71-9269

QSA GLOBAL

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1 March 2006

Mr. Robert Nelson, Chief
Licensing Section
Spent Fuel Project Office
Office of Nuclear Material Safety and Safeguards
U.S. Nuclear Regulatory Commission
11555 Rockville Pike
One White Flint
Rockville, MD 20852

Subject: Amendment for USA/9269/B(U)-96 for Addition of Se-75 as Authorized Contents for the Model 650L Transport Package

Dear Mr. Nelson:

Enclosed is a hard copy of the original documentation we submitted on 31 Oct 2005 to amend the referenced Type B certificate. Also enclosed is a copy of the 9 Feb 2006 letter we submitted to you clarifying review for this package to include Se-75 as well as an email from Kenny Nguyen dated 23 Nov 2006 which references the re-formatting of our original submission sent in on 31 Oct 2005. Should you have any additional questions or wish to discuss this submission, please contact me as shown below.

Sincerely,

Lori Podolak

Lori Podolak
Product Licensing Specialist
Regulatory Affairs Department
Ph: (781) 272-2000 ext 241
Fax: (781) 359-9191
Email: Lori.Podolak@qsa-global.com

NMSS01

From: "Kenny Nguyen" <KDN@nrc.gov>
To: <Lori.Podolak@qsa-global.com>
Date: 11/23/2005 11:10:20 AM
Subject: Re: QSA Global Type B Electronic Submission 650L

Hi Lori,

Fast Web View needs to be enable. Other than that, it looks great!

Thanks,
Kenny Nguyen
OIS/IRSD/ADDPS
301-415-2046

>>> "Lori Podolak" <Lori.Podolak@qsa-global.com> 11/23/05 10:45 AM >>>
Kenny,

Attached is a reformatted version of the file originally submitted to the NRC for USA/9269/B(U) on 31 Oct 05. Please let me know if this format is acceptable or if it still requires modification. Thanks,

Lori Podolak

Lori Podolak
Product Licensing Specialist
QSA Global Inc.
40 North Avenue
Burlington, MA 01803

On October 10th 2005, we changed our name to QSA Global Inc.
As QSA Global Inc., we remain committed to providing you with the same level of world class service you have come to expect from AEA Technology QSA, Inc.

QSA GLOBAL

QSA Global, Inc.
40 North Avenue
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9 February 2006

Mr. Robert Nelson, Chief
Licensing Section
Spent Fuel Project Office
Office of Nuclear Material Safety and Safeguards
U.S. Nuclear Regulatory Commission
11555 Rockville Pike
One White Flint
Rockville, MD 20852

Subject: Renewal for USA/9269/B(U)-96 for Addition of Se-75 as Authorized Contents for the Model 650L Transport Package

Dear Mr. Nelson:

QSA Global Inc. wishes to clarify that the renewal request we submitted for your review on 31 October 2005 also includes the addition of Se-75 to the authorized contents as special form capsules up to a maximum activity of 300 Ci. The supportive documentation and justification for this Se-75 request is contained in the SAR submitted with our 31 October 2005 application for this transport package.

Should you have any additional questions or wish to discuss this submission prior to our response, please contact me as shown below.

Sincerely,

Lori Podolak

C Kaufman — RA/QA Approval — 9 Feb 06 — Date

Lori Podolak
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AEA Technology
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31 October 2005

ATTN: Document Control Desk
Director, Spent Fuel Project Office
Office of Nuclear Material Safety and Safeguards
U.S. Nuclear Regulatory Commission
11555 Rockville Pike
One White Flint
Rockville, MD 20852

RE: Renewal Application for USA/9269/B(U)-85

Dear Director:

Enclosed please find an application for an amendment in entirety to the Type B(U) approval of the Model 650L transport package. Please note that AEA Technology QSA Inc has recently changed ownership and the new name is QSA Global Inc. There is no change in the organisational structure or safety/regulatory programs of our facility.

The application was completed following updated submission guidance and includes additional compliance information in accordance with IAEA Regulations for the Safe Transport of Radioactive Material, 1996 Edition (Revised), No. TS-R-1. We request the renewal of this Type B(U) package transport certificate and that the renewed certificate be endorsed to the –96 version of IAEA (TS-R-1). This is an electronic submission made in accordance with 10 CFR 71.1 in CD-ROM format. Copies of this submission are authorised for publication on the USNRC document sites and for use in evaluation of this application. The contact information for questions related to this submission is:

Lori Podolak — Phone No.: (781) 272-2000 ext 241
Product Licensing Specialist
Regulatory Affairs Department — Email: Lori.Podolak@qsa-global.com
QSA Global Inc.
40 North Avenue
Burlington, MA 01463

The CD-ROM labeled "QSA Model 650L SAR Rev 3" contains the following file:

File Name	File Size	Sensitivity Level	Description
001_QSA Model 650L SAR Rev 3	16 MB	Publicly Available	Rev 3 to the SAR for the Model 650L package including a list of affected pages.

The electronic submission is made in Adobe Acrobat format. There are no special instructions regarding the use of the CD-ROM in order to open the files. Should you have any additional questions or wish to discuss this submission after receipt please contact me at the number shown above.

Sincerely,

Lori Podolak
Product Licensing Specialist
Regulatory Affairs Department

C. Roughman	31 Oct 05
RA/QA Approval	Date
	31 Oct 05
Engineering Approval	Date

Enclosures: Revision 3 to SAR
List of Affected Pages

Safety Analysis Report for the Model 650L Transport Package

List of Affected Pages	
Revision 1, 19 November, 1999	Replacement of Appendix A Index; Added Drawing R65006, Revision F to Appendix A.
Revision 2, 31 October, 2000	Replacement of Appendix A Index; Added Drawing R65006, Revision G to Appendix A.
Revision 3, 4 November 2005	Reformatting of the SAR to cover compliance to IAEA TS-R-1 and NRC guidance format. Addition of Se-75 as authorized nuclide.

Safety Analysis Report

QSA Global Inc.

Model 650L
Type B(U) - 96
Transport Package

31 October 2005

Revision 3

Contents

List of Tables

List of Figures

Section 1 - GENERAL INFORMATION

1.1 Introduction

The Model 650L is designed as an industrial radiography source changer and transport package for Type B quantities of special form radioactive material. It conforms to the Type B(U)-96 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 Package Description

(Reference:

- *10 CFR 71.33*
- *IAEA TS-R-1, paragraph 220 & 807)*

The Model 650L package is constructed in accordance with the drawings included in Section 1.4. The package measures approximately 13 ¼ inches (337 mm) in tall by 10 inches (254 mm) wide by 8 ¼ inches (210 mm) deep. The general package information is shown in Table 1.2a:

Table 1.2a: Model 650L Package Information

Identification	Nuclide	Form	Maximum Capacity[1]	Chemical/ Physical Form	Maximum Content Weight	Maximum Decay Heat[3]	Maximum DU Weight	Maximum Package Weight
650L	Ir-192	Special Form[2] Sources	240 Ci	Metal	< 1 gram	4.8 Watts	44 lbs (20 kg)	90 lbs (41 kg)
	Se-75	Special Form[2] Sources	300 Ci	Metal-Selenide Compound	< 1 gram	1.52 Watts		

[1] Maximum Activity for Ir-192 is defined as output Curies as required in ANSI N432 and 10 CFR 34.20 and in line with TS-R-1 and Rulemaking by the USNRC and the USDOT published in the Federal Register on 26 January 2004.
[2] Special Form is defined in 10 CFR 71, 49 CFR 173, and IAEA TS-R-1.
[3] Maximum decay heat for Ir-192 is calculated by correcting the output activity to content activity. A factor of 2.3 is used for Ir-192 to account for source capsule and self-absorption in this conversion. No corrections are made for Se-75.

