:

F = The internal air pressure (54 psi)

A = The area of the inside closure $\left(4\,\text{in}^2 = \pi \cdot \frac{(2.26\,\text{in})^2}{4}\right)$

(Reference: Drawing No. 70290, Sheet 7 of 9, "Model 702 Isotope Shipping Container Descriptive Assembly," Revision K)

$$F = (A)(\text{Pressure})$$

Therefore the force on all 6 bolts is (54 psi)(4 in^2) - 216 lbs. The stress area of the 3/8-16 bolt is 0.0775 in^2. Multiplying this by 6 (number of cask bolts) gives a total stress area of the bolts as 0.465 in^2. Therefore, the maximum stress on each bolt is 216 lbs/0.465 in^2 = 465 psi. At a temperature of 870°C (1,600°F), the yield strength of type 304 stainless steel is 10,000 psi (Reference: Department of Defense Aerospace Structural Metals Handbook, Metals and Ceramics Information Center, Battelle, 1991 Edition). Thus, the maximum stress in the bolts is 5% of their yield strength.

If the gasket melts (leaks) as expected, Section 3.6.2, "Model 702 Series Type B(U) Source Capsule Thermal Analysis" provides an analysis of the source capsule, which serves as the primary containment, under the thermal test conditions. This analysis demonstrates that the maximum internal gas pressure at 800°C (1,472°F) would be 54 psi. Under these conditions, the maximum stress in the capsule would be less than the yield strength of the material.

3.5.3 Maximum Thermal Stresses

A finite element analysis, contained in Appendix D, concludes no significant thermal stresses are generated during the thermal test.

3.5.4 Evaluation of Transport Package Performance for Thermal Test

The Neoprene gasket on the Model 702 will be destroyed when subjected to the Hypothetical Accident Conditions of Transport thermal test conditions. The other package materials, however, are suitable for use at 800°C (1,472°F) (see Table 4). The depleted uranium, which is susceptible to oxidation, is enclosed within stainless steel and would not be exposed to oxygen. The transport package will undergo no loss of structural integrity or shielding. The pressures and temperatures generated have been demonstrated to be within acceptable limits.

3.6 Thermal Analysis Details

3.6.1 Surface Temperature Analysis

Reference:

- *10 CFR 71.43(g)*
- *IAEA TS-R-1, paragraphs 617 and 652*

This analysis calculates the maximum surface temperature of the Model 702 transport package in the shade (i.e., no insolation effects), assuming an ambient temperature of 38°C (100°F), per 10 CFR 71.43(g).

To assure conservatism, the following assumptions are used:

- The transport package is assumed to undergo free convective heat transfer and radiative heat transfer from the top, bottom, and four sides.

- The inside transport package faces are perfectly insulated so there is no conduction into the transport package.

- The transport package is approximated as a rectangular box with dimensions the same as the protective cage, 18 inches (457 mm) long, 18 inches (457 mm) wide, and 15 inches (381 mm) high. No heat transfer is assumed to occur at the sides of the skid.

- The surfaces of the transport package are assumed to be solid, although the top and two sides of the cage have holes. The faces are considered to be sufficiently thin so that no temperature gradients exist in the faces.

- The entire decay heat (86 Watts) is deposited in the exterior surfaces of the transport package.

  (Note: 86 Watts is the approximate gamma decay heat for 10,000 Curies of Ir-192.)

Table 3: Isotope Heat Generation in the Model 702

Isotope	Device Capacity	Heat Generation (Watts)
Ir-192	10,000 Ci	86
Cs-137	1,000 Ci	7
Se-75	10,000 Ci	51
Yb-196	10,000 Ci	54
Co-60	15 Ci	0.3

- The emissivity coefficient of the steel transport package is assumed to be 0.8.

Using these assumptions, the maximum wall temperature (T_W) is found using the following steady state heat balance:

$$Q_D = Q_R + Q_T + Q_S + Q_B \qquad \text{(Equation 8)}$$

Where:

Q_D	=	86 Watts (decay heat deposited on the surface)
Q_R	=	Heat radiated from surface of package
Q_T	=	Heat convected from top of package
Q_S	=	Heat convected from sides of package
Q_B	=	Heat convected from bottom of package

From Section 2.6.1.1,

$$Q_R = B\ E\ A_{TS}\ \{(T_W + 273)^4 - (T_A + 273)^4\}$$

Where:

B	=	5.67×10^{-8} W/m^2 K^4 (Stefan-Boltzmann Constant)
E	=	0.8 (Emissivity)
A_{TS}	=	1.115 m^2 (top, bottom, and side surface area)
T_W	=	The maximum surface temperature of the package (°C)
T_A	=	38°C (ambient temperature)

Therefore:

$$Q_R = 5.06 \times 10^{-8}\{(T_W + 273)^4 - (311)^4\} \qquad \text{(Equation 9)}$$

Also from Section 2.6.1.1,

$$Q_T = 0.54\ [(g\ \beta\ (T_W - T_A)\ L^3) / (\nu\ \alpha)]^{1/4}\ (K / L)\ A_T\ (T_W - T_A)$$

Where:

g	=	9.8 m/s^2
β	=	0.00303 (1/T_{avg} assuming that T_{avg} = 330°K)
L	=	0.114 m (Area / Perimeter)
ν	=	18.9 x 10^{-6} m^2/s
α	=	26.9 x 10^{-6} m^2/s
K	=	28.52 x 10^{-3} W/mK
A_T	=	0.209 m^2 (the top surface area)

Therefore:

$$Q_T = 0.485\ (T_W - 38)^{1.25} \qquad \text{(Equation 10)}$$

Also from Section 2.6.1.1,

$$Q_S = [0.68+0.67\{g\beta(T_W-T_A)L^3/\nu\alpha\}^{1/4}/\{1+(0.492/\nu/\alpha)^{9/16}\}^{4/9}](K/L)\ A_S\ (T_W - T_A)$$

Where:

L	=	0.104 m (Area / Perimeter)
A_S	=	0.697 m^2 (the total surface area of sides)

Therefore:

$$Q_S = 0.130\ (T_W - 38) + 1.58\ (T_W - 38)^{1.25} \qquad \text{(Equation 11)}$$

Also from Section 2.6.1.1,

$$Q_B = 0.27\ [(g\ \beta\ (T_W - T_A)\ L^3) / (\nu\ \alpha)]^{1/4}\ (K / L)\ A_B\ (T_W - T_A)$$

Where:

L	=	0.114 m (Area / Perimeter)
A_B	=	0.209 m^2 (the bottom surface area)

Therefore:

$$Q_B = 0.242\ (T_W - 38)^{1.25} \qquad \text{(Equation 12)}$$

Substituting Equations 9, 10, 11, and 12 into Equation 8:

$$86 \text{ Watts} = 5.06 \times 10^{-8}\{(T_W + 273)^4 - (311)^4\} + 0.485\,(T_W - 38)^{1.25} + 0.130\,(T_W - 38) + 1.58\,(T_W - 38)^{1.25} + 0.242\,(T_W - 38)^{1.25}$$

Iteration of this relationship yields a maximum wall temperature (T_W) of 46°C (115°F), which is less than the maximum 50°C (122°F) allowed by the references.

3.6.2 Model 702 Series Type B(U) Source Capsule Thermal Analysis

Reference:

- *IAEA TS-R-1, paragraph 660*

This analysis demonstrates that the pressure inside the Model 702 source capsule, when subjected to the Hypothetical Accident Conditions of Transport thermal test, does not exceed the pressure which corresponds to the minimum yield strength at the thermal test temperature.

The source capsules used in the 702 are all special form tested and approved. The thermal test for special form capsules involves heating the capsules at 800°C for at least 10 minutes and allowing the capsules to cool afterwards. Test capsules are tested for leak tightness after this test and must pass intact in order to achieve special form status.

The thermal test from the hypothetical accident conditions of transport requires heating the package to a temperature of 800°C for a period of 30 minutes. From the Finite Element Analysis (FEA) of the 702 cask, the internal cask cavity temperature reaches 800°C between 20 and 30 minutes into the heating. At this point the cask would be allowed to cool back to ambient temperature.

Special form capsules are also brought up to the 800°C temperature and allowed to cool prior to integrity testing. The FEA demonstrated that the cask will withstand the stresses induced by the thermal test and the special form capsules also demonstrate their ability to retain integrity at 800°C. Therefore it is concluded that the container and contents meet the requirements of this section.

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Section 4 - CONTAINMENT

4.1 Containment Boundary

4.1.1 Containment Vessel

The containment system consists of the Model 702 transport package and the radioactive source capsule. This source capsule shall be qualified as Special Form radioactive material under 49 CFR 173 and IAEA TS-R-1.

4.1.2 Containment Penetrations

There are no penetrations of the containment.

4.1.3 Seals and Welds

All welds are in accordance with AEA Technology QSA, Inc. Quality Program Requirements and specifications on the descriptive drawings. The integrity of the source weld is tested by a leak test meeting the requirements of ISO 9978 (1992), "Radiation Protection Sealed Radioactive Series- Leakage Test Methods" or later revisions.

4.1.4 Closure

The closure device is a combination of the welded special form source capsule and the bolted Model 702 cask cover. The attached cask cover, with tungsten insert(s) when applicable, maintains the source in the shielded position as described in Section 1.2.1.

4.2 Requirements for Normal Conditions of Transport

4.2.1 Containment of Radioactive Material

The source capsules used in conjunction with the transport package have satisfied the requirements for the special form radioactive material as prescribed in 10 CFR 71.75, 49 CFR 173.469 and IAEA TS-R-1. There will be no release of radioactive material under the Normal Conditions of Transport.

4.2.2 Pressurization of the Containment Vessel

Pressurization of the source capsules and cask cavity under the conditions of the Hypothetical Accident Conditions thermal test resulted in stresses below the yield strength of the capsule material and cask cover bolts. These analyzes are provided in Section 3.6.2, and Section 3.5.2 respectively.

4.2.3 Containment Criterion

The normal conditions of transport criteria listed in 10 CFR 71.71 will result in no loss of transport package containment as prescribed in 10 CFR 71.51(a)(1). This conclusion is based on information presented in Sections 2.6, "Normal Conditions of Transport" and 3.4, "Thermal Evaluation for Normal Conditions of Transport."

4.3 Containment Requirements for Hypothetical Accident Conditions

4.3.1 Containment of Radioactive Material

The hypothetical accident conditions outlined in 10 CFR 71.73 will result in no loss of transport package containment. This conclusion is based on information presented in Section 2.7, "Hypothetical Accident Conditions of Transport." and 3.5, "Thermal Evaluation for Hypothetical Accident Conditions of Transport."

4.3.2 Pressurization of the Containment Vessel

Pressurization of the package and source capsules under the hypothetical accident conditions was determined to have no detrimental effect on the capsules ability to maintain containment. In addition the cask cover bolts provide an additional measure of security in ensuring pressurization of the package under the accident conditions. The containment will withstand the pressure variations of transport.

4.3.3 Containment Criterion

Sections 2.7, "Hypothetical Accident Conditions of Transport" and 3.5, "Thermal Evaluation for Hypothetical Accident Conditions of Transport" show that the transport package meets the containment requirements of 10 CFR 71.51(a)(2).

4.4 Special Requirements

Not applicable.

Section 5 - SHIELDING EVALUATION

5.1 Design Features

The principal shielding in the Model 702 transport package is the depleted uranium shield assembly and optional tungsten insert(s) used when necessary to obtain allowable dose rates as well as fix source capsule locations within the shield. The depleted uranium shielding weighs approximately 209 pounds (95 kg). The shielding is cast as two pieces (shield and cover). Each piece is completely enclosed by stainless steel.

5.2 Source Specification

5.2.1 Gamma Source

The gamma sources allowed for transport in the Model 702 are listed in Table 1, Section 1.3.

5.3 Model Specification

MicroShield, version 5.05, was used to determine the loading capacity for the isotopes referenced in Table 1. Survey measurements using Ir-192 verified these results and provided ratios to determine if the survey measurements after testing would disqualify any of the isotopes from use. Since the testing results showed that an insignificant change had occurred in the radiation profiles, all isotopes were considered acceptable.

5.4 Shielding Evaluation

Since only one shipping cask was used for all tests, radiation profiles were only taken on the TP81(A) specimen. The test specimen was profiled three times: before testing, after the 1.2 meter (4 foot) drop test, and after the final puncture test. Data was extrapolated to 10,000 Curies when profiles were performed using sources with less activity.

Note that the puncture test of specimen TP81(A) was the last test performed on any of the test specimens. As a result, the final TP81(A) profile is considered to cover the post drop results of all Test Specimens.

All radiation profile data are within regulatory acceptance limits, as shown in Table 6.

Table 6: Radiation Profiles for Test Specimen TP81(A)

		Before Tests		After 1.2 Meter (4 Foot) Drop Test		After Puncture Test
Specimen	Specimen Surface	At Surface	At One Meter	At Surface	At One Meter	At One Meter (Note 1)
	Reg. Limits	200	10	200	10	1000
TP81(A) S/N 24	Top	20	0.5	17	0.6	1.0
	Right	37	1.0	35	0.8	1.1
	Front	30	0.5	27	0.9	1.1
	Left	44	1.1	35	0.8	1.1
	Rear	27	0.9	22	0.8	0.8
	Bottom	3	< 0.4 (Note 2)	1.8	< 0.1 (Note 2)	0.8 (Note 3)

Notes:

1. Radiation profile at the surface is not required for the Hypothetical Accident Condition test (see 10 CFR 71.51(a)(2)). The shipping cask had been removed from cage/skid prior to final puncture test and was profiled without the cage/skid assembly.

2. Background level is 0.3 mR/hr.

3. Activity measured at surface of shipping cask.

4. Measured exposure rates reported above extrapolated to a capacity activity of 10,000 Ci of Ir-192.

5. All exposure rates in units of mR/hr.

Section 6 - CRITICALITY EVALUATION

Not applicable.

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Section 7 - Operating Procedure

7.1 Procedure for Loading the Transport Package

To load a Model 702 transport package prior to transportation:

NOTE: All removal and installation of radioactive material contained within the 702 must be performed in a shielded cell/enclosure capable of holding the maximum isotope capacity of this container. This can only be performed by persons specifically authorized under an NRC or agreement state license. All necessary safety precautions and regulations must be observed to ensure safe transfer of the radioactive material.

NOTE: Prior to hardware (bolts, nuts, washers, threaded rods, etc.) installation and use, assure they are in good condition with no damage, specifically damage to threads.