1.2.1 Packaging

Except for the shield assembly, fill foam and some components of the lock assembly, all materials of construction are stainless steels. The major components of the package consist of the following:

- Inner and Outer Shells
- Depleted Uranium shield
- Locking assemblies
- Protective Lid

The following paragraphs describe the major components of the transport package.

1.2.1.1 Source Capsule and Shield Assembly: The special form capsule is shielded by a titanium "U" tube set in depleted uranium. The tube is crimped in the middle of the "U" to provide a positive stop for the source assembly and two "effective" source tubes in the shield. On some source changers, additional shielding is provided by lead positioned at various locations around the depleted uranium shield. The lead is secured in place prior to setting the shield in the shell configuration with polyurethane foam (see Section 1.2.1.2).

1.2.1.2 Inner and Outer Shells: The shield assembly is protected by two carbon steel shells. The inner shell is rectangular and the outer shell is cylindrical. The shells are positioned between two stainless steel top and bottom plates. The plates are secured with four stainless steel, 5/16-18 hex head through bolts. All steel-uranium interfaces are separated with copper shims. The void between the depleted uranium shield and the inner and outer shells is filled with rigid polyurethane foam.

1.2.1.3 Protective Lid: During transport, the locking assembly is protected by a carbon steel lid. The lid is secured to the top plate by four stainless steel, 3/8-16 hex head bolts. The lid is provided with a tamper indicating seal during shipment.

1.2.1.4 Source Locking Assembly: The package incorporates two stainless steel and brass locking assemblies which secure the source(s) inside the shield. Each lock assembly secures one source in one source tube. The locking assemblies are secured to the top plate by four ¼-20 stainless steel screws. Two of the screws on each lock assembly are safety wired for added security of the lock assembly to the top plate.

1.2.2 Containment System

(Reference:

- *10 CFR 71.33(a)(4)*
- *IAEA TS-R-1, paragraph 213 and 501(b))*

The locking assembly on the Model 650L transport packages is shown on the drawing included in Section 1.4. The radioactive material of these source assemblies is sealed in a special form source capsule. The source capsule, stop ball and connector are swaged to a flexible steel wire to form the source wire assembly.

The containment system for the Model 650L transport package is the radioactive source capsule referred to in Section 4.1 of this Safety Analysis Report. This source capsules transported in the 650L transport package are certified as special form radioactive material under 10 CFR Part 71, USDOT regulations in 49 CFR and the IAEA Regulations for the Safe Transport of Radioactive Material (TS-R-1).

1.2.3 Contents

(Reference:
- *10 CFR 71.33(b)*
- *IAEA TS-R-1, Section IV & paragraph 807(a))*

The Model 650L transport package is designed to transport special form capsules containing the isotopes listed in Table 1.2a. The maximum decay heat for Ir-192 in Table 1.2a has been adjusted to account for content activity of the source. Based on the decay energy and total content activity, Ir-192 produces the maximum decay heat when transported in this package. Actual content to output activity varies based on the capsule configuration as well as variations in isotope self-absorption. A factor of 2.3 was used for Ir-192 to convert output activity to content activity as this factor reflects the worst case variation for Ir-192 sources transported in this package. No correction was necessary for Se-75 as the activity transported is based on content activity and not output activity. The source capsules are loaded into the Model 650L device and secured according to the procedure described in Section 7.

The maximum weight of the contents for the shield containers is also listed in Table 1.2a. The content weight values are calculated based on the package capacity and the lowest specific activity of Ir-192 (200 Ci/gram) used in source production for these devices.

Note: Ir-192 of higher specific activity can be used but this would produce sources with lower total mass of the contents. Se-75 has a lower density than Ir-192 and will produce source capsules of lesser maximum weight than their Ir-192 counterparts. Values listed in the Table 1.2a are the maximum content masses.

1.2.4 Operational Features

This package does not involve complex containment systems for source securement. The sources for this package are all special form, welded capsules. The source wire assembly is held securely in the device by components of the lock assembly attached to the top plate. One of these components, the lockslide, engages the source wire and prevents it from being pulled through the top of the lock assembly.

When the Model 650L device is prepared for transport, the lock slide is locked in the secured position by a key lock, a shipping cap is installed above the source in the lock assembly, and the protective lid is secured to the top plate over the lock assemblies.

1.3 General Requirements for All Packages

1.3.1 Minimum Package Size

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

The Model 650L transport package is approximately 10 inches (254 mm) long, 8 ¼ inches (210 mm) wide and 13 ¼ inches (337 mm) high. Therefore, it exceeds the minimum package size requirements specified in the referenced regulations.

1.3.2 Tamper-Indicating Feature

(Reference:

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

Two bolts which secure the protective lid of the Model 650L package to the top plate, are seal wired to provide a tamper indicating seal for the package. This seal wire is not readily breakable, therefore if it is broken during transport, it serves as evidence of possible unauthorized access to the contents.

1.4 **Appendix:** Drawings of the Model 650L transport packages.

Section 1.4 Appendix: Drawings of the Model 650L transport packages.

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 Description of Structural Design

(Reference:

- *10 CFR 71.33(a)*
- *IAEA TS-R-1, paragraph 220 & 807(b))*

2.1.1 Discussion

The Model 650L transport package is described in Section 1.2.

2.1.2 Design Criteria

The Model 650L 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.

2.1.3 Weight and Centers of Gravity

The transport package weighs a maximum of 90 lbs (41 kg). The center of gravity of the 650L transport packages is approximately 4 ¼ inches (64 mm) above the bottom plate along its central axis.

2.1.4 Identification of Codes and Standards for Package Design

2.1.4.1 Package Design

See Section 2.1.2 relating to design criteria of the package. No specific codes or standards were directly incorporated in the design effort of the finished assembly for the 650L transport packages. However the design was based on the Type A and Type B(U) container requirements of 49 CFR, 10 CFR 71 and IAEA regulations in effect at the time of the package component design.

2.1.4.2 Fabrication & Assembly

All container fabrication (including assembly) is controlled under the QSA Global Inc. Quality Assurance Plan approved by the USNRC and ISO. All welding under this plan adheres to AWS or ASME standards appropriate to the materials and designs fabricated. All safety critical hardware meets ASME-B18 standards. All external fabrication deemed critical to safety is either verified to equivalent in-house standards or dedicated as appropriate for use prior to release as part of this transport package.

The containers were designed and fabricated under a QSA Global Inc. (or its predecessors) QA program in the USA. Any new manufactured containers to this design will continue to be completed under the QSA Global Inc. Quality Assurance Plan approved by the USNRC and ISO.

2.1.4.3 Maintenance & Use

Maintenance and use of these transport container assemblies is described in Sections 7 and 8.

2.2 Materials

(Reference:

- *10 CFR 71.33(a)(5)*
- *IAEA TS-R-1, paragraph 220 & 807(b))*

2.2.1 Material Properties and Specifications

Table 2.2a lists the relevant mechanical properties (at ambient temperature) of the principal materials used in the Model 650L transport package. The location and use of these materials is shown on the drawings contained in Section 1.4. The reference for the table information is listed in the last column of the table.