1. After installing the radioactive material into the 702, with tungsten insert(s) if applicable to shield or fix the capsules in place, install the gasket. The gasket must be in good physical condition with no rips or tears. Place the cask cover onto the top of the 702 cask and seat the cover properly. To seat properly, the lid must lie flush with the top of the cask. This will effectively shield the container so that it can be safely handled.

2. The cask can then be removed from the shielded cell/enclosure. The operator should verify that the radioactive material is properly stored by surveying all sides of the cask.

3. The cask cover can then be properly installed on the cask and secured with the six 3/8-16 x 7/8 inch long hex head bolts. Install lock washers and a flat washer with the bolt. Torque the bolts to 160 ±5 inch-pounds.

4. Seal wire two of the hex head bolts on the cask cover.

5. Place the cask onto the metal skid. Insert the four 1/2-13 hex head bolts with lockwashers through the cask bottom plate mounting holes and into the 4 holes on the steel plate of the metal skid. Torque the bolts to 370 ±5 inch-pounds.

6. Place the cask hold down assembly (clamp ring) onto the top of the cask. Inspect the four 1/2-13 threaded rods to assure that they are not damaged or bent. Insert the rods through the clamp ring and into the 4 steel weldments on the skid.

7. Secure the bottom of the threaded rod with a 1/2-13 square nut. The rod should completely engage the nut.

8. Secure the threaded rods with a 1/2-13 hex nut and steel lockwashers at the top of the clamp ring. Torque these to 370 ±5 inch-pounds.

9. Wipe test the cask and metal skid over an area of 300 square centimeters and assure the level of removable contamination is less that 0.00001 μCi per cm^2.

10. Place the metal protective cage on the skid and secure it in 4 corners with lockwashers, flatwashers, and 1/2-13 hex head bolts. Torque the bolts to 370 ±5 inch-pounds.

11. Seal wire one of the drilled bolts to provide a tamper indicator seal. The seal wire should pass through the drilled head of the bolt and around the steel tubing, as shown in drawing R70290, sheet 1.

12. Visually inspect the transport package:

    - Assure the bolts have all been secured and torqued properly.
    - Assure the hold down rods are not bent or damaged. If the rods are bent, they must be replaced prior to shipment.
    - Assure all seal wires are properly installed. Assure there are no cuts or holes in the protective metal cage. (Small dents are okay).
    - Assure the radioactive material labels are installed at two opposite sides of the cage. Assure they are legible and not defaced.
    - Assure all welded areas are not cracked or bent. If there is any evidence of bent or cracked welds contact AEAT/QSA prior to shipping.
    - Assure all threaded holes do not have damaged threads. If there are damaged threads, do not use the container. Contact AEAT/QSA for repair information.
    - Assure metal skid sits firmly on the ground.

13. Assure all the conditions of the Certificate of Compliance are met and the transport package has all the required markings.

14. Survey the transport package with a survey meter at the surface and at a distance of one meter from the surface to determine the proper radioactive shipping labels to be applied to the transport package as required by 49 CFR 172.403. If the radiation levels are greater than 200 mR/hr at the surface or 10 mR/hr at one meter from the surface, the container must not be shipped.

15. Brace the transport package so that it cannot change position during transport.

16. Ship the container according to proper procedures for transporting radioactive material as established in 49 CFR 171-178.

Note: The US Department of Transportation, in 49 CFR 173.22(c), requires each shipper of Type B quantities of radioactive material to provide prior notification to the consignee of the dates of shipment and expected arrival.

7.2 Procedure for Unloading the Transport Package

The consignee of a transport package of radioactive material must make arrangements to receive the transport package when it is delivered. If the transport package is to be picked up at the carrier's terminal, 10 CFR 20.1906 requires that this be done expeditiously upon notification of its arrival.

Upon receipt of a transport package of radioactive material:

1. Survey the transport package with a survey meter as soon as possible, preferably at the time of pick-up and no more than three hours after it was received during normal working hours.

   Radiation levels should not exceed 200 mR/hr at the surface of the transport package, nor 10 mR/hr at a distance of 1 meter from the surface.

2. Record the actual radiation levels on the receiving report.

3. If the radiation levels exceed these limits, secure the container in a Restricted Area and notify the appropriate personnel in accordance with 10 CFR 20 or applicable Agreement State regulations.

4. Inspect the outer container for physical damage.

5. Record the radioisotope, activity, model number, and serial number of the source and the transport package model number and serial number.

6. Unload the 702 in accordance with the applicable licensing provisions for the user's facility related to radioactive material handling.

Operation of the Model 702 transport package must be in accordance with the operating instructions supplied with the transport package, per 10 CFR 71.89.

7.3 Preparation of an Empty Transport Package for Transport

In the following instructions, an *empty* transport package refers to a Model 702 transport package without an active source contained within the depleted uranium shielded container.

To ship an empty transport package:

1. Perform the following procedure to confirm that there are no unauthorized sources within the container:

    a. Place the Model 702 in a shielded cell/enclosure capable of holding the maximum isotope capacity of this container. Remove the cover. Remove any tungsten insert(s) and visually inspect the container for any source capsules.

    b. Inspect the tungsten insert(s) for source capsules.

    c. Using remote manipulators, mirrors, and radiation monitors if necessary, inspect the container to verify that it is empty.

    d. Once the tungsten insert(s) are determined to be empty, place them back into the container and install the cask cover.

    e. Secure the cover with the six bolts.

2. Assure that the levels of removable radioactive contamination on the outside surface of the transport package do not exceed 0.00001 μCi per square centimeter.

3. When it is confirmed that the Model 702 transport package is empty, survey the device and prepare the transport package for transport depending upon the radiation levels obtained, as given in 49 CFR 173.

Section 8 - ACCEPTANCE TESTS AND MAINTENANCE PROGRAM

8.1 Acceptance Test

8.1.1 Visual Inspection

Visually inspect each Model 702 transport package to be shipped to assure the following:

1. The transport package was assembled properly to the applicable drawing R70290.
2. All fasteners as required by the applicable drawings are properly installed and secured.
3. The relevant labels are attached, contain the required information, and are marked in accordance with 10 CFR 20.1904, 10 CFR 40.13(c)(6)(i), 10 CFR 34, and 10 CFR 71 or equivalent Agreement State regulations.

8.1.2 Structural and Pressure Tests

Not applicable.

8.1.3 Leak Tests

The source capsules (primary containment) are wipe tested for leakage of radioactive contamination upon initial manufacture. The removable contamination must be less than 0.005 microcuries. The source capsules will also be subjected to leak tests under ISO 9978. The source capsules are not used if they fail any of these tests.

8.1.4 Component Tests

Not applicable.

8.1.5 Tests for Shielding Integrity

The radiation levels at the surface of the transport package and at 1 meter from the surface are measured upon manufacture. These radiation levels, when extrapolated to the rated capacity of the transport package, must not exceed 200 mR/hr at the surface, nor 10 mR/hr at 1 meter from the surface of the transport package. Failure of this test will prevent use of the transport package as a Type B(U) package.

8.1.6 Thermal Acceptance Tests

Not applicable.

8.2 Maintenance Program

8.2.1 Structural and Pressure Tests

Not applicable.

8.2.2 Leak Tests

As described in Section 8.1.3, "Leak Tests," the radioactive source assembly is leak-tested at manufacture.

8.2.3 Subsystem Maintenance

The transport package is inspected for tightness of fasteners, proper seal wires, and general condition prior to each use.

8.2.4 Valves, Rupture Discs and Gaskets on Containment Vessel

The gasket is inspected prior to each shipment. If there are any rips, tears, or degradation of the rubber, the gasket will be replaced.

8.2.5 Shielding

Prior to each use, a radiation survey of the transport package is made to assure that the radiation levels do not exceed 200 mR/hr at the surface, nor 10 mR/hr at 1 meter from the surface.

8.2.6 Thermal

Not applicable.

8.2.7 Miscellaneous

Inspections and tests designed for secondary users of this transport package under the general license provisions of 10 CFR 71.12(b) are provided in Section 7.

Appendix A: Model 702 Drawing

A-1 **Model 702 Isotope Shipping Container Descriptive Assembly, R70290, 9 Sheets, Revision K**

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FIGURE WITHHELD UNDER 10 CFR 2.390

PART NAME	QTY.	DESCRIPTION
BOLT ASSEMBLY	4	300 SERIES STAINLESS STEEL
SEAL WIRE	1 MIN.	.03 DIA. NOMINAL
702 WARNING LABEL	2	6 X 7 3/8 MILD STEEL
CAGE PLATE	2	1/32 THK. 304 STAINLESS STEEL PLATE
SKID WELDMENT	1	SEE SHEET 3
PROTECTIVE CAGE	1	SEE SHEET 4

UNLESS OTHERWISE SPECIFIED:
ALL DIMENSIONS ARE INCHES, TOLERANCE ±1/16

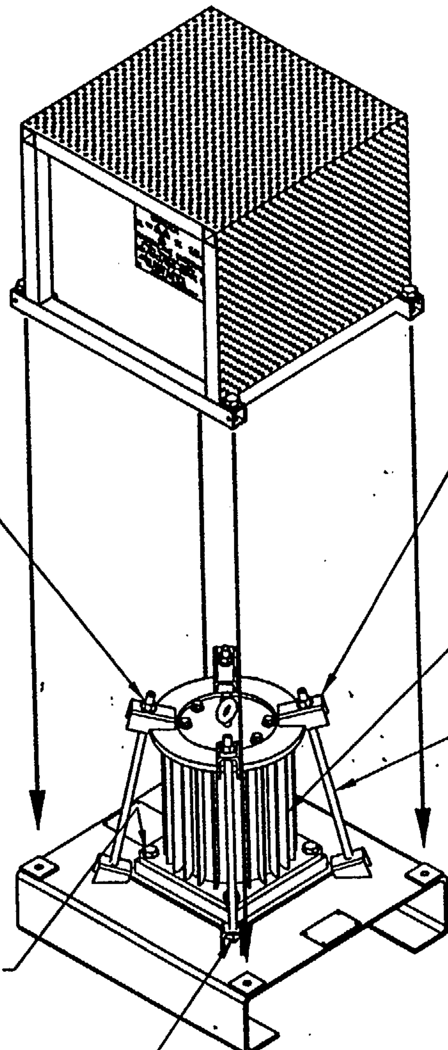
AEA TECHNOLOGY QSA
40 NORTH AVE, BURLINGTON, MA 01803

DESCRIPTIVE DRAWING

TITLE MODEL 702 ISOTOPE SHIELD SHIPPING CONTAINER

SIZE B | DWG. NO. R70290 | REV K

SCALE: 1/4 | SHEET 1 OF 9



PART NAME	QTY.	DESCRIPTION
HEX HEAD BOLT	4	½-13 ST.STL.
SQUARE NUT	4	½-13 ST.STL.
HEX NUT	4	½-13 ST.STL.
LOCKWASHER	8	½ ST.STL.
HOLD-DOWN CLAMP	1	SEE SHEET 5
304 ST.STL. THREADED ROD	4	14¾ ±1/8 LENGTH 1/2-13 THREADED
SHIPPING CASK	1	SEE SHEET 6

UNLESS OTHERWISE SPECIFIED:
ALL DIMENSIONS ARE INCHES, TOLERANCE ±1/16

AEA TECHNOLOGY
QSA
40 NORTH AVE, BURLINGTON, MA 01803

DESCRIPTIVE DRAWING

TITLE MODEL 702
ISOTOPE SHIELD SHIPPING CONTAINER

SIZE	DWG. NO.	R70290	REV
B	SCALE: 1/8	SHEET 2 OF 9	K

FIGURE WITHHELD UNDER 10 CFR 2.390

UNLESS OTHERWISE SPECIFIED: ALL DIMENSIONS ARE INCHES, TOLERANCE ±1/16	
AEA TECHNOLOGY QSA 40 NORTH AVE, BURLINGTON, MA 01803	DESCRIPTIVE DRAWING
TITLE	MODEL 702 ISOTOPE SHIELD SHIPPING CONTAINER
SIZE B	DWG. NO. R70290
SCALE: 1/8	SHEET 3 OF 9
REV K	

FIGURE WITHHELD UNDER 10 CFR 2.390

UNLESS OTHERWISE SPECIFIED:
ALL DIMENSIONS ARE INCHES, TOLERANCE ±1/16

AEA TECHNOLOGY
QSA
40 NORTH AVE, BURLINGTON, MA 01803

DESCRIPTIVE DRAWING

TITLE MODEL 702
ISOTOPE SHIELD SHIPPING CONTAINER

SIZE	DWG. NO.		REV
B	R70290		K
	SCALE: 1/8	SHEET 4 OF 9	

FIGURE WITHHELD UNDER 10 CFR 2.390

UNLESS OTHERWISE SPECIFIED: ALL DIMENSIONS ARE INCHES, TOLERANCE ±1/16		
AEA TECHNOLOGY QSA 40 NORTH AVE. BURLINGTON, MA 01803	DESCRIPTIVE DRAWING	
TITLE	MODEL 702 ISOTOPE SHIELD SHIPPING CONTAINER	
SIZE B	DWG. NO. R70290 SCALE: 1/4 SHEET 5 OF 9	REV K

FIGURE WITHHELD UNDER 10 CFR 2.390

UNLESS OTHERWISE SPECIFIED: ALL DIMENSIONS ARE INCHES, TOLERANCE ±1/16	
AEA TECHNOLOGY QSA 40 NORTH AVE, BURLINGTON, MA 01803	DESCRIPTIVE DRAWING
TITLE MODEL 702 ISOTOPE SHIELD SHIPPING CONTAINER	
SIZE B	DWG. NO. R70290
SCALE: 1/4	SHEET 6 OF 9
REV K	

FIGURE WITHHELD UNDER 10 CFR 2.390

UNLESS OTHERWISE SPECIFIED: ALL DIMENSIONS ARE INCHES, TOLERANCE ±0.03		
AEA TECHNOLOGY QSA 40 NORTH AVE, BURLINGTON, MA 01803	DESCRIPTIVE DRAWING	
TITLE MODEL 702 ISOTOPE SHIELD SHIPPING CONTAINER		
SIZE B	DWG. NO. R70290	REV K
	SCALE: 1/2	SHEET 7 OF 9