Table 2.2a: Mechanical Properties of Principal Safety Related Transport Package Materials

Material	Tensile Strength	Yield Strength	Source
Depleted Uranium	65 kpsi	30 kpsi	Reference #2
Copper	25 kpsi	9 kpsi	Reference #3, page 224
Titanium	145 kpsi	134 kpsi	Reference 4 page 98
Lead	1.8 kpsi	8 kpsi	Reference 3 page 550
Stainless Steel	75 kpsi	30 kpsi	Reference #1, page 854
Carbon Steel	53 kpsi	36 kpsi	Reference 1, page 205
Strain-Hardened Stainless Steel Bolts	125 kpsi	100 kpsi	Reference 5, page 25

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.

4. American Society for Materials, Metals Handbook desk Edition , Metals Park Ohio 1985

5. ASTM Standard A193, "Standard Specification for Alloy-Steel and Stainless Steel Bolting Materials for High-Temperature Service", 1992.

2.2.2 Chemical, Galvanic or Other Reactions

(Reference:
- *USNRC, 10 CFR 71.43(d)*
- *IAEA TS-R-1, paragraph 613 and 642)*

The non-safety related materials are brass and polyurethane. These materials are more susceptible to corrosion and chemical reaction than the safety materials, but pose no threat to safety or containment. The safety related materials, used in the construction of the Model 650L transport package, are depleted uranium metal, stainless steel, carbon steel, titanium, lead (in some cases) and copper. There will be no significant chemical or galvanic action between any of these components.

To prevent the possible formation of a eutectic alloy of steel and depleted uranium during the Hypothetical Accident Conditions thermal scenario, defined by 10 CFR 71.73(c)(4), copper separators are used at all steel-uranium interfaces. The steel-uranium eutectic alloy temperature is approximately 1,337°F (725°C). However, vacuum conditions and extreme cleanliness of the surfaces are necessary to produce the eutectic alloy at this low temperature. Due to the conditions in which the depleted uranium shield components are assembled and used in the shield containers, conditions sufficient to allow formation of this eutectic do not exist. With these container constructions, there will be no significant chemical or galvanic reaction between package components during normal or hypothetical accident conditions of transport.

2.2.3 Effects of Radiation on Materials

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

Lead, depleted uranium, steel and polyurethane foam have been used in this package as well as other transport packaging for decades without degradation of the package performance over time due to irradiation from the package contents.

2.3 Fabrication and Examination

(Reference:
- *10 CFR 71.33(a)(5)*
- *IAEA TS-R-1, paragraph 232, 310, 638 and 807(b))*

2.3.1 Fabrication

Package components are procured, manufactured and inspected for use under QSA Global Inc. NRC approved QA Program Number 0040.

2.3.2 Examination

Section 8 describes the acceptance testing and routine maintenance requirements for package components used on the Model 650L packages.

2.4 Lifting and Tie-Down Standards for All Packages

2.4.1 Lifting Devices

(Reference:
- *USNRC, 10 CFR 71.45(a)*
- *IAEA TS-R-1, paragraphs 502(b), 606, 607 and 608)*

The Model 650L transport package is designed to be lifted by the bottom or top plates or the top lid. The top lid is secured to the top plate by four 3/8-16, strain-hardened stainless steel hex head bolts. The bottom plate is secured to the top plate by four 5/16-18 stainless steel hex head bolts. Since the package can be lifted by either the top or bottom plate, analysis of the stress due to lifting considers the strength of the 5/16-18 through bolts, which are more limiting than the lid bolts.

Each 5/16-18 bolt has a cross-sectional area of 0.0524 in^2 (33.8 mm^2). The yield strength of the material is 30,000 psi. Thus, each bolt can support at least 1,572 lbs (713 kg) of force, or more than 17 times the package weight before failing. Therefore, the lifting device complies with the requirements of 10 CFR 71.45(a).

2.4.2 Tie-Down Devices

(Reference:
- *USNRC, 10 CFR 71.45(b) (1) (2) (3)*
- *IAEA TS-R-1, paragraph 606 and 636)*

The Model 650L has no system of tie down devices that are a structural part of the transport package. The package can be blocked and braced according to standard transportation practices.

2.5 General Considerations

(Reference:
- *10 CFR 71.41(a)*
- *IAEA TS-R-1, paragraph 807(c))*

2.5.1 Evaluation by Test

Evaluations by direct testing are documented in Test Plan 80 Report which is contained in Section 2.12.2.

2.5.2 Evaluation by Analysis

Evaluations by analysis are described in the section they apply to in this Safety Analysis Report or when applicable in Test Plan 80 Report contained in Section 2.12.2.

2.6 Normal Conditions of Transport

2.6.1 Heat

(Reference:

- *USNRC, 10 CFR 71.71(c)(1)*
- *IAEA TS-R-1, paragraph 615, 617, 618, 637, 651, 662 and 664)*

The heat sources for the Model 650L transport package is listed in Table 1.2a. Iridium-192, releases approximately 8.6 milliwatts per Curie based on assuming a decay energy of 1.46 MeV/decay. The thermal evaluation for the heat test is described in Section 3 and is based on the decay energy of Ir-192 as this is greater than Se-75 (see Table 1.2a).

2.6.1.1 Summary of Pressures and Temperatures

(Reference:

- *IAEA TS-R-1, paragraph 615 and 661)*

Table 2.6.1.a: Summary Temperatures Normal Transport

Temperature Condition	Model 976	Comments
Insolation (38°C in full sun)	70°C (158°F)	Section 3.4.1.1.
Decay Heating (38°C in shade)	46°C (115°F)	Section 3.4.1.2

As all components are vented to ambient, no pressure will build up in the package under Normal Transport conditions that would adversely effect package performance or integrity. Evaluation of pressures for this package are contained in Section 3.4.2 and summarized in Table 3.1.4.a.

2.6.1.2 Differential Thermal Expansion

Any thermal expansion encountered during Normal Transport will be insignificant with respect to the manufacturing tolerances for the components of this package.

2.6.1.3 Stress Calculations

Stress calculations for normal transport of this package are contained in Sections 2.4.1 and 2.7.4.3. Results of these calculations demonstrate that the package meets the requirements for Normal Transport.

2.6.1.4 Comparison with Allowable Stresses

The Model 650L package was fully tested and passed under Normal Conditions of transport. It is therefore concluded that the package will satisfy the performance requirements specified by the regulations.

2.6.2 Cold

(Reference:
- *USNRC, 10 CFR 71.71 (c)(2)*
- *IAEA TS-R-1, paragraph 615, 637 and 664)*

The carbon steel components of the Model 650L transport package are susceptible to brittle fracture at low temperature. To assess the package performance under the worst case test conditions, the drop and penetration tests described in 10 CFR 71.71(c)(7) and (10) were performed with the package at the coldest temperature referenced in the regulations. This condition was most likely to produce package failure under these test conditions due to the brittle fracture nature of these package components. The transport package successfully met Type B(U)-96 Transport Tests requirements at temperatures below -40°C (-40°F), the minimum specified in the 10 CFR 71.71(c)(2), therefore it is concluded that the Model 650L transport package will withstand the normal transport cold condition.