FIGURE WITHHELD UNDER 10 CFR 2.390

UNLESS OTHERWISE SPECIFIED: ALL DIMENSIONS ARE INCHES, TOLERANCE ±0.03		
AEA TECHNOLOGY QSA 40 NORTH AVE, BURLINGTON, MA 01803	DESCRIPTIVE DRAWING	
TITLE MODEL 702 ISOTOPE SHIELD SHIPPING CONTAINER		
SIZE B	DWG. NO. R70290	REV K
	SCALE: 1/2	SHEET 8 OF 9

FIGURE WITHHELD UNDER 10 CFR 2.390

UNLESS OTHERWISE SPECIFIED:
ALL DIMENSIONS ARE INCHES, TOLERANCE ±0.03

AEA TECHNOLOGY
QSA
40 NORTH AVE, BURLINGTON, MA 01803

DESCRIPTIVE DRAWING

TITLE MODEL 702
ISOTOPE SHIELD SHIPPING CONTAINER

SIZE	DWG. NO.	R70290		REV
B	SCALE: 1/2		SHEET 9 OF 9	K

Appendix B: Test Plan 81 (Model 702)

B-1 Test Plan 81, Revision 1

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SENTINEL

TEST PLAN NO. 81, Rev. 1

TEST PLAN COVER SHEET

TEST TITLE: Model 702 Transport Package Type B Transport Tests	
PRODUCT MODEL: Model 702	
ORIGINATED BY: [signature]	DATE: 30 MAR 99

TEST PLAN REVIEW

ENGINEERING APPROVAL: [signature]	DATE: 31 MAR 99
QUALITY ASSURANCE APPROVAL: D.W. Kurtz	DATE: 31 Mar 99
REGULATORY APPROVAL: C. Kaufman	DATE: 31 Mar 99

COMMENTS:

TEST RESULTS REVIEW

ENGINEERING APPROVAL:	DATE:
QUALITY ASSURANCE APPROVAL:	DATE:
REGULATORY APPROVAL:	DATE:

Amersham QSA

AEA TECHNOLOGY
QSA

AEA Technology
QSA Inc.
40 North Avenue
Burlington, MA 01803
Telephone (781) 272-2000
Telephone (800) 815-1383
Facsimile (781) 273-2216

Mr. Ross Chappell
Package Certification Section
Spent Fuel Project Office
US Nuclear Regulatory Commission
11555 Rockville Pike
One White Flint
Rockville, MD 20852

30 March 1999

Dear Mr. Chappell:

Enclosed is Revision 1 of Test Plan 81 for the Model 702 Type B(U) transport package. The Model 702 transport package will be subjected to the test series described in the enclosed test plan, in accordance with 10 CFR 71 and IAEA Safety Series No. 6 (1985, as amended 1990).

As we discussed in our meeting with you on March 9, we have made the following changes to Test Plan 81:

1. The Case 1 Orientation for the 1.2 Meter Drop Test has been changed from Vertical, Upside Down to Top Long-Edge Down to damage the protective cage and decrease the distance from the cage to the cask.

2. The Case 1 and Case 2 Orientations for the 9 Meter Drop Test have been added to try to separate the cask from the shipping skid, and to try to damage the protective cage, by dropping the test specimen in the Horizontal Short-Side Down and Top Long-Edge Down orientations.

3. The configuration of the test specimen for the Puncture Bar Test will be based on an assessment of the damage to the units in each of the three 9 Meter Drop Tests. The worst case configuration will be used, based on whether the protective cage and/or the cask becomes detached from the skid. Since the same cask is being used for all testing, one puncture bar test will be performed. The unit will be dropped in a Vertical Upside Down orientation onto the puncture bar to compound damage to the cask cover bolts from the Case 3 (Vertical Upside Down) 9 meter drop test.

We request approval of the test plan for the Model 702 so we can complete testing by April 16. Please contact me if you require any additional information at 781-272-2000 extension 210. We greatly appreciate your assistance with this review.

Sincerely,

Cathleen Roughan

Cathleen Roughan
Regulatory Affairs and Safety Manager

Test Plan 81

Model 702 Transport Package
Type B Transport Tests

March 1999

Contents

List of Figures, Tables and Worksheets

AEA Technology/QSA Test Plan 81

1.0 Introduction

This document describes Type B(U) transport package testing of the AEA Technology Model 702 Transport Package, Certificate of Compliance Number 6613. The purpose of the testing is to demonstrate that the package meets the NRC requirements for Type B(U) packages under Normal Conditions of Transport (10 CFR 71.71), and Hypothetical Accident Conditions (10 CFR 71.73), and the criteria stated in IAEA Safety Series 6 (1985, as amended 1990).

The test plan specifies the test package configurations, testing equipment and scenarios, justifies the package orientations, and provides test worksheets to record key steps in the testing sequence.

Refer to Appendix A for a descriptive drawing of the test specimen.

2.0 Transport Package Description

The Model 702 Transport Package is 20 inches high, 21 inches long, and 19 inches wide in overall dimension. The gross weight of the package is 410 lb. The Model 702 Transport Package consists of the following components:

- Shipping Cask: The special form source is contained in a shipping cask. The outer shell of the shipping cask is a 0.18 inch thick stainless steel cylinder with a 3/8 inch thick base. Welded to the shell are 24 cooling fins that measure 1/8 inch thick x ¾ inch wide x 10.25 inch long. Inside the outer shell is a 196 lb. depleted uranium (DU) shield. The DU shield has an inner stainless steel liner that is welded at the top to the outer shell. For this test, the source cavity will be filled with a tungsten plug weighing approximately 8 lbs., to bound the loaded device weight.

- Cask Cover Assembly: A cover assembly encloses the top portion of the shipping cask. The cover assembly includes a 21 lb. DU shield encased in a stainless steel shell. The cover assembly flange is anchored to the inner liner of the shipping cask with six 3/8 inch diameter stainless steel bolts. A 1/16 inch thick neoprene rubber gasket is used to seal the cover assembly. The total weight of the cover assembly is approximately 30 lbs.

- Skid: The skid consists primarily of ¼ inch thick carbon steel, formed into a flat base with rolled "legs" on two sides of the skid. The legs have a height of approximately 4 inches. Plates of ¼ inch and 1-inch thickness are welded to the formed skid to provide a mounting pedestal for the shipping cask. The shipping cask assembly is attached to the skid with four ½ inch diameter bolts (stainless steel).

- Cask Hold Down Assembly: The shipping cask is further secured to the skid by a hold down assembly. The assembly consists of four ½ inch threaded stainless steel rods that are anchored to the skid through bottom "feet" that are welded to the skid. The rods clamp down on a hold down ring that fits on top of the shipping cask and around the cask cover.

- Protective Cage: To protect personnel handling the package, a carbon steel cage is placed over the cask. The protective cage assembly is a frame constructed of 1.25 inch square tubing with a wall thickness of 0.120 inches. Perforated, 0.047 inch thick steel is attached to the frame. The frame is attached to the skid with four ½ inch diameter stainless steel bolts that attach to the skid at tapped holes.

The Model 702 package is shown in the following figures (Figures-1 and 2).

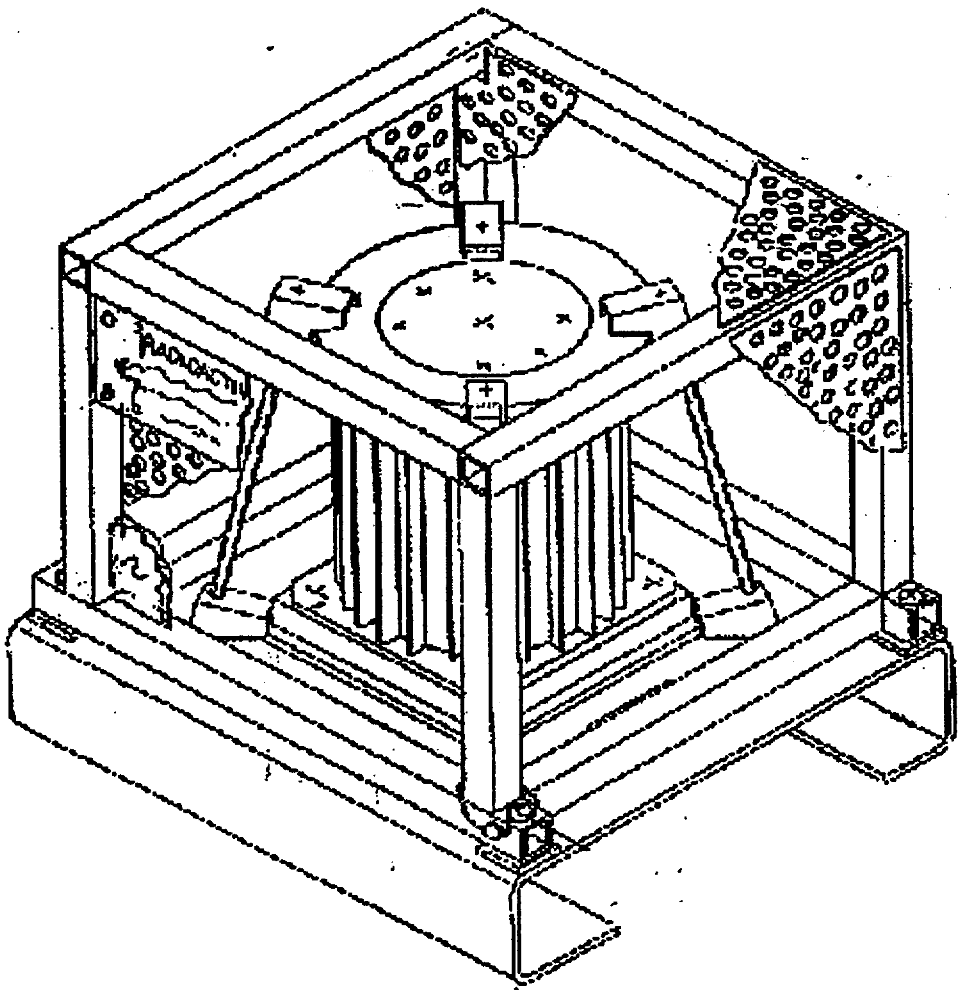


Figure 1. Isometric View of Model 702 Package

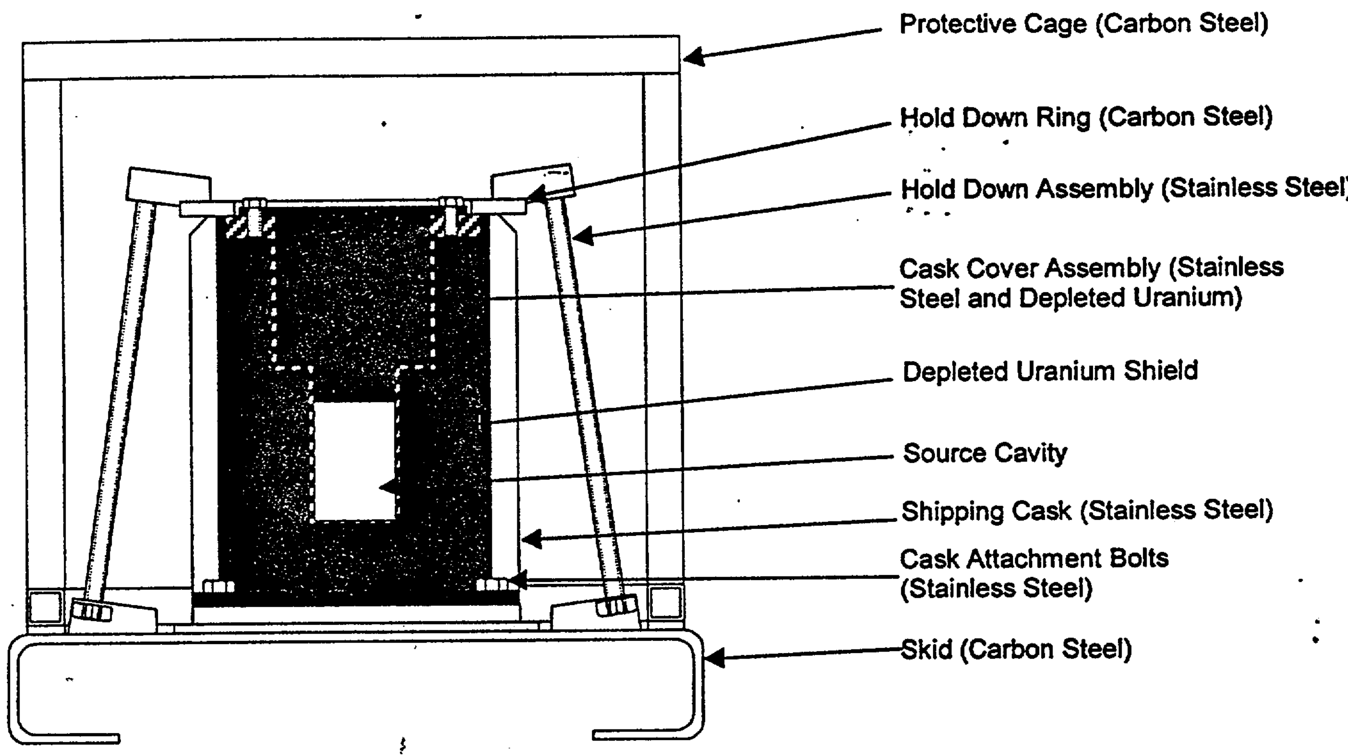


Figure 2. Side View of Model 702 Package

3.0 Regulatory Compliance

The purpose of this plan, which was developed in accordance with AEAT/QSA SOP-E005, is to ensure that the Model 702 Transport Package meets the Type B transport package requirements of 10 CFR 71 and IAEA Safety Series No. 6 (1985, as amended 1990).

The Normal Conditions of Transport tests (10 CFR 71.71) to be performed are the compression test, penetration test, and 1.2 meter (4 foot) free drop.

Water spray preconditioning of the package is not performed as the Model 702 packages are constructed of waterproof materials throughout. The water spray would not contribute to any degradation in structural integrity.

The Hypothetical Accident Tests (10 CFR 71.73) to be performed are the 9 meter (30 foot) free drop, puncture test, and thermal test (if applicable).

The crush test (10 CFR 71.73(c)(2)) is not performed because the radioactive contents are special form radioactive material.

The immersion test and all other conditions specified in 10 CFR 71 will be evaluated separately.

4.0 System Failures and Package Orientations

The tests in this plan focus on damaging those components of the package which could result in removal of the cover or which could affect the integrity of the shield.

System failures that could affect package integrity and cause radiological dose rates to exceed the regulatory limits include:

- Failure of Cask Cover Bolts – During the free drop or puncture tests, failure of the cask cover bolts could result in the source becoming partially or completely exposed.

- Failure of the Cask or Cover Assembly Shell – Failure (e.g., puncture) of the cask or cover assembly or failure of the inner liner to outer shell weld could expose the depleted uranium (DU) shield, which could oxidize during the thermal test.

- Separation of the Cask from the Skid – If the cask/skid bolts or the tie down assembly fail during the 9 meter (30 foot) drop test, the cask may strike the impact surface. In addition, the package could then be further damaged in the puncture bar test when the cask impacts on the puncture bar.

- Crushing or Buckling of the Protective Cage – If there is significant deformation of the protective cage during the 1.2 meter (four foot) drop, the distance from the source to the package external surface would be decreased. If there is significant deformation of the protective cage during the 9 meter (30 foot) drop, the cask may strike the impact surface.

The limiting orientation for the penetration bar test is discussed in Section 8.6.2.

The 1.2 meter (four foot) drop test orientation considered most likely to cause crushing or buckling of the protective cage is top, long edge down (see Figure 5).

Three orientations are considered most likely to cause damage during the 9 meter (30 foot) drop tests, i.e., the most likely to cause unacceptable external dose rates. For all three orientations, the worst case temperature is the lower limit of -40°C due to embrittlement of the DU and Carbon Steel components.

- Case 1, Horizontal, Short-Side Down (Fig. 6) – The skid is stiffer in this orientation than in the long-side down, so the maximum moment is applied to the hold down feet and the cask bolts. The impact may also cause buckling and/or brittle failure of the carbon steel protective cage structure. Detachment of the cask from the skid is possible due to thread failure of the tapped holes in the skid and brittle failure of the hold down assembly "feet" which are welded to the skid.

- Case 2, Top, Short Edge Down (Fig. 7) – The impact may cause significant deformation of the carbon steel protective cage. Detachment of the cask from the skid is possible due to thread failure of the tapped holes in the skid and brittle failure of the hold down assembly "feet" which are welded to the skid.

- Case 3, Vertical, Top Down (Fig. 8) – An impact in this orientation will apply the maximum tensile load to the cask cover bolts and inner liner weld. The impact may also cause buckling and/or brittle failure of the carbon steel protective cage structure. Detachment of the cask from the skid is possible due to thread failure of the tapped holes in the skid and brittle failure of the hold down assembly "feet" which are welded to the skid. Following the 9 meter (30 foot) drop tests, an assessment will be made to determine the worst case configuration for the puncture test. The following configurations are possible:

- If the cask AND the cage become detached from the skid in any of the 9 meter (30 foot) drops, or if the cask otherwise exits from the skid/cage assembly, then the puncture test will be performed with the cask alone (i.e., without the skid, hold down assembly, and cage).

- If the cage becomes detached but the cask remains attached to the skid in any of the 9 meter (30 foot) drops, then the puncture test will be performed with the cask attached to the skid but without the cage.

- If the cage remains attached to the skid and the cask does not exit the cage, in all 9 meter (30 foot) drops, then the puncture test will be performed with the cask as is (attached or not) and the cage attached to the skid. The assessment will identify the cage and skid assembly that has damage most likely to be detrimental to the unit in the puncture bar test.

The worst case orientation for the puncture test is considered to be vertical, upside down onto the puncture bar. This will compound damage to the cask cover bolts from the Case 3 (vertical, top down) 9 meter (30 foot) drop test. This orientation is considered most likely to cause significant damage to the unit and will bound all other drop orientations. This orientation will be modified, if necessary, based on the results of the engineering assessments conducted after the 9 meter (30 foot) drop tests.

5.0 Assessment of Package Conformance

The Model 702 Transport Package must meet the Type B(U) transport package requirements of 10 CFR 71. The conformance criteria are detailed in the following two subsections.

5.1 Regulatory Requirements

- Normal Conditions of Transport Tests (71.43(f)): There should be no loss or dispersal of radioactive contents, no significant increase in external surface radiation levels and no substantial reduction in the effectiveness of the packaging.

- Hypothetical Accident Conditions (71.51(a)(2)): There should be no escape of radioactive materials greater than A_2 in one week and no external dose rate greater than 1 R/hr at one meter from the external surface when the package contains its maximum design radioactive contents.

5.2 Test Package Contents

The Model 702 is designed to carry special form Sources. Containment of the radioactive source is tested at manufacture. The source capsule design has been certified by the Competent Authority in accordance with the performance requirements for special form as specified in 10 CFR Part 71.75 and 49 CFR Part 73.469.

The test plan therefore does not discuss/specify tests of the containment of the radioactive source. The purpose of the tests is to demonstrate that the shielding remains effective within the limits specified by the regulations, and that the source remains contained within the device.

6.0 Construction and Condition of Test Specimens

For this test plan, one Model 702 test specimen will be used with three protective cages.

As the number of 702 units is limited, the test unit cask will be taken from the field population. This represents worst case, as a newly built 702 will not have undergone the abuse of a unit currently in use. If necessary, the unit will be modified to correspond to R-TP81 Rev B.

The Model 702 is not portable; therefore the unit will not be preconditioned prior to the hypothetical accident condition tests. Nevertheless, only one cask will be used for both the normal transport and the hypothetical accident condition tests. Three protective cages will be used during testing. The protective cage used for the normal transport condition tests will be reused for the Case 1, 9 meter (30 foot) free drop test. Separate protective cages will be used for the Case 2 and Case 3, 9 meter (30 foot) free drop tests.

For all Drop Test Cases the temperature of the carbon steel portions of the package must be below -40°C (-40°F) at the time of each test, a minimum temperature required by IAEA, Safety Series 6 (1985, as amended 1990). The low temperature represents the worst-case condition for the package because of the potential for brittle fracture of carbon steel components.

7.0 Material and Equipment List

The equipment lists, checklists, and data sheets in Section 9.0 list the key materials and equipment specified in 10 CFR 71 and the necessary measurement instruments.

When video recording is specified, select video cameras with the highest shutter speed practical to record testing.

Additional materials and equipment may be used to facilitate the tests.

8.0 Test Procedure

Three specimens are to be tested to determine the transport integrity of the package. The testing sequence is shown below:

1. Test specimen preparation and inspection
2. Compression test (10 CFR 71.71(c)(9))
3. Penetration test (10 CFR 71.71(c)(10))
4. 1.2 Meter (4 foot) free drop test (10 CFR 71.71(c)(7))
5. First intermediate test inspection
6. 9 Meter (30 foot) free drop test (10 CFR 71.73(c)(1))
7. Puncture test (10 CFR 71.73(c)(3))
8. Second intermediate test inspection
9. Thermal test (10 CFR 71.73(c)(4)) (if applicable -- see section 8.12)
10. Final test inspection

Since preconditioning is not required for the Model 702, only one specimen will be put through the entire test sequence. The remaining two specimens must complete the hypothetical accident conditions tests (Steps 6 through 10 in the testing sequence shown above). If test conditions such as the orientation at impact are not met during the test, the specimen may be replaced with a specimen of equivalent construction. The replacement must go through the entire test sequence. Note that the thermal test may not be required for any specimen depending on the assessment performed by **Engineering, Quality Assurance,** and **Regulatory Affairs** after the puncture test.

8.1 Roles and Responsibilities

The responsibilities of the groups identified in this plan are:

- **Engineering** executes the tests according to the test plan and summarizes the test results. **Engineering** also provides technical input to assist Regulatory Affairs and Quality Assurance as needed.
- **Regulatory Affairs** monitors the tests and reviews test reports for compliance with regulatory requirements.
- **Quality Assurance** oversees test execution and test report generation to ensure compliance with the AEAT/QSA Quality Assurance Program.
- **Engineering, Regulatory Affairs,** and **Quality Assurance** are jointly responsible for assessing test and specimen conditions relative to 10 CFR 71.

- **Quality Control**, a function that reports directly to Quality Assurance, is responsible for measuring and recording test and specimen data throughout the test cycle. **Engineering, Regulatory Affairs**, or **Quality Assurance** may also measure and record test and specimen data.

8.2 Specimen Temperature Measurement

The penetration, drop, and puncture tests are to be carried out while the carbon steel portions of the package are at or below -40°C. Temperature measurements will be made by positioning thermocouples on the skid, cage, and cask cover.

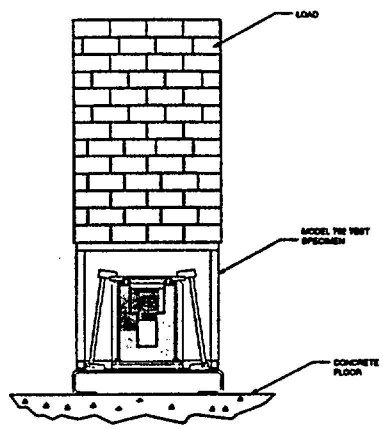
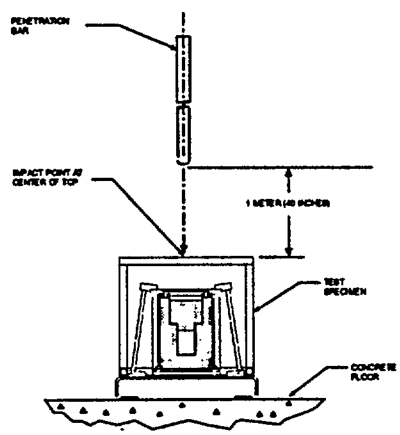
8.3 Test Specimen Preparation and Inspection

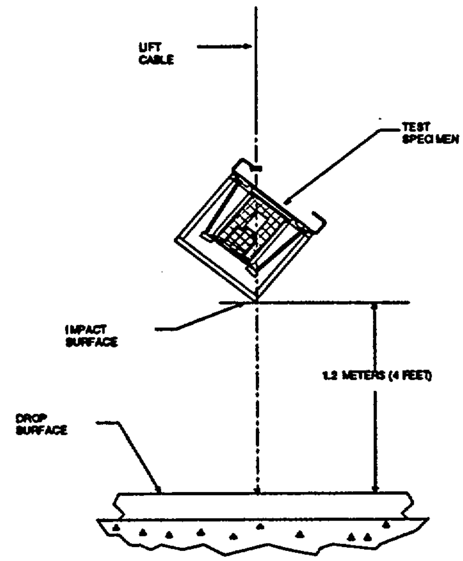
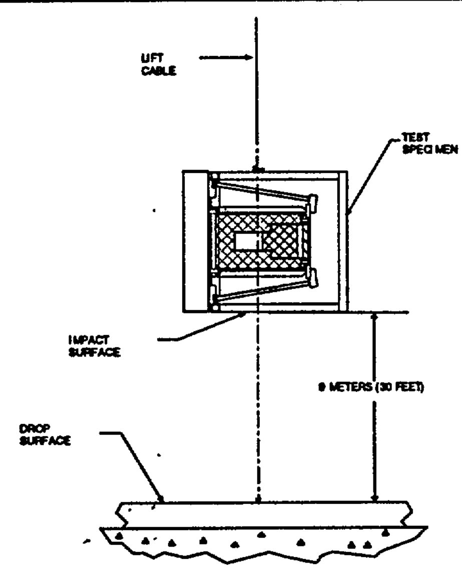
Refer to the *Specimen Preparation List* in Section 9.0 to ensure that the test sequence is followed. Sign and date the list when completed.

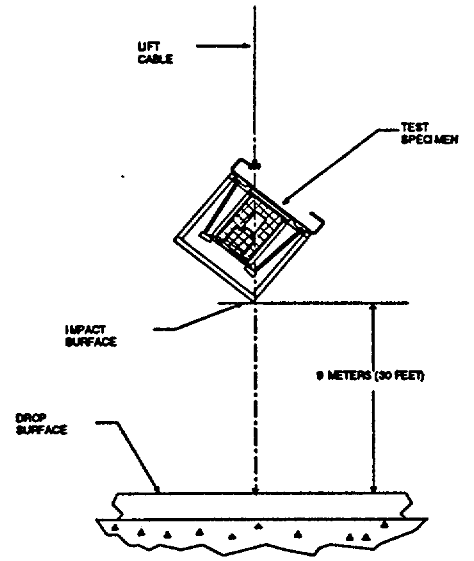
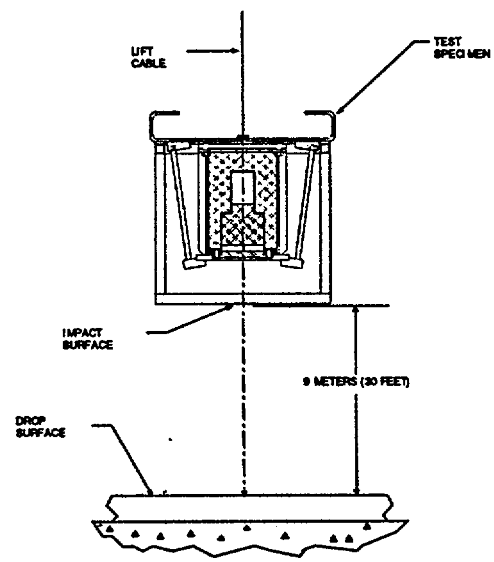
To prepare the test units:

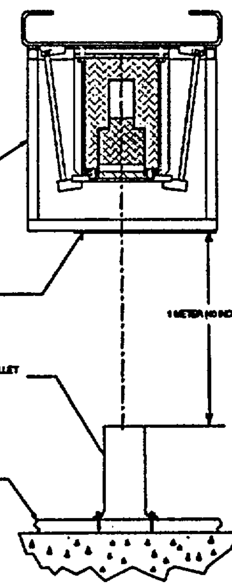
1. Inspect the test units to ensure that they comply with the requirements of Drawing R-TP81, Revision B.
2. Weigh the shipping cask and the tungsten plug.
3. Weigh the assembled test packages.
4. Perform and record the radiation profile in accordance with AEAT/QSA Work Instruction WI-Q09 for the test packages.
5. **Quality Control, Engineering, Regulatory Affairs, and Quality Assurance** will jointly verify that the test specimens comply with Drawing R-TP81, Revision B, and the AEAT/QSA Quality Assurance Program.
6. Place thermocouples on the cask, skid, and protective cage.
7. Prepare specimen TP81(A) and the cage/skid assemblies for TP81(B) and TP81(C) for transport.
8. Clearly and indelibly mark the units with identification.