2.6.3 Reduced External Pressure

(Reference:
- *USNRC, 10 CFR 71.71 (c)(3)*
- *IAEA TS-R-1, paragraph 643 & 619*

The Model 650L transport package is open to the atmosphere and contains no components which could create a differential pressure relative to atmospheric conditions or components within the package. The authorized contents are special form source capsules that meet a minimum ISO 2919-1999 classification of Class 3 for pressure. This classification is more limiting than the reduced external pressure requirement as it covers 25 kN/m^2 to 7MN kN/m^2. Therefore, the reduced external pressure requirements of 3.5 psi in 10 CFR, 8.7 psi (60 kPa) in 49 CFR and IAEA will not adversely affect the package containment.

Reference: ISO 2919-1999, Radiation Protection – Sealed radioactive sources - General requirements and classification.

2.6.4 Increased External Pressure

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

The Model 650L transport package is open to the atmosphere and contain no components which could create a differential pressure relative to atmospheric conditions. The authorized contents are special form source capsules that meet a minimum ISO 2919-1999 classification of Class 3 for pressure. This classification is more limiting than the increased external pressure requirement as it covers 25 kN/m^2 to 7MN kN/m^2. Therefore, the increased external pressure requirements of 20 psi in 10 CFR 71 will not adversely affect the package containment.

2.6.5 Vibration

(Reference:

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

The Model 650L (or its predecessor the 650) package has been in use for over two decades without failure due to vibration. The lock attachment screws and end plate through screws are tightened to a prescribed torque and safety wired to prevent unintentional release even after repeated use. It is therefore concluded that the Model 650L packages will withstand vibration normally incident to transport.

2.6.6 Water Spray

(Reference:

- *USNRC, 10 CFR 71.71(c)(6)*
- *IAEA TS-R-1, paragraph 719, 720 and 721)*

The Model 650L transport package is 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)*
- *IAEA TS-R-1, paragraph 722(a))*

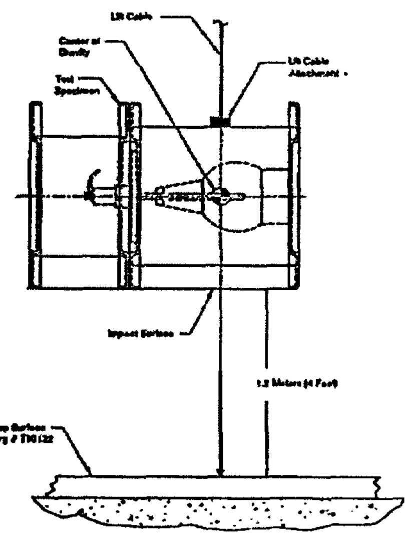
The drop test pad used in the 1.2 m free drop, 9 m drop, and puncture tests consists of a monolithic concrete base 7.4 ft x 7.3 ft x 1.25 ft thick. The approximate weight of the concrete is 14,850 lbs. A 3.9 ft x 4 ft x 1 in thick steel plate was embedded in this concrete slab at the time of its construction. Before and after testing the drop pad was visually inspected for damage which could have a significant impact on package testing.

Three test specimens, as described in Test Plan 80 Report (Section 2.12.2) were subjected to the 1.2 meter (4 foot) free drop followed by the hypothetical accident 9 m drop and puncture bar drop tests. All free drop and penetration tests were conducted with the test specimen temperatures at or below -40°C (-40°F). The test specimens included standard locking assemblies. Drop orientation impact locations for the 1.2 m free drop are shown in Figures 2.6a through 2.6c. The justification for these orientations is provided in Sections 2.6.7.1 through 2.6.7.3.

The Model 650L package maintained its structural integrity and shielding effectiveness under the normal transport drop test conditions and the package complies with the requirements of this section.

2.6.7.1 Horizontal Long-Side Down Orientation

The intent of this orientation was to determine if the depleted uranium shield could move laterally through the foam during impact (which could result in source pullout from the titanium tubes), and whether brittle failure of the inner and outer shells could occur due to the low temperature testing. The long-side down orientation was selected because the long side of the package has a stiffer configuration than the short-side. This results in a shorter deceleration and higher impact load. Testing for this orientation (shown in Figure 2.6a) was performed on test specimen TP80(A).



1.2 Meter (4 Foot) Drop Orientation for Specimen TP80(A)

Figure 2.6a - Model 650L (TP80(A)) 1.2 m Drop Test Orientation Horizontal Long-Side Down Drop

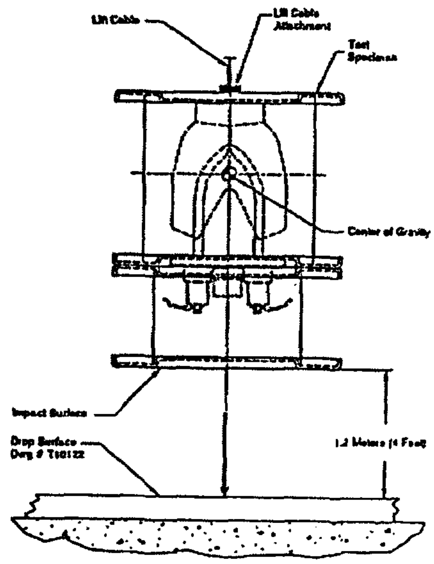
Damage to TP80(A) was limited to impact witness marking on the bottom plate, top plate and both lid flanges. There was no significant change in the radiation profile of the test specimen after the 1.2 m (4 ft) drop test (See Section 5).

2.6.1.2 Vertical Upside Down Orientation

The intent of this test orientation was to determine if any of the following could occur and have a significant impact on the package:

2.6.1.2.1 deformation of the lid weldment,
2.6.1.2.2 crushing of the foam between the depleted uranium shield and top plate,
2.6.1.2.3 deformation (bowing upward) of the top plate due to the impact load of the depleted uranium shield applied through titanium source tubes and foam,
2.6.1.2.4 failure of the through bolts, or
2.6.1.2.5 failure of the locking assemblies could occur.

These deformations or failures could result in partial pullout of the source from its shielded position. Testing for this orientation (shown in Figure 2.6b) was performed on test specimen TP80(B).



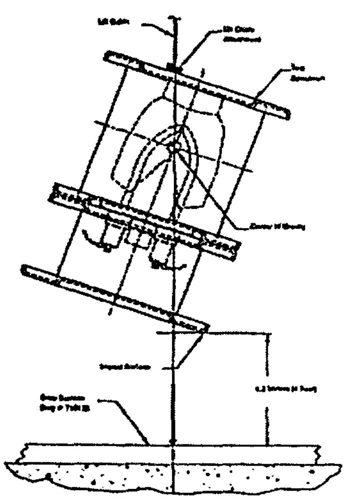
1.2 Meter (4 Foot) Drop Orientation for Specimen TP80(B)

Figure 2.6b - Model 650L (TP80(B)) 1.2 m Drop Test Orientation Vertical Upside Down Drop

Damage to TP80(B) was limited to impact witness marking on the top of the lid. There was no significant change in the radiation profile of the test specimen after the 1.2 m (4 ft) drop test (See Section 5)

2.6.1.3 Vertical Top Corner Drop Orientation

The intent of this test orientation was to determine if failure of the lid or lid closure bolts could occur which could expose the locking assembly to damage during subsequent Hypothetical Accident Testing. Failure of the locking assembly could result in source pullout. Additionally, this orientation would load the through bolts in tension and could cause them to fail. Testing for this orientation (shown in Figure 2.6b) was performed on test specimen TP80(C).