8.4 Summary of Test Schedule

Test	Paragraph	Specimen	Diagram
Compression	71.71(c)(9)	TP81(A)	
Penetration	71.71(c)(10)	TP81(A)	

Test	Paragraph	Specimen	Diagram
1.2 Meter (4 Foot) Free Drop, Top, Long Edge Down	71.71(c)(7)	TP81(A)	
9 Meter (30 Foot) Free Drop, Horizontal, Short-Side Down	71.73(c)(1)	TP81(A)	

Test	Paragraph	Specimen	Diagram
9 Meter (30 Foot) Free Drop, Top, Long Edge Down	71.73(c)(1)	TP81(B)	
9 Meter (30 Foot) Free Drop, Vertical, Top Down	71.73(c)(1)	TP81(C)	

Test	Paragraph	Specimen	Diagram
Puncture, Vertical, Upside Down onto Cask Cover	71.73(c)(3)	TP81(C)	

8.5 Compression Test (10 CFR 71.71(c)(9))

The first test is the compression test, per 10 CFR 71.71(c)(9), in which the package is placed under a load of at least 2080 pounds. This load is the greater of five times the maximum package weight or 2 lbf/in^2 multiplied by the vertically projected area:

5 x 410 lbf = 2050 lbf

21" wide x 19" long x 2 lbf/in^2 = 798 lbf

Refer to *Equipment List 1* for information about required tools. Use *Checklist 1* to ensure that test sequence is followed. Use *Data Sheet 1* to record testing results. Sign and date all action items and record required data on the appropriate worksheets.

8.5.1 Compression Test Setup

To prepare specimen TP81(A) for the compression test:

1. Review the setup shown in Figure 3.
2. Place the specimen on a concrete surface oriented in its normal, upright transport position.
3. Gradually place a minimum of 2080 pounds uniformly distributed onto the specimen as shown in Figure 3.
4. Test specimen in accordance with *Checklist 1*.

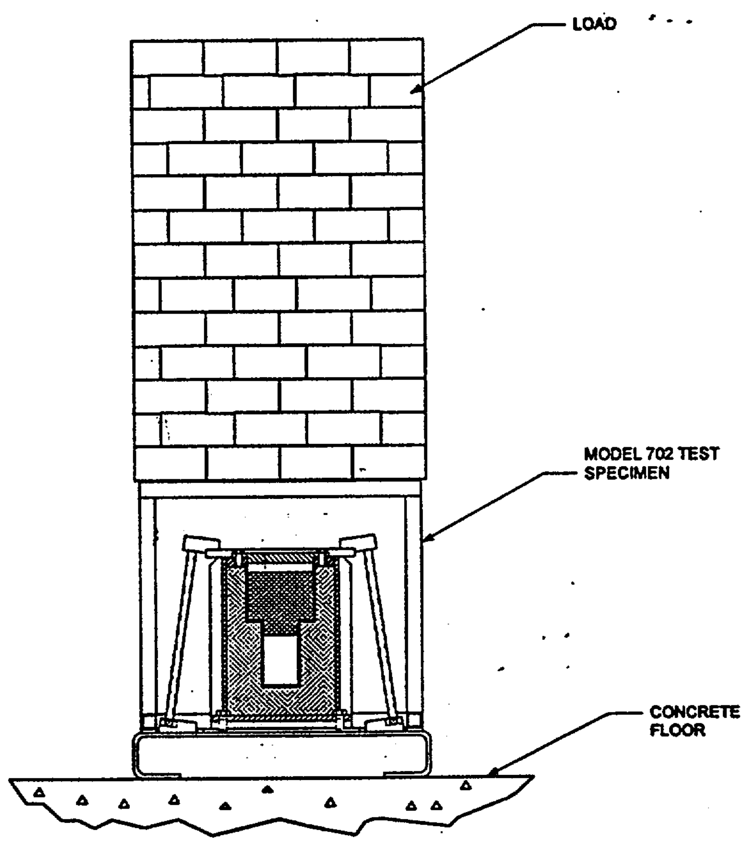


Figure 3. Compression Test Setup

8.5.2 Compression Test Assessment

Upon completion of the test, **Engineering, Regulatory Affairs,** and **Quality Assurance** team members will jointly take the following actions:

1. Review the test execution to ensure that the test was performed in accordance with 10 CFR 71.71.

2. Assess the damage to the specimen to decide whether testing of that specimen is to continue.

3. Evaluate the condition of the specimen to determine if changes are necessary in the package orientation for the penetration test to achieve maximum damage.

8.6 Penetration Test (10 CFR 71.71(c)(10))

The compression test is followed by the penetration test, per 10 CFR 71.71(c)(10), in which a penetration bar is dropped from a height of at least 40 inches to impact a specified point on the package. The bar is dropped through free air.

Refer to *Equipment List 2* for information about required tools. Use *Checklist 2* to ensure that the test sequence is followed. Use *Data Sheet 2* to record testing results. Sign and date all action items and record required data on the appropriate worksheets.

8.6.1 Penetration Test Setup

This test requires that the carbon steel portions of the test specimen be at -40°C or below at the time of the penetration bar release. The worksheet calls for measuring and recording the specimen temperature before and after the test.

To set up package TP81(A) for the penetration test:

1. Place the specimen on the drop surface (Drawing AT10122, Revision B) and position it according to the orientation described in the next section.

2. Position the penetration bar shown in Drawing BT10129, Revision B, directly above the specified point of impact, and raise the bar at least 40 inches above the target.

3. Measure the specimen's surface temperature to ensure that the package is at the required temperature.

4. Test specimen in accordance with *Checklist 2*.

8.6.2 Penetration Test Orientation

Test specimen TP81(A) is placed vertically, right side up on the drop surface specified in Drawing AT10122, Revision B. The desired impact point is on the perforated steel shell of the protective cage directly above the cask cover.

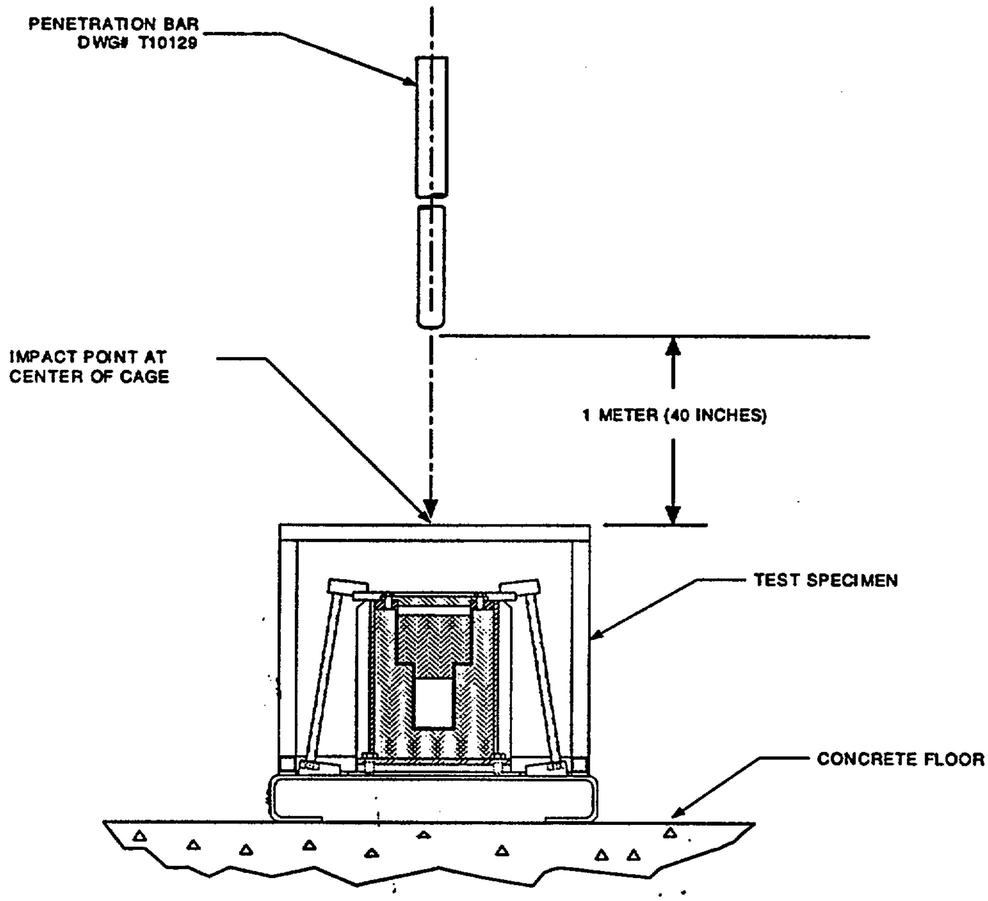


Figure 4. Penetration Test Orientation

8.6.3 Penetration Test Assessment

Upon completion of the test, **Engineering, Regulatory Affairs,** and **Quality Assurance** team members will jointly take the following actions:

1. Review the test execution to ensure that the test was performed in accordance with 10 CFR 71.71.

2. Assess the damage to the specimen to decide whether testing of that specimen is to continue.

3. Evaluate the condition of the specimen to determine if changes are necessary in the package orientation for the 1.2 meter (4 foot) free drop test to achieve maximum damage.

8.7 1.2 Meter (4 Foot) Free Drop Test (10 CFR 71.71(c)(7))

The final Normal Transport Conditions test is the 1.2 meter (4 foot) free drop as described in 10 CFR 71.71(c)(7). The drop compounds any damage caused in the first two tests. Upon completion of this step, the first intermediate test inspection will be performed.

Refer to *Equipment List 3* for information about required tools. Use *Checklist 3* to ensure that the test sequence is followed. Use *Data Sheet 3* to record testing results. Sign and date all action items and record required data on the appropriate worksheets.

8.7.1 1.2 Meter (4 Foot) Free Drop Test Setup

In this test, specimen TP81(A) is released from a height of 1.2 meter (4 feet) and lands on the steel drop surface specified in Drawing AT10122, Revision B.

This test requires that the carbon steel portions of the test specimen be at -40°C or below at the time of impact. Follow the instructions in the appropriate checklist for measuring and recording the test specimen temperature before and after the drop.

To set up specimen TP81(A) for the 1.2 meter (4 foot) free drop test:

1. Use the drop surface specified in Drawing AT10122, Rev. B.

2. Measure and record the test specimen temperature to ensure that the package is at the specified temperature.

3. Place the specimen on the drop surface and position it according to the orientation shown in Figure 5.

4. Raise the package so that the impact target is at least 4.0 feet above the drop surface.

5. Test specimen in accordance with *Checklist 3*.

8.7.2 1.2 Meter (4 Foot) Free Drop Test Orientation, Specimen TP81(A)

The impact surface of Specimen TP81(A) is the top, long edge of the protective cage as shown below.

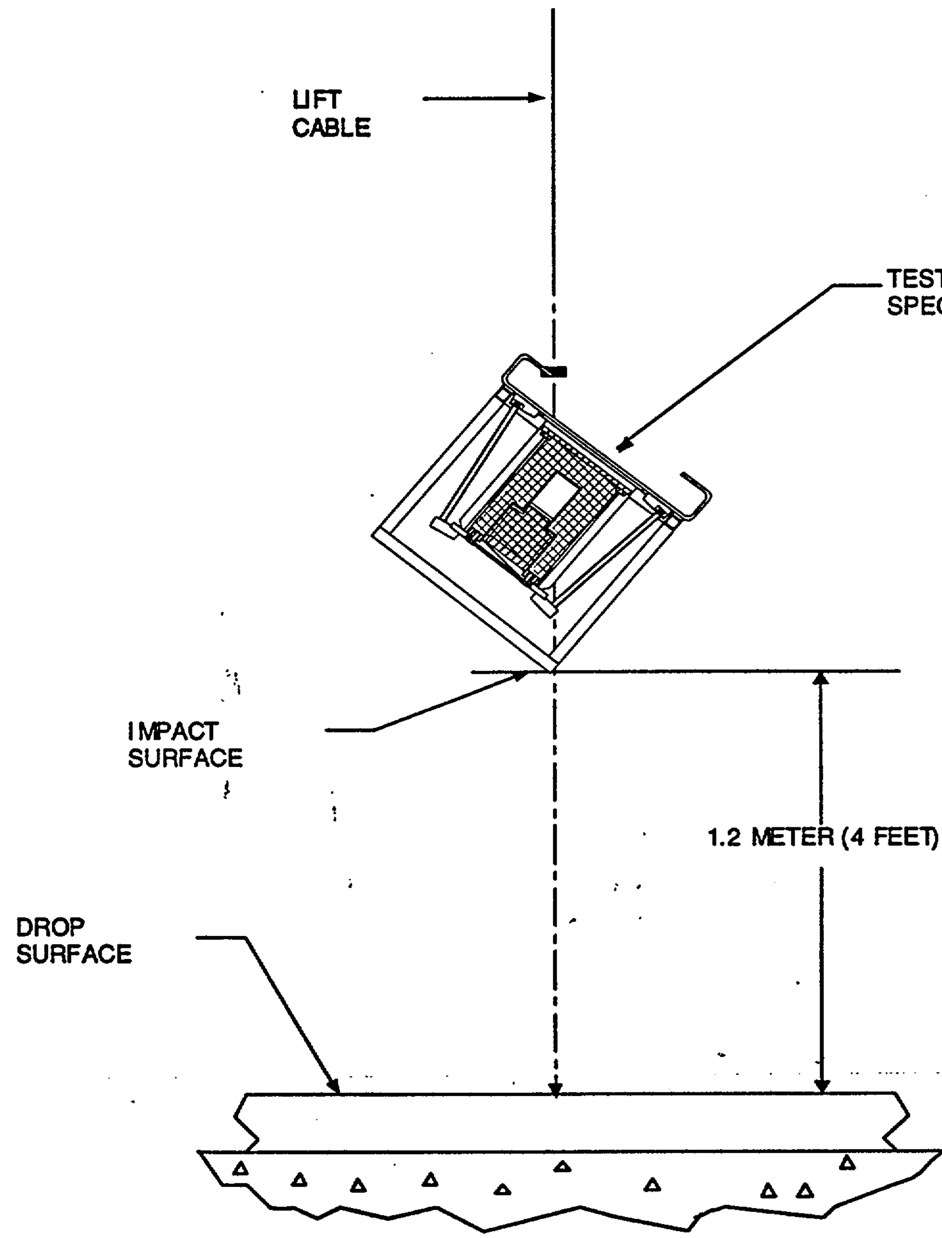


Figure 5. 1.2 Meter (4 Foot) Free Drop Test Orientation, Specimen TP81(A)

8.7.3 1.2 Meter (4 Foot) Free Drop Test Assessment

Upon completion of the test, **Engineering, Regulatory Affairs,** and **Quality Assurance** team members will jointly perform the following tasks:

1. Review the test execution to ensure that the test was performed in accordance with 10 CFR 71.71.

2. Assess the damage to the specimen to decide whether testing of that specimen is to continue.

3. Measure and record any damage to the test specimen.

4. Perform and record the radiation profile in accordance with AEAT/QSA Work Instruction WI-Q09.

8.8 First Intermediate Test Inspection

Engineering, Regulatory Affairs, and **Quality Assurance** team members will make an assessment of the test specimen and jointly determine whether the specimen meets the requirements of 10 CFR 71.