1.2 Meter (4 Foot) Drop Orientation for Specimen TP80(C)

Figure 2.6c - Model 650L (TP80(C)) 1.2 m Drop Test Orientation
Vertical Top Corner Down Drop

Damage to TP80(C) was limited to a 2 inch (50.8 mm) long crack in the top of the protective lid and the flange corner was bent in the drop. There was no significant change in the radiation profile of the test specimen after the 1.2 m (4 ft) drop test (See Section 5)

2.6.8 Corner Drop

(Reference:

- *USNRC, 10 CFR 71.71(c)(8)*
- *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.

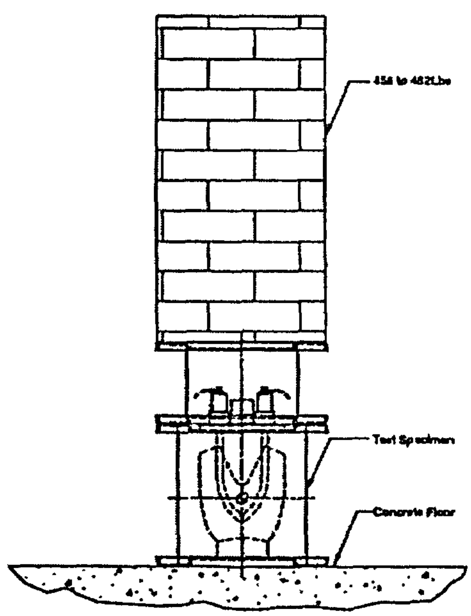
2.6.9 Compression

(Reference:

- *USNRC, 10 CFR 71.71(c)(9)*
- *IAEA TS-R-1, paragraph 723)*

Test Plan 80 Report (Section 2.12.2) documents that the three test specimens (TP80(A), TP80(B) and TP80(C)) were subjected to compressive loads of 462 lbs (210 kg), 458 lb (208 kg) and 459 lb (208 kg) respectively, for a period of 24 hours (See Figure 2.6d). These loads exceed five times the maximum transport package weight of 90 lbs (41 kg). These loads are also greater than 13 kPa (2 lb/in^2) multiplied by the vertically projected area of the transport package.

Following the test, no damage to the specimens was observed. Radiation profiles performed at the conclusion of the test showed no significant increase in radiation levels. The Model 650L package maintained its structural integrity and shielding effectiveness and demonstrated that the packages comply with the requirements of this section.



Compression Test Orientation – All Specimens

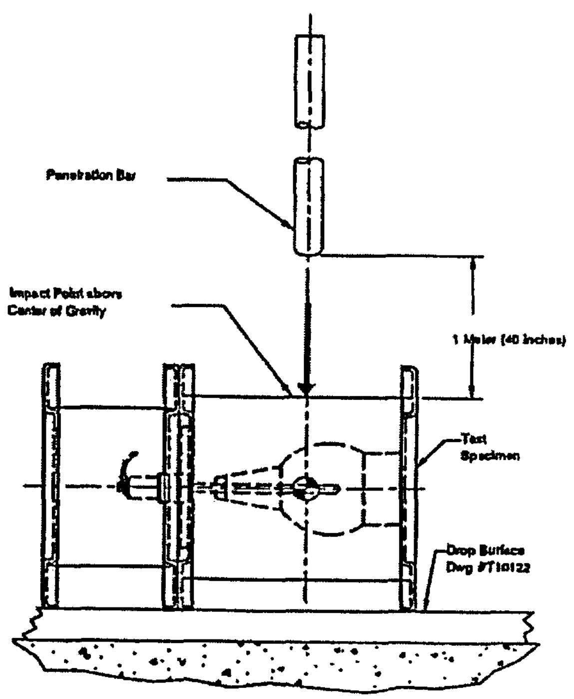
Figure 2.6d - Model 650L Compression Test Orientation

2.6.10 Penetration

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

Test Plan 80 Report (Section 2.12.2) documents that the three test specimens (TP80(A), TP80(B) and TP80(C)) were subjected to the penetration test. Each specimen was impacted on the long side of the package with the intention of damaging the outer shell (See Figure 2.6e). The penetration bar impacted as intended and caused no significant damage to the specimens. In each case there was a small indentation at the point of impact.

Radiation profiles performed after testing showed no significant increase in radiation levels. The Model 650L package maintained its structural integrity and shielding effectiveness and demonstrated that the packages comply with the requirements of this section.



Penetration Test Orientation – All Specimens

Figure 2.6e - Model 650L Penetration Test Orientation

2.7 Hypothetical Accident Conditions of Transport

(Reference:

- *USNRC, 10 CFR 71.73*
- *IAEA TS-R-1, paragraph 726)*

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 (3) test specimens were used to conduct the hypothetical accident tests. Testing was performed after the test specimens had undergone the testing in Section 2.6 for Normal Conditions of transport. Detailed description of this testing is contained in Test Plan 80 Report (Section 2.12.2).

2.7.1 Free Drop

(Reference:

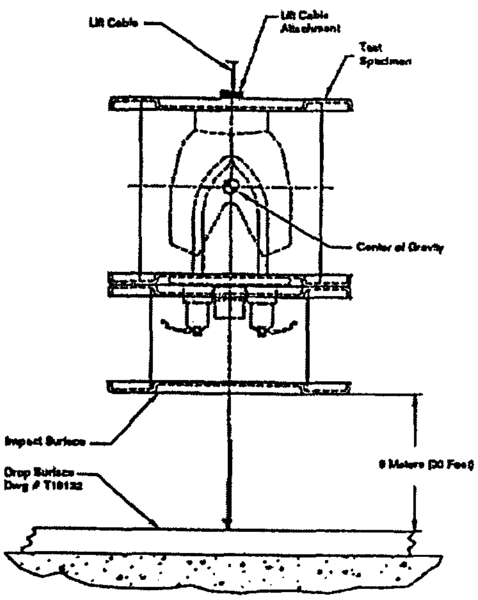
- *USNRC, 10 CFR 71.73(c)(1)*
- *IAEA TS-R-1, paragraph 727(a))*

Justification for all test unit drop orientations are included in Test Plan 80 Report (Section 2.12.2). All tests were conducted with the test specimen temperatures at or below -40°C (-40°F). The test specimens included standard locking assemblies.

2.7.1.1 End Drop

This orientation was used for Test Specimen TP80(B) and the orientation is shown in Figure 2.7a. The test specimen impacted flat on the top of the lid. One of the lid rivnuts cracked open, but the lid bolt remained in place. There was no other damage to the lid or lid bolts/rivnuts.

The top plate deflected up, resulting in source displacements of about 1/32 inch (0.8 mm) and 1/16 inch (1.6 mm). The carbon steel outer shell unzipped along the spot weld line and opened up about ½ inch (12 mm). The carbon steel inner shell fractured (brittle fracture) in the middle of the short side and opened up a crack about ½ inches (13 mm) wide and 3 inches (76 mm) long. The crack started at the top (under the top plate). At the end of this opening, the crack turned and continued behind the foam that fills the volume between the inner and outer shells. The foam cracked and several small pieces came out.

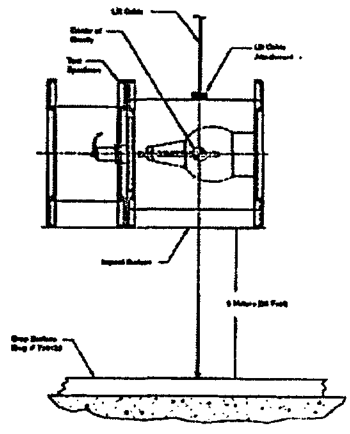


9 Meter (30 Foot) Drop Orientation for Specimen TP80(B)

Figure 2.7a - Model 650L (TP80(B)) 9 m Drop Test Orientation – End Drop

2.7.1.2 Side Drop

This orientation was used for Test Specimen TP80(A) and the orientation is shown in Figure 2.7b. The test specimen rotated slightly so that the long edge of the bottom plate struck the ground first. The long edge of the bottom plate deformed, but no cracking was observed. The outer shell deformed at the interface with the long edge of the bottom plate. There were impact witness marks on the long edge of the top plate and the long edge of the bottom lid flange. There was a small deformation of the lid top flange.

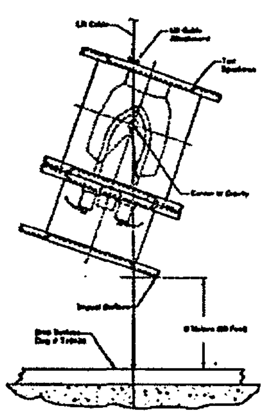


9 Meter (30 Foot) Drop Orientation for Specimen TP80(A)

Figure 2.7b - Model 650L (TP80(A)) 9 m Drop Test Orientation – Side Drop

2.7.1.3 Corner Drop

This orientation was used for Test Specimen TP80(C) and the orientation is shown in Figure 2.7c. The specimen impacted on the top corner of the lid. The crack in the top flange of the lid, which initiated during the 1.2 meter (4 ft) drop test, increased and the top surface of the lid deflected inside the lid about ½ inch (13 mm) along one edge. The lock assemblies were not impacted during the drop. The column section of the lid and the bottom flange of the lid remained intact. There was no damage to the lid bolts or rivnuts.



9 Meter (30 Foot) Drop Orientation for Specimen TP80(C)

Figure 2.7c - Model 650L (TP80(C)) 9 m Drop Test Orientation – Corner Drop

2.7.1.4 Oblique Drops

The oblique drop was not performed. In an oblique drop, the energy generated at impact would be distributed across the initial and secondary impact surfaces (two upper and one lower flange). This will produce less force on impact at the initial impact location and the force from the secondary impact will cause deformation of the flanges without contributing to damage which could result in container failure.

Unlike the End, Side and Corner drops described in Sections 2.7.1.1 through 2.7.1.3, an oblique drop is less likely to cause a container failure by the mechanisms identified in Test Plan 80 Report (Section 2.12.2). These included displacement of the sources relative to the shield within the container shells and breach of the container shells sufficient to allow oxidation of the depleted uranium shield during the thermal test.

2.7.1.5 Summary of Results

(Reference:
- *USNRC, 10 CFR 71.73(a) and (b)*
- *IAEA TS-R-1, paragraph 726)*

See Table 2.7.8.1 for additional test unit results summary. In all cases, radiation profiles performed at the conclusion of all testing showed no significant increase in radiation levels for the test units and demonstrated that the 650L packages comply with the requirements of this section.

2.7.2 Crush

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

Not applicable. This package is not used for the Type B transport of normal form radioactive material.

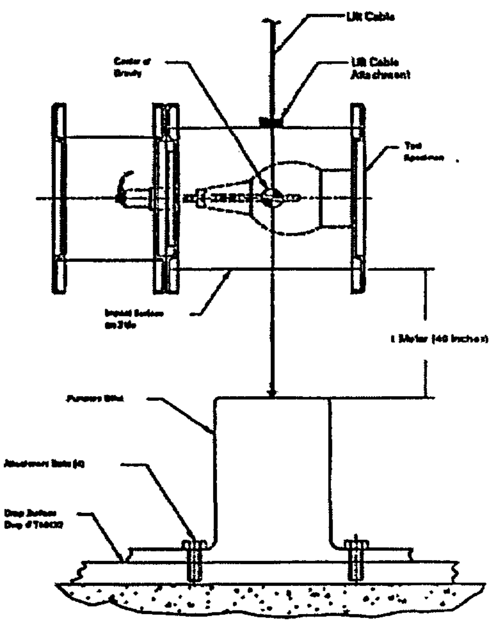
2.7.3 Puncture

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

The puncture bar is a 6 inch diameter x 12 inch long, mild steel solid bar attached to a 12 inch x 12 inch x ½ inch thick mild steel base. The bar is attached to the base with a ¼ inch circumferential fillet weld. The puncture bar is attached to the drop test pad steel plate by four stainless steel bolts. Justification for all test unit puncture orientations are included in Test Plan Report 80 (Section 2.12.2) and results are summarized in the Sections 2.7.3.1 through 2.7.3.4. All tests were conducted with the test specimen temperatures at or below -40°C (-40°F). The test specimens included standard locking assemblies.

2.7.3.1 Test Specimen TP80(A)

Test Specimen TP80(A) impacted the puncture bar so that it impacted the horizontal long side of the package (see Figure 2.7d). There was a small dent on the long side of the outer shell just above the bottom plate and there were witness marks on the top plate.



Puncture Drop Orientation for Specimen TP80(A)

Figure 2.7d - Model 650L (TP80(A)) Puncture Test Orientation Horizontal Long-Side of the Package

2.7.3.2 Test Specimen TP80(B)

Test Specimen TP80(B) was dropped horizontally so that the edge of the puncture bar impacted the axial crack. This orientation was selected to increase the damage from the 9 meter (30 ft) drop test and to try to further open the axial crack.

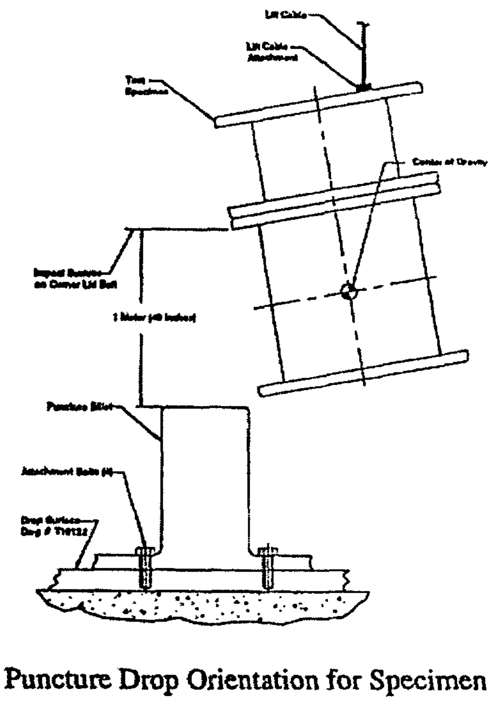
The test specimen impacted directly on the crack. There were small indentations on both sides of the crack where the puncture bar impacted, but no further opening of the crack was observed.