8.9 9 Meter (30 Foot) Free Drop Test (10 CFR 71.73(c)(1))

The first Hypothetical Accident Conditions test is the 9 meter (30 foot) free drop as described in 10 CFR 71.73(c)(1).

Refer to *Equipment List 4* for information about required tools. Use *Checklist 4* to ensure that the test sequence is followed. Use *Data Sheet 4* to record testing results. Sign and date all action items and record required data on the appropriate worksheets.

8.9.1 9 Meter (30 Foot) Free Drop Test Setup

In this test, the package is released from a height of 9 meters (30 feet) and lands on the steel drop surface specified in Drawing AT10122, Revision B.

This test requires that the carbon steel portions of the test specimen be at -40°C or below at the time of impact. Follow the instructions in the appropriate checklist for measuring and recording the test specimen temperature before and after the drop.

To set up a package for the 9 meter (30 foot) free drop test:

1. Use the drop surface specified in Drawing AT10122, Rev. B.

2. Measure and record the test specimen temperature to ensure that the package is at the specified temperature.

3. Place the specimen on the drop surface and position it according to the appropriate orientation:

   - Refer to Figure 6 for the TP81(A) package orientation
   - Refer to Figure 7 for the TP81(B) package orientation

- Refer to Figure 8 for the TP81(C) package orientation

4. Raise the package so that the impact target is at least 9 meters (30 feet) above the drop surface.

5. Test the specimen in accordance with *Checklist 4*.

8.9.2 9 Meter (30 Foot) Free Drop Test Orientation, Specimen TP81(A)

The impact surface of Specimen TP81(A) is the short side of the protective cage as shown below.

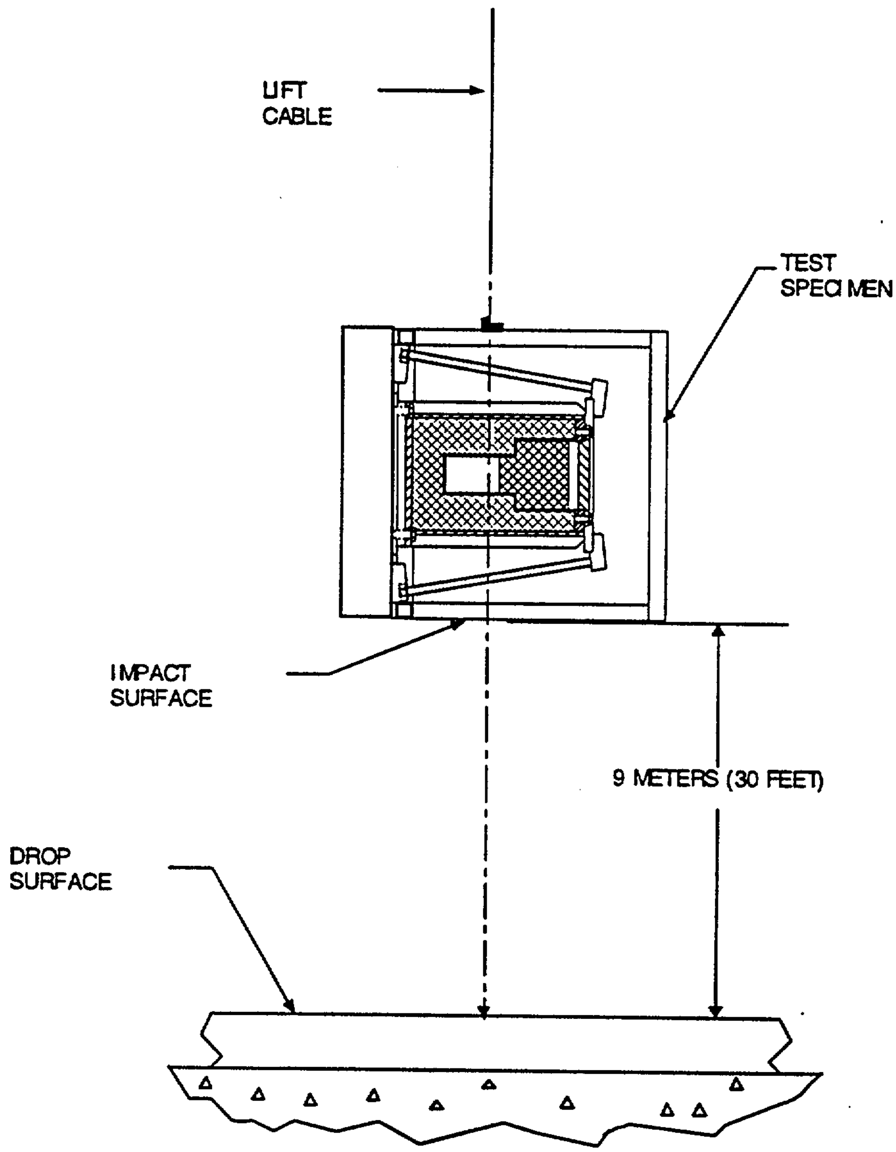


Figure 6. 9 Meter (30 Foot) Free Drop Orientation, Specimen TP81(A)

8.9.3 9 Meter (30 Foot) Free Drop Test Orientation, Specimen TP81(B)

The impact surface of Specimen TP81(B) is the top long edge of the protective cage as shown below.

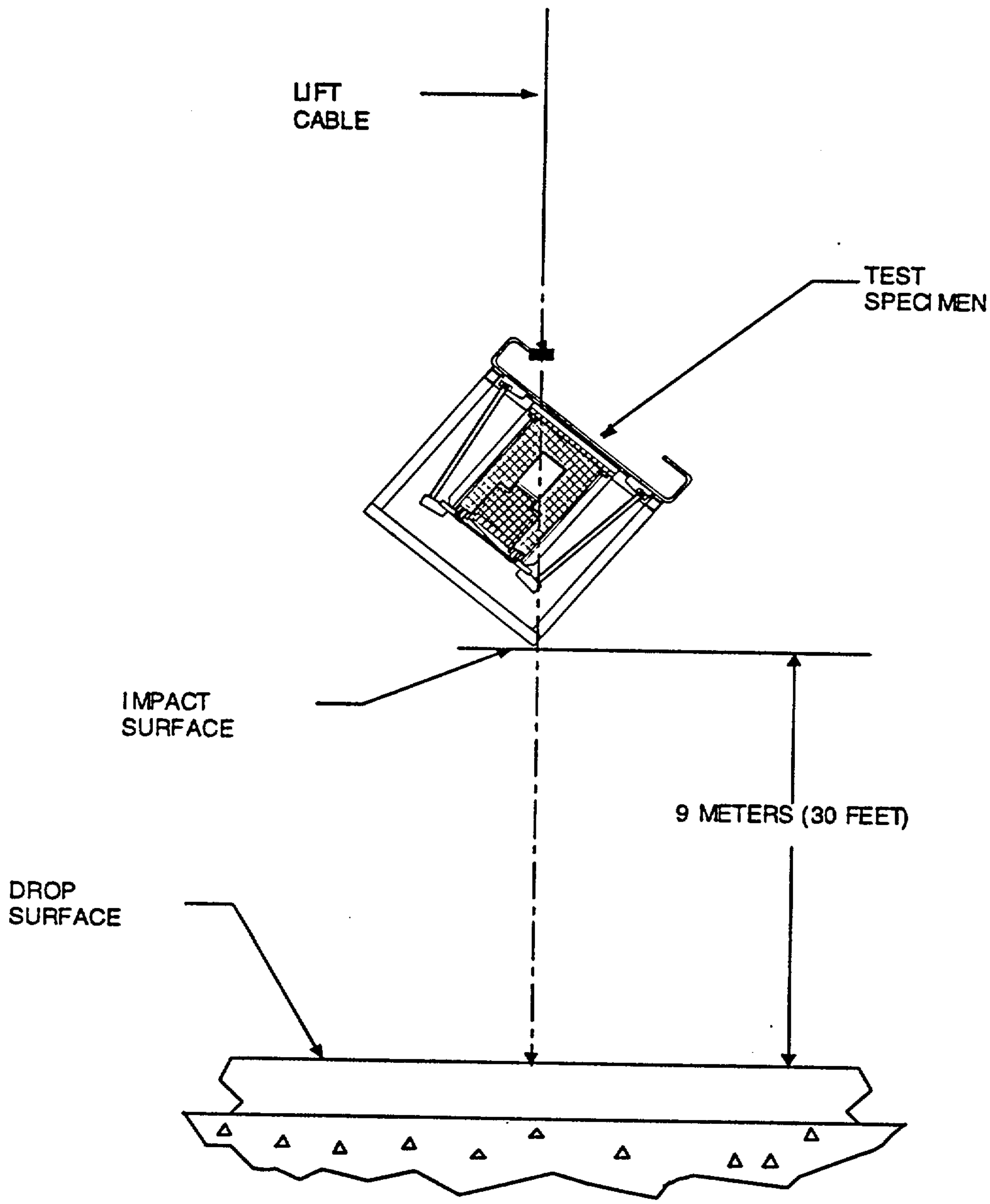


Figure 7. 9 Meter (30 Foot) Free Drop Orientation, Specimen TP81(B)

8.9.4 9 Meter (30 Foot) Free Drop Test Orientation, Specimen TP81(C)

The impact surface of Specimen TP81(C) is the top of the protective cage as shown below.

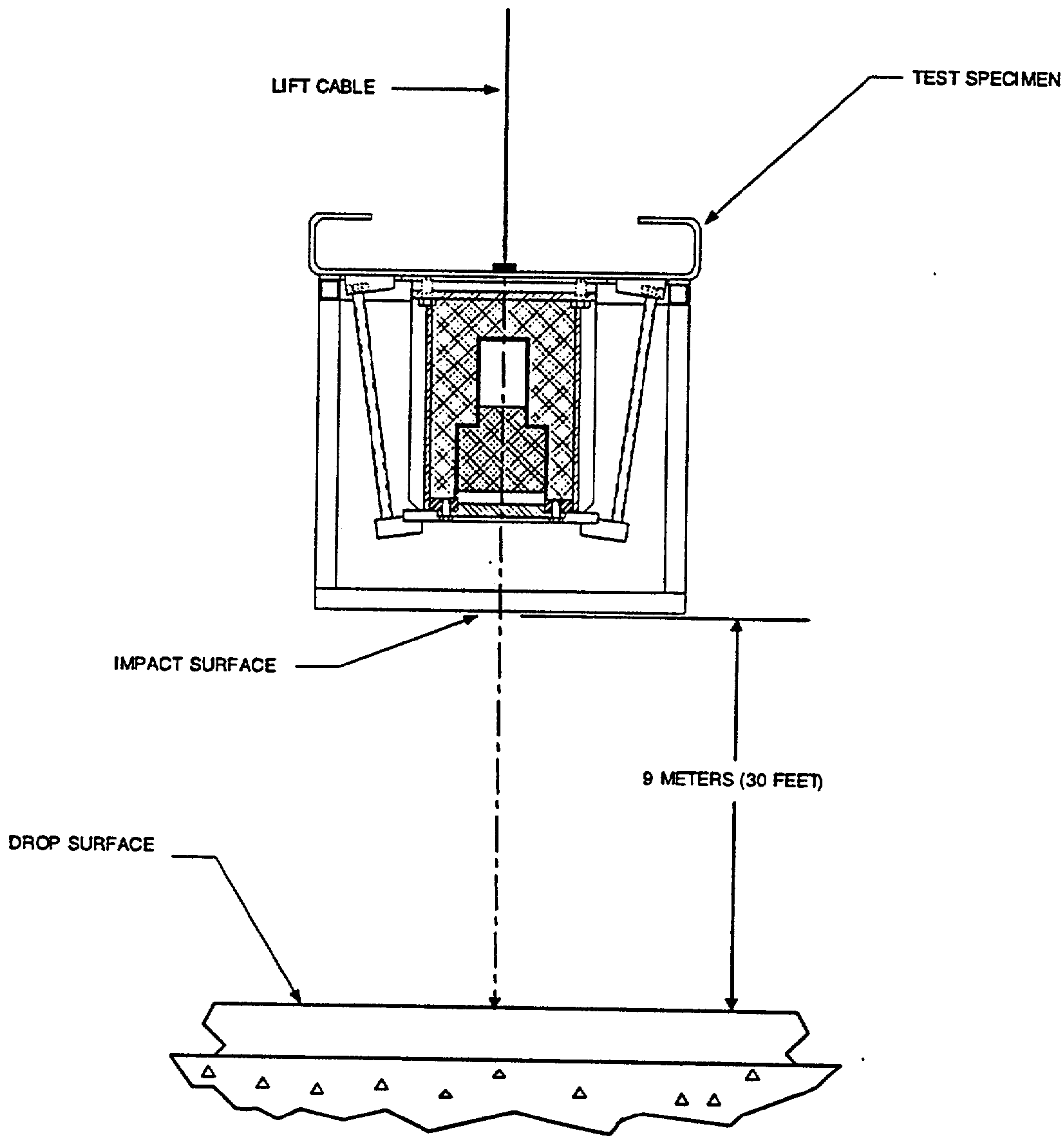


Figure 8. 9 Meter (30 Foot) Free Drop Orientation, Specimen TP81(C)

8.9.5 9 Meter (30 Foot) Free Drop Test Assessment

Upon completion of the test, **Engineering, Regulatory Affairs,** and **Quality Assurance** team members will jointly perform the following tasks:

1. Review the test execution to ensure that the test was performed in accordance with 10 CFR 71.73, and in accordance with the impact orientation and other conditions specified in this plan.