2.7.3.3 Test Specimen TP80(C)

Test Specimen TP80(C) was dropped on the puncture bar in two orientations. The first orientation dropped the package so that the edge of the puncture bar impacted the crack in the lid. This orientation was selected to increase the damage from the 9 meter (30 ft) drop test with the specific intention of increasing the lid crack opening and trying to impact the lock assemblies.

On impact the edge of the puncture bar hit the top plate of the lid within the column of the lid increasing damage to the lid slightly. The lock assemblies were not impacted and remained protected by the lid. The lid bolts and rivnuts remained intact.

The second drop orientation for this package dropped the specimen so that the edge of the puncture bar impacted the underside of the top plate corner at a lid bolt rivnut. The intent of this orientation was to pry up the top plate and load the through bolts in tension. This orientation was also intended to damage the lid bolt connection. See Figure 2.7e.



Second Puncture Drop Orientation for Specimen TP80(C)

Figure 2.7e - Model 650L (TP80(C)) 2nd Puncture Test Orientation Underside of Top Endplate

In the drop, the specimen impacted on the under side of the top plate corner. There was a small deformation of the top plate edge at the impact point. The lid bolts/rivnuts were not damaged. No gaps were created at the top plate/shell interface and the through bolts remained secure.

2.7.3.5 Summary of Results

(Reference:

- *USNRC, 10 CFR 71.73(a) and (b)*
- *IAEA TS-R-1, paragraph 726)*

See Table 2.7.8.1 for additional test unit results summary. A more detailed summary is given in Test Plan 80 Report (Section 2.12.2). In all cases, radiation profiles performed at the conclusion of the puncture testing showed no significant increase in radiation levels for the test units and demonstrated that the 650L packages comply with the requirements of this section.

2.7.4 Thermal

(Reference:

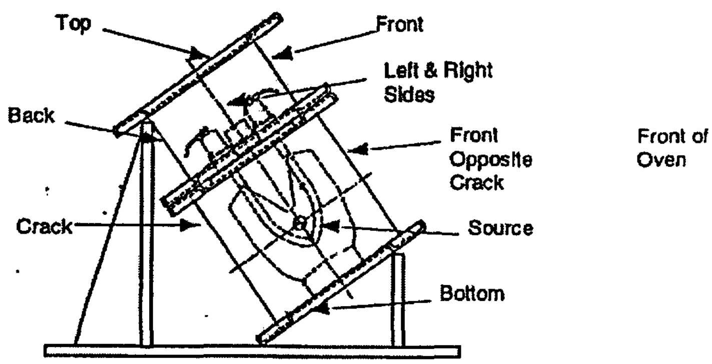
- *USNRC, 10 CFR 71.73(c)(4)*
- *IAEA TS-R-1, paragraph 651 through 655, and 728)*

The thermal test was performed for test specimen TP80(B). The damage produced during the drop and puncture tests had allowed maximum source displacement in the shield as well as the potential for shield oxidation during the thermal test. The thermal test was not considered necessary for the other test specimens since their results would be less severe than TP80(B).

For TP80(B), lead shims placed under the depleted uranium shield were expected to melt during thermal testing. This would allow the shield to drop down towards the bottom plate and away from the top plate. Since the lock assemblies remained securely attached to the top plate this would allow the source assemblies to be raised above the fully shielded position in the shield.

The crack in the inner shell and the opening in the outer shell provided a path for air to reach the depleted uranium shield during thermal testing. Therefore oxidation of the shield was possible.

To obtain the largest possible displacement of the shield during thermal testing, the test specimen was placed on a jig to raise the side face of the unit to an angle (53° above horizontal) that positioned the center of gravity of the shield over the bottom plate inside edge (See Figure 2.7f). The side with the crack was facing down.



TP80(B) Orientation and Thermocouple Locations

Figure 2.7f - Model 650L (TP80(B)) Thermal Test Orientation

During thermal testing, the test period of 30 minutes was started after all specimen thermocouples measured at least 810°C (1,490°F). To allow sufficient air for combustion of the specimen's polyurethane foam, the door of the oven was held open by 1 inch (25 mm) thick insulating strips placed on each side of the furnace door. This created a 1 inch (25 mm) wide by 36 inch (914 mm) long opening at the top and bottom of the oven door (total opening of 72 in^2 (465 mm^2)).

At the end of the 30 minute test interval, the specimen was removed from the furnace and allowed to self extinguish and cool down. Post-test visual inspections showed that the crack width did not change (but a cracked piece of the inner shell had dropped out of position). The polyurethane foam had burned off and some minor oxidation of the shield had occurred as evidenced by a small amount of depleted uranium oxide below the cracked shell.

Post-test radiographs showed that the shield had shifted down as expected. This resulted in some pullout of the source tubes from the top plate (less than 0.5 inches (13 mm)). The radiation profile of the device performed following the thermal test showed that the highest observed radiation level, 28 mR/hr at one meter was well below the allowable level of 1,000 mR/hr at one meter. Therefore, the 650L satisfies the thermal test requirements of 10 CFR 71.73(c)(4) and IAEA TS-R-1.

2.7.4.1 Summary of Pressures and Temperatures

(Reference:

- *IAEA TS-R-1, paragraph 502(d))*

Table 2.7a: Summary Table of Temperatures

Surface Temperature Condition	Model 650L Package
During Fire Test (Maximum Temperature)	996°C (1,825°F)
Post-Fire (Maximum Temperature)	884°C (1,623°F)

The Model 650L container is vented to atmosphere. As such, no pressure will build up in the package under Hypothetical Accident conditions.

Table 2.7b: Summary Table of Maximum Pressures

Package Configuration	Void Volume (in^3)	Fire Conditions 800°C (1,472°F) Pressure Developed
650L	0	0 psig

2.7.4.2 Differential Thermal Expansion

Physical testing has shown that any differential thermal expansion in the package has no detrimental effect on its ability to pass the thermal testing portion of the Hypothetical Accident Conditions. Design clearances between fitted components in the 650L are sufficient to allow for thermal expansion at the test temperature. It can be drawn from the actual testing results in Test Plan 80 Report (Section 2.12.2) that thermal expansion does not have a significant effect on the Model 650L package.

2.7.4.3 Stress Calculations

As was noted in Section 2.7.4.2, thermal differentials will have no detrimental effect on the interfaces between the steel shells, shield, endplates, lock assemblies or protective lid. The Model 650L transport package is open to the atmosphere and contains no components which could create a differential pressure relative to atmospheric conditions.

2.7.4.4 Comparison of Allowable Stresses

The Model 650L package was fully tested and passed under Normal and Hypothetical Accident Conditions of transport. It is therefore concluded that the Model 650L package will satisfy the performance requirements specified by the regulations.

2.7.5 Immersion - Fissile Material

(Reference:

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

Not applicable. This package is not used for transport of Type B quantities of fissile material.

2.7.6 Immersion - All Packages

(Reference:

- *USNRC, 10 CFR 71.73 (c)(6)*
- *IAEA TS-R-1, paragraph 701 and 729)*

The Model 650L transport package is open to the atmosphere and contains no other components that would create a differential pressure under immersion. All materials are impervious to water and would not be affected.

The primary containment system in the model 650L package is a special form source, which meets the ISO 2919-1999 requirements for Class 3 pressure testing. Therefore the 650L could withstand the immersion test as Class 3 is in excess of the required 150 kPa (21.7 lb ft/in2).