2. Select skid/cage assembly for use in the puncture bar test (see Section 4). The orientation is shown in Section 8.10.2, Figure 9.

8.10 Puncture Test (10 CFR 71.73(c)(3))

The 9 meter (30 foot) free drop is followed by the puncture test, per 10 CFR 71.73(c)(3), in which the package is dropped from a height of at least 1 meter (40 inches) onto the puncture billet specified in the Drawing CT10119, Revision C.

The billet is to be bolted to the drop surface used in the free drop tests. The 12-inch high puncture billet meets the minimum height (8 inches) required in 10 CFR 71.73(c)(3). The specimen has no projections or overhanging members longer than 8 inches, which could act as impact absorbers, thus allowing the billet to cause the maximum damage to the specimen.

Refer to *Equipment List 5* for information about required tools. Use *Checklist 5* to ensure that the test sequence is followed. Use *Data Sheet 5* to record testing results. Sign and date all action items and record required data on the appropriate worksheets.

This test requires that the carbon steel portions of the test specimen be at -40°C or below at the time of impact. Follow the instructions in the appropriate checklist for measuring and recording the test specimen temperature before and after the drop.

8.10.1 Puncture Test Setup

To set up a test specimen for the puncture test:

1. Measure and record the test specimen temperature to ensure that the package is at the specified temperature.

2. Position the test specimen according to Figure 9.

3. Check the alignment of the center-of-gravity with the targeted point of impact.

4. Raise the package so that there are at least 1 meter (40 inches) between the package and the top of the puncture billet.

5. Test the specimen in accordance with *Checklist 5*.

8.10.2 Puncture Test Orientation, Specimen TP81(C)

The test specimen is dropped vertically, top down onto the puncture billet. The orientation of the package is shown below. The desired impact point is on the cask cover bolts.

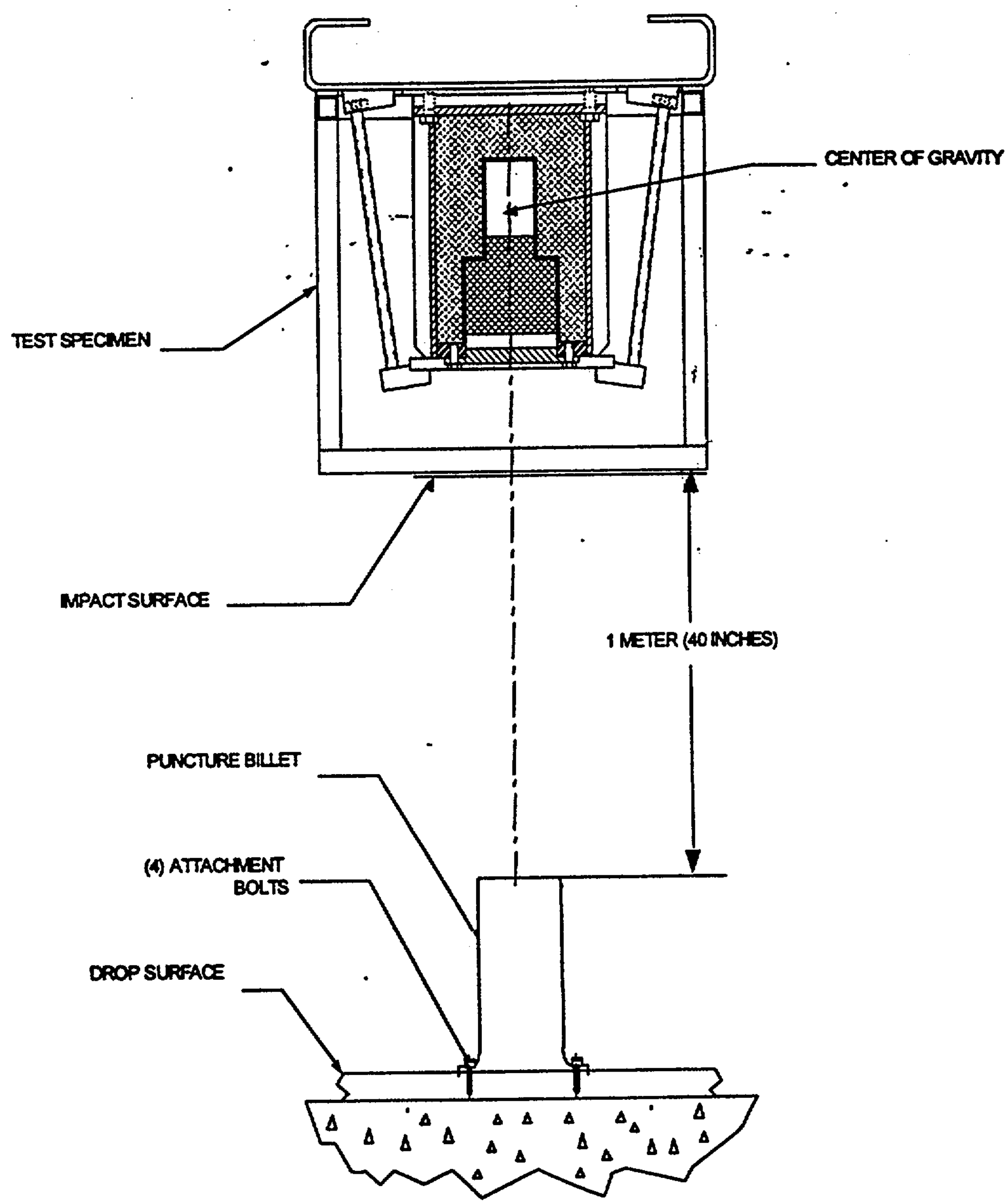


Figure 9. Puncture Test Orientation

8.10.3 Puncture Test Assessment

Upon completion of the test, **Engineering, Regulatory Affairs, and Quality Assurance team** members will jointly perform the following tasks:

1. Review the test execution to ensure that the test was performed in accordance with 10 CFR 71.73, and in accordance with any other conditions specified in this plan.

2. Assess the damage to the specimen to decide whether testing of the specimen is to continue.

8.11 Second Intermediate Test Inspection

Perform a second intermediate test inspection of specimen after the puncture test and before the thermal test.

1. Measure and record any damage to the test specimen.

2. Reassemble the package using an active source.

3. Measure and record a radiation profile of the test specimen in accordance with AEAT/QSA Work Instruction WI-Q09.

4. Review all results and decide whether a thermal test should be performed.

8.12 Thermal Test (10 CFR 71.73(c)(4))

The final requirement is the thermal test specified in 10 CFR 71.73(c)(4). The thermal performance of the package may be evaluated by analysis rather than by testing depending on the damage sustained by the package following the puncture test. The assessment as to whether to continue with the thermal test will be documented in the second intermediate test inspection described above.

Refer to *Equipment List 6* for information about required tools. Use *Checklist 6* to ensure that the test sequence is followed. Use *Data Sheet 6* to record testing results. Sign and date all action items and record required data on the appropriate worksheets.

8.12.1 Test Specimen Orientation

The decision to perform thermal testing will be based on an assessment of the damage sustained by the package following the puncture test. The thermal test orientation will also be determined based on an assessment of the test specimen condition.

8.12.2 Thermal Test Setup

To ensure sufficient heat input to the test specimens, the oven will be pre-heated to a temperature of not less than 810°C (1490°F). This temperature, above the required 800°C (1472°F), includes an allowance for measurement uncertainty.

The test environment is a vented oven capable of creating a time weighted average temperature of at least 810°C (1490°F).

Thermocouples will be attached to the specimen top, bottom, and two side surfaces. The two side surface thermocouples will be positioned 180 degrees apart, facing the front and back of the oven.

The external thermocouples will be shielded from the radiant heat of the oven so that the surface temperature of the transport package can be accurately measured.

When the oven has been pre-heated to 810°C (1490°F), the package will be placed in the oven in the orientation determined to be worst case. When the surface temperature has risen to no less than 810°C (1490°F), the test will start. The package will remain in the oven for a period of 30 minutes after the start of the test.

To allow for combustion, the oven door will remain slightly open. It has been determined that a gap of one inch at the top and bottom of the oven door allows airflow into the oven and allows the oven to maintain its temperature. The oven door is 36 inches long. As a result, there will be about a 36 square inch opening at both the top and bottom of the furnace door. This allows for the natural convection of air into the furnace.

If the specimen is burning when the oven is opened, the unit will be allowed to extinguish by itself and then cool naturally. Although solar radiation assumed during a hypothetical accident could reduce the rate of package cool down, such a reduction in cool down rate is considered to have a negligible effect on the package compared with the 30 minutes of exposure to 810°C (1490°F). Therefore, this test plan does not require insolation effects to be explicitly modeled during package cool down. Appropriate measures should be taken to avoid the radiological risks associated with this potential hazard. The final evaluation of the package is performed when the specimen reaches ambient temperature.

8.12.3 Thermal Test Procedure

To perform the thermal test:

1. Reassemble the package using the same simulated nest (plug) used in the specimen during the previous tests.
2. Make sure that the source position and the package configuration are the same as they were immediately after the puncture test.
3. Attach the thermocouples to the test specimen's measurement locations.
4. Preheat the oven temperature to not less than 810°C (1490°F).
5. When the oven temperature is stable at above 810°C (1490°F), place the specimen in the oven, and partially close the door.
6. When the temperature of the surface of the specimen rises above 810°C (1490°F), start the 30-minute time interval.
7. Throughout the test, measure and record the oven and the test specimen temperatures.
8. At the end of the 30 minute time interval, remove the test specimen.

WARNING: If the package is burning, appropriate safety measures must be in place to avoid the risks associated with burning depleted uranium. Consult with the oven operator and other appropriate personnel.

9. Allow the package to self-extinguish and cool.

10. Record any damage to the package and make a photographic and radiographic record of shield position and damage.

8.12.4 Thermal Test Assessment

Upon completion of the test, **Engineering, Regulatory Affairs,** and **Quality Assurance** team members will jointly perform the following task:

1. Review the test execution to ensure that the test was performed in accordance with 10 CFR 71.73 and the test conditions specified in this plan.

8.13 Final Test Inspection

Perform the following inspections after completion of all the required testing:

1. Measure and record any damage to the test specimen.
2. Measure and record a radiation profile of the test specimen in accordance with AEAT/QSA Work Instruction WI-Q09.
3. Document and assess the radiation level at one meter from the surface of the package.
4. Determine whether it is necessary to dismantle the test specimen for inspection of hidden component damage or failure.
5. If proceeding with the inspection, record and photograph the process of removing any component.
6. Measure and record any damage or failure found in the process of dismantling the test specimen.

Engineering, Regulatory Affairs, and **Quality Assurance** team members will make a final assessment of the test specimen, and jointly determine whether the specimen meets the requirements of 10 CFR 71.

9.0 Worksheets

Use the following worksheets for executing these tests. There are three worksheets for each test: an equipment list, a test procedure checklist, and a data sheet.

Use the test equipment list to record the serial number of each measurement device used. Attach a copy of the relevant inspection report or calibration certificate after verifying the range of accuracy of the equipment.

Quality Control will initial each step on the checklist as it is executed and record data as required. The **Engineering, Regulatory Affairs,** and **Quality Assurance** representatives must witness all testing to ensure the testing is performed in accordance with this test plan and 10 CFR 71.

Make copies of the forms for additional attempts. Maintain records of all attempts.

Note: Equipment List 6, Checklist 6, and Data Sheet 6 will only be required if it is determined that damage to a specimen is sufficient to warrant a thermal test.

Specimen Preparation List

Step	TP81(A)	TP81(B)	TP81(C)
1. Serial Number:			
2. Weight of tungsten plug (lb):			
3. Weight of cask (lb):			
4. Weight of skid (lb):			
5. Weight of cage (lb):			
6. Total weight of package (lb):			
7. Attach thermocouples to the cask, the skid, and the protective cage.			
8. All fabrication and inspection records documented in accordance with the AEAT QA Program?			
9. Does the unit comply with the requirements of Drawing R-TP81, Revision B?			
10. Has the radiation profile been recorded in accordance with AEAT QSA Work Instruments WI-Q09?			
11. Is the package prepared for transport?			

Verified by:	Print Name:	Signature:	Date:
Engineering			
Regulatory Affairs			
Quality Assurance			

Equipment List 1: Compression Test

Description	Enter the Model and Serial Number	Attach Inspection Report or Calibration Certificate
Weight Scale		
Record any additional tools used to facilitate the test and attach the appropriate inspection report or calibration certificate.		

	Print Name:	Signature:	Date:
Completed by:			
Verified by:			

Checklist 1: Compression Test

Step	TP81(A)
1. Position the specimen on concrete surface, per the appropriate drawing.	Figure 3
2. Measure the ambient temperature.	
Note the instrument used:	
3. Apply a uniformly distributed weight of at least 2080 pounds on the top of the protective cage for a period of 24 hours.	
Record the actual weight:	
Note the instrument used:	
Record start time and date:	
4. After 24 hours, remove the weight.	
Record end time and date:	
5. Measure the ambient temperature.	
Note the instrument used:	
6. Photograph the test specimen and record any damage on Data Sheet 1.	
7. **Engineering, Regulatory Affairs and Quality Assurance** make a preliminary assessment, per Section 8.5.2. Record the assessment on Data Sheet 1. Determine what changes are necessary in package orientation for the penetration test to achieve maximum damage.	

Verified by:	Print Name:	Signature:	Date:
Engineering			
Regulatory Affairs			
Quality Assurance			

Data Sheet 1: Compression Test

Test Unit Model and Serial Number:		Test Specimen: **TP81 (A)**
Test Date:	Test Time:	Test Plan 81 Step No.: **8.5**
Describe test orientation and setup:		
Describe on-site inspection (damage, broken parts, etc.):		
On-site assessment: Engineering: ____________ Regulatory: ____________ QA: ____________		
Describe any post-test disassembly and inspection:		
Describe any change in source position: **NOT APPLICABLE**		
Completed by:		Date:

Equipment List 2: Penetration Test

Description	Enter the Model and Serial Number	Attach Inspection Report or Calibration Certificate
Penetration Bar	Drawing BT10129, Rev. B	
Drop Surface	Drawing AT10122, Rev. B	
Thermometer		
Thermocouple		
Thermocouple		
Thermocouple		
Record any additional tools used to facilitate the test and attach the appropriate inspection report or calibration certificate.		

	Print Name:	Signature:	Date:
Completed by:			
Verified by:			

Checklist 2: Penetration Test

Step	TP81(A)
1. Immerse specimen in dry ice or cool in freezer to bring carbon steel portions of the specimen below –40°C.	
2. Position the package as shown in the referenced figure.	Figure 4
3. Begin video recording of the test.	
4. Inspect the orientation setup and verify the bar height.	
5. Photograph the set-up in at least two perpendicular planes.	
6. Measure the ambient temperature and the specimen temperatures. Ensure that the specimen is at the specified temperature. Note the instrument used:	
Record the ambient temperature:	
Record the cask temperature:	
Record the skid temperature:	
Record the protective cage temperature:	
7. Drop the penetration bar.	
8. Check to ensure that penetration bar hit the specified area.	
9. Measure the specimen's surface temp. Ensure that specimen is at specified temp.	
Note the instrument used:	
10. Photograph the test specimen and record any damage on Data Sheet 2.	
11. **Engineering, Regulatory Affairs and Quality Assurance** make a preliminary assessment, per Section 8.6.3. Record the assessment on Data Sheet 2. Determine what changes are necessary in package orientation for the 1.2 meter (4 foot) free drop to achieve maximum damage.	

Verified by:	Print Name:	Signature:	Date:
Engineering			
Regulatory Affairs			
Quality Assurance			

Data Sheet 2: Penetration Test

Test Unit Model and Serial Number:		Test Specimen: **TP81 (A)**
Test Date:	Test Time:	Test Plan 81 Step No.: **8.6**
Describe test orientation and setup:		
Describe impact (location, rotation, etc.):		
Describe on-site inspection (damage, broken parts, etc.):		
On-site assessment: Engineering: ____________ Regulatory: ____________ QA: ____________		
Describe any post-test disassembly and inspection:		
Describe any change in source position: **NOT APPLICABLE**		
Describe results of any pre- or post-test radiography:		
Completed by:		Date:

Equipment List 3: 1.2 Meter (4 Foot) Free Drop

Description	Enter the Model and Serial Number	Attach Inspection Report or Calibration Certificate
Drop Surface	Drawing AT10122, Rev. B	
Thermometer		
Thermocouple		
Thermocouple		
Thermocouple		
Record any additional tools used to facilitate the test and attach the appropriate inspection report or calibration certificate.		

	Print Name:	Signature:	Date:
Completed by:			
Verified by:			

Checklist 3: 1.2 Meter (4 Foot) Free Drop

Step	TP81(A)
1. Immerse specimen in dry ice or cool in freezer to bring carbon steel portions of the specimen below –40°C.	
2. Measure the ambient temperature.	
Note the instrument used:	
3. Attach the test specimen to the release mechanism.	
4. Begin video recording of the test.	
5. Measure specimen temperatures. Ensure specimen is at specified temperature. Note the instrument used:	
Record the cask temperature:	
Record the skid temperature:	
Record the protective cage temperature:	
6. Lift and orient the test specimen as shown in the specified referenced figure.	Figure 5
7. Inspect the orientation setup and verify drop height.	
8. Photograph the set-up in at least two perpendicular planes.	
9. Release the test specimen.	
10. Measure specimen temperatures. Ensure specimen is at specified temperature. Note the instrument used:	
Record the cask temperature:	
Record the skid temperature:	
Record the protective cage temperature:	
11. Photograph the test specimen and record any damage on Data Sheet 3.	
12. Measure and record a radiation profile of the test specimen in accordance with AEAT/QSA Work Instruction WI-Q09.	
13. **Engineering, Regulatory Affairs and Quality Assurance** make a preliminary assessment, per Section 8.7.3. Record assessment on Data Sheet 3. Determine what changes are necessary in package orientation for the 9 meter (30 foot) free drop to achieve maximum damage.	

Verified by:	Print Name:	Signature:	Date:
Engineering			
Regulatory Affairs			
Quality Assurance			

Data Sheet 3: 1.2 Meter (4 Foot) Free Drop

Test Unit Model and Serial Number:		Test Specimen: **TP81 (A)**
Test Date:	Test Time:	Test Plan 81 Step No.: **8.7**

Describe drop orientation and drop height:

Describe impact (location, rotation, etc.):

Describe on-site inspection (damage, broken parts, etc.):

On-site assessment:

Engineering: ____________ Regulatory: ____________ QA: ____________

Describe any post-test disassembly and inspection:

Describe any change in source position: **NOT APPLICABLE**

Describe results of any pre- or post-test radiography:

Completed by:	Date:

Equipment List 4: 9 Meter (30 Foot) Free Drop

Description	Enter the Model and Serial Number	Attach Inspection Report or Calibration Certificate
Drop Surface	Drawing AT10122, Rev. B	
Thermometer		
Thermocouple		
Thermocouple		
Thermocouple		
Record any additional tools used to facilitate the test and attach the appropriate inspection report or calibration certificate.		

	Print Name:	Signature:	Date:
Completed by:			
Verified by:			

Checklist 4: 9 Meter (30 Foot) Free Drop

Step	TP81(A)	TP81(B)	TP81(C)
1. Immerse specimen in dry ice or cool in freezer to bring carbon steel portions of the specimen below –40°C.			
2. Measure the ambient temperature.			
Note the instrument used:			
3. Attach the test specimen to the release mechanism.			
4. Begin Video Recording of the test..			
5. Measure specimen temperatures. Ensure specimen is at specified temperature. Note the instrument used:			
Record the cask temperature:			
Record the skid temperature:			
Record the protective cage temperature:			
6. Lift and orient the test specimen as shown in the specified referenced figure.	Figure 6	Figure 7	Figure 8
7. Inspect the orientation setup and verify drop height.			
8. Photograph the setup in at least two perpendicular planes.			
9. Release the test specimen.			
10. Measure specimen temperatures. Ensure specimen is at specified temperature. Note the instrument used:			
Record the cask temperature:			
Record the skid temperature:			
Record the protective cage temperature:			
11. Photograph the test specimen and record any damage on Data Sheet 4.			
12. **Engineering, Regulatory Affairs and Quality Assurance** make a preliminary assessment, per Section 8.9.5. Record assessment on Data Sheet 4. Determine what changes are necessary in package orientation for the puncture test to achieve maximum damage.			

Verified by:	Print Name:	Signature:	Date:
Engineering			
Regulatory Affairs			
Quality Assurance			

Data Sheet 4: 9 Meter (30 Foot) Free Drop

Test Unit Model and Serial Number:		Test Specimen: **TP81(A)**
Test Date:	Test Time:	Test Plan 81 Step No.: **8.9**
Describe drop orientation and drop height:		
Describe impact (location, rotation, etc.):		
Describe on-site inspection (damage, broken parts, etc.):		
On-site assessment: Engineering: ____________ Regulatory: ____________ QA: ____________		
Describe any post-test disassembly and inspection:		
Describe any change in source position: **NOT APPLICABLE**		
Describe results of any pre- or post-test radiography:		
Completed by:		Date:

Data Sheet 4: 9 Meter (30 Foot) Free Drop

Test Unit Model and Serial Number:		Test Specimen: **TP81(B)**
Test Date:	Test Time:	Test Plan 81 Step No.: **8.9**

Describe drop orientation and drop height:

Describe impact (location, rotation, etc.):

Describe on-site inspection (damage, broken parts, etc.):

On-site assessment:

Engineering: ____________________ Regulatory: ____________________ QA: ____________________

Describe any post-test disassembly and inspection:

Describe any change in source position: **NOT APPLICABLE**

Describe results of any pre- or post-test radiography:

Completed by:	Date:

Data Sheet 4: 9 Meter (30 Foot) Free Drop

Test Unit Model and Serial Number:		Test Specimen: TP81(C)
Test Date:	Test Time:	Test Plan 81 Step No.: 8.9

Describe drop orientation and drop height:

Describe impact (location, rotation, etc.):

Describe on-site inspection (damage, broken parts, etc.):

On-site assessment:

Engineering: ____________ Regulatory: ____________ QA: ____________

Describe any post-test disassembly and inspection:

Describe any change in source position: **NOT APPLICABLE**

Describe results of any pre- or post-test radiography:

Completed by:	Date:

Equipment List 5: Puncture Test

Description	Enter the Model and Serial Number	Attach Inspection Report or Calibration Certificate
Drop Surface	Drawing AT10122, Rev. B	
Puncture Billet	Drawing CT10119, Rev. C	
Thermometer		
Thermocouple		
Thermocouple		
Thermocouple		
Record any additional tools used to facilitate the test and attach the appropriate inspection report or calibration certificate.		

	Print Name:	Signature:	Date:
Completed by:			
Verified by:			

Checklist 5: Puncture Test

Step	TP81(C)
1. Immerse specimen in dry ice or cool in freezer to bring carbon steel portions of the specimen below –40°C.	
2. Measure the ambient temperature.	
Note the instrument used:	
3. Attach the test specimen to the release mechanism:	
4. Begin Video Recording of the test.	
5. Measure specimen temperatures. Ensure specimen is at specified temperature. Note the instrument used:	
Record the cask temperature:	
Record the skid temperature:	
Record the protective cage temperature:	
6. Lift and orient the test specimen as shown in the specified referenced figure, or as determined during the assessment of the 9 meter (30 foot) drop test.	Figure 9
7. Inspect the orientation setup and verify drop height.	
8. Photograph the set-up in at least two perpendicular planes.	
9. Release the test specimen.	
14. Measure specimen temperatures. Ensure specimen is at specified temperature. Note the instrument used:	
Record the cask temperature:	
Record the skid temperature:	
Record the protective cage temperature:	
10. Photograph the test specimen and record any damage on Data Sheet 5.	
11. Profile the shipping cask.	
12. **Engineering, Regulatory Affairs and Quality Assurance** make a preliminary assessment, per Section 8.10.5. Record assessment on Data Sheet 5. Determine what changes are necessary in package orientation for thermal test to achieve maximum damage.	

Verified by:	Print Name:	Signature:	Date:
Engineering			
Regulatory Affairs			
Quality Assurance			

Data Sheet 5: Puncture Test

Test Unit Model and Serial Number:		Test Specimen: **TP81 (C)**
Test Date:	Test Time:	Test Plan 81 Step No.: **8.10**

Describe drop orientation and drop height:

Describe impact (location, rotation, etc.):

Describe on-site inspection (damage, broken parts, etc.):

On-site assessment:

Engineering: ____________________ Regulatory: ____________________ QA: ____________________

Describe any post-test disassembly and inspection:

Describe any change in source position: **NOT APPLICABLE**

Describe results of any pre- or post-test radiography:

Completed by:	Date:

Equipment List 6: Thermal Test

Description	Enter the Model and Serial Number	Attach Inspection Report or Calibration Certificate
Thermocouple		
Thermocouple		
Thermocouple		
Thermocouple		
Oven		
Oven thermostat		
Record any additional tools used to facilitate the test and attach the appropriate inspection report or calibration certificate.		

	Print Name:	Signature:	Date:
Completed by:			
Verified by:			

Checklist 6: Thermal Test

Step	TP81(A)	TP81(B)	TP81(C)
1. Record the serial number of the test specimen.			
2. Preheat the oven to 810°C (1490°F).			
3. Attach the thermocouples. Ensure the recording devices are active, and that the external thermocouples are shielded.			
4. Place the package in the oven in the worst case orientation and partially close the oven door such that a 1 inch by 36 inch opening is provided. Record the time.			
5. When all of the test specimen's surface temperatures exceed 810°C (1490°F), begin the 30-minute time interval. Record the time.			
6. Monitor and record the test specimen and the oven temperatures throughout the 30-minute period to ensure that they are above 810°C (1490°F).			
7. At the end of the 30-minute test period, remove the test specimen from the oven. Record the time.			
8. Describe combustion when door is opened.			
NOTE: If specimen continues to burn, let it self-extinguish and cool naturally.			
9. Measure and record the ambient temperature.			
10. Photograph the test specimen and record any damage on Data Sheet 6.			
11. If necessary, radiograph the unit to document its condition.			
12. Profile the test specimen.			
13. Engineering, Regulatory Affairs and Quality Assurance make a preliminary assessment relative to 10 CFR 71. Record assessment on Data Sheet 6.			

Verified by:	Print Name:	Signature:	Date:
Engineering			
Regulatory Affairs			
Quality Assurance			

Data Sheet 6: Thermal Test

Test Unit Model and Serial Number:		Test Specimen:
Test Date:	Test Time:	Test Plan 81 Step No.: **8.12**

Describe test orientation and setup:

Describe package during testing:

Describe on-site inspection (damage, broken parts, etc.):

On-site assessment:

Engineering: ____________________ Regulatory: ____________________ QA: ____________________

Describe any post-test disassembly and inspection:

Describe any change in source position: **NOT APPLICABLE**

Describe results of any pre- or post-test radiography:

Completed by:	Date:

Appendix A

Test Plan Drawing -	**R-TP81, Revision B**
702 Descriptive Drawing -	**R-70290, Revision E**

Appendix C: Test Plan 81 Report (Model 702)

C-1 Test Plan 81 Report (Not Including Appendices A, B, and C)

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SENTINEL

TEST PLAN NO. 81, Rev. 1	
TEST PLAN COVER SHEET	
TEST TITLE: Model 702 Transport Package Type B Transport Tests	
PRODUCT MODEL: Model 702	
ORIGINATED BY: [signature]	DATE: 30 MAR 99
TEST PLAN REVIEW	
ENGINEERING APPROVAL: [signature]	DATE: 31 MAR 99
QUALITY ASSURANCE APPROVAL: D.W. Kurtz	DATE: 31 Mar 99
REGULATORY APPROVAL: C. Kongham	DATE: 31 Mar 99
COMMENTS:	
TEST RESULTS REVIEW	
ENGINEERING APPROVAL: [signature]	DATE: 03 Nov 99
QUALITY ASSURANCE APPROVAL: C. Kongham	DATE: 9 Nov 99
REGULATORY APPROVAL: [signature]	DATE: 11 Nov 99

Amersham QSA

TEST PLAN 81 REPORT

MODEL 702

September 8, 1999

Prepared By: Laura Ridzon, MPR Associates, Inc. Date: 08 SEPT 1999

Reviewed By: Nicholas J. Marrone, MPR Associates, Inc. Date: 8 SEPT 1999

Approved By: Caroline S. Schlaseman, MPR Associates, Inc. Date: 8 SEPT 99

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