2.7.7 Deep Water Immersion Test (for Type B Packages Containing More than 10^5 A_2)

(Reference:

- *USNRC, 10 CFR 71.61*
- *IAEA TS-R-1, paragraph 657, 658 and 730)*

Not applicable. This package does not transport normal form radioactive material in quantities exceeding $10^5 A_2$.

2.7.8 Summary of Damage

(Reference:

- *USNRC, 10 CFR 71.73(a) and (b)*
- *IAEA TS-R-1, paragraph 701, 702, 716 and 726)*

Table 2.7c summarizes the results of the Normal Conditions of Transport and Hypothetical Accident testing performed on the Model 650L transport packages.

Table 2.7c: Summary of Damages During Test Plan 80

Test Specimen	Test	Actual Impact Point	Damage Observed at Test Site
TP80(A) 80 lb (36.3 kg)	Compression	Weight applied to top of protective lid	No damage.
	Penetration Bar	Side of Container Shell (See Figure 2.6e)	Impact Mark. No other visible damage.
	4-foot free drop	Horizontal Long Side of Package	• Impact mark on edge of plates • Small Change in radiation profile (See Section 5 and Test Plan 80 Report Section 2.12.2)

Test Specimen	Test	Actual Impact Point	Damage Observed at Test Site
	30-foot free drop	Horizontal Long Side of Package	Bent bottom plate flange inward.
	Puncture drop	Horizontal Long Side of Package	Shallow dent on outer shell at impact point.
	Post Test Inspection	NA	• Protective Lid remained securely in place. • Locks were undamaged, sources secured. • No significant change in source positions. • Small change in radiation profile.
TP80(B) 83.6 lb (37.9 kg)	Compression	Weight applied to top of protective lid	No damage.
	Penetration Bar	Side of Container Shell (See Figure 2.6e)	Impact Mark. No other visible damage.
	4-foot free drop	Vertical Upside Down on Protective Lid	• Impact mark on top of protective lid. • Small change in radiation profile (See Section 5 and Test Plan 80 Report Section 2.12.2)
	30-foot free drop	Vertical Upside Down on Protective Lid	• Outer shell split open from top to bottom. • Inner shell cracked creating a 3 inch (76.2 mm) long by ½ inch (12.7 mm) wide opening. • Small upward deflection of top plate.
	Puncture drop	Crack in Shell Produced by 9 m drop	Bent shell inward slightly in area of crack.
	Post Drop Test Inspection	NA	• Protective Lid remained securely in place. • Locks were undamaged, sources secured. • Top plate deflection at center about 0.16 inch (4.1 mm). • No damage to through bolts. • No significant change in source position. • Outer and inner shells cracked; opening 3 inch (76.2 mm) long by ½ inch (12.7 mm) wide opening.
	Thermal	See Figure 2.6f	• Shield moved down as expected. • Polyurethane foam burned off exposing the shield. • Some oxidation of the shield near the shell crack occurred. • Shield self-extinguished after removal from oven. • Source pullout less than ½ inch (12.7 mm). • Maximum radiation level at one meter from the package was 28 mR/hr.
TP80(C) 89 lb (40.4 kg)	Compression	Weight applied to top of protective lid	No damage.
	Penetration Bar	Side of Container Shell (See Figure 2.6e)	Impact Mark. No other visible damage.

Test Specimen	Test	Actual Impact Point	Damage Observed at Test Site
	4-foot free drop	Top Corner Down on Protective Lid	• Bent corner of lid and cracked top plate of lid (brittle fracture). • Small change in radiation profile (See Section 5 and Test Plan 80 Report Section 2.12.2)
	30-foot free drop	Top Corner Down on Protective Lid	• Increased lid top plate crack length in vicinity of impact point. • Lock assemblies still protected by the lid.
	Puncture drop #1	Vertical Upside Down on Protective Lid	Broke inside of lid top plate (locks still protected.
	Puncture drop #2	Underside of Top Endplate (See Figure 2.7e)	Top plate deformed slightly.
	Post Test Inspection	NA	• Protective Lid remained securely in place. • Locks were undamaged, sources secured. • No significant change in source positions. • Small change in radiation profile.

Based on the results and assessments for the test specimens addressed in Test Plan 80 Report (see Section 2.12.2), it is concluded that the Model 650L transport packages maintain structural integrity and shielding effectiveness during Hypothetical Accident Conditions and Normal Conditions of Transport.

2.8 Accident Conditions for Air Transport of Plutonium

Not applicable. This package is not used for transport of plutonium.

2.9 Accident Conditions for Fissile Material Packages for Air Transport

Not Applicable. This package is not used for transport of Type B quantities of fissile material.

2.10 Special Form

(Reference:

- *USNRC, 10 CFR 71.75*
- *IAEA TS-R-1, paragraphs 602-604)*

The Model 650L transport package is designed for use with a special form source capsules which meets the ISO 2919-1999 requirements for Class 3 pressure testing. The source capsule must be special form and meet the ISO 2919-1999 Class 3 pressure criteria for transport in the Model 650L.

2.11 Fuel Rods

Not applicable. This package is not used for transport of fuel rods.

2.12 Appendix

2.12.1 Test Plan 80 Rev 1 (March 1999).

2.12.2 Test Plan 80 Report Minus Manufacturing Records (June 1999).

Section 2.12.1 Appendix: Test Plan 80 Rev 1 (March 1999)

AEA TECHNOLOGY QSA

	TEST PLAN NO. 80 REV. 1
TEST PLAN COVER SHEET	
TEST TITLE: TEST PLAN 80, REVISION 1, MODEL 650L SOURCE CHANGER TYPE B TRANSPORT TESTS	
PRODUCT MODEL: 650L	
ORIGINATED BY: [signature] (MPR)	DATE: 12 MAR 99
TEST PLAN REVIEW	
ENGINEERING APPROVAL: [signature]	DATE: 12 MAR 99
QUALITY ASSURANCE APPROVAL: Daniel W. Kurtz	DATE: 12 Mar 99
REGULATORY APPROVAL: [signature]	DATE: 12 Mar 99
COMMENTS:	
TEST RESULTS REVIEW	
ENGINEERING APPROVAL:	DATE:
QUALITY ASSURANCE APPROVAL:	DATE:
REGULATORY APPROVAL:	DATE:

SENTINEL

Test Plan 80

Revision 1

Model 650L

Source Changer

Type B Transport Tests

March 1999

Prepared By: Caroline S. Schlaseman Date 12 MAR 99

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Contents

List of Figures, Tables and Worksheets

AEA Technology/QSA Test Plan 80

1.0 Introduction

This document describes Type B(U) transport package testing of the SENTINEL Model 650L Source Changer, Certificate of Compliance Number 9269. 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), 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 drawing of the test specimen.

2.0 Transport Package Description

The Model 650L source changer shown in Appendix A is 13 ¼" high, 10" long, and 8 ¼" wide in overall dimension, and has a maximum weight of 90 lb. The package consists of the following components:

- Source Capsule and Shield Assembly: The Special Form Source is contained in a capsule and is attached to the source wire assembly. The source is shielded by a Titanium "U" tube that is enclosed in a depleted uranium (DU) shield.

- Outer Casing: The shield assembly is encased in two Carbon Steel shells. The inner shell is rectangular and is 0.135" thick. The outer shell is circular and is 0.048" thick. The shells are positioned between two, Stainless Steel, 0.135" thick top and bottom plates. The plates are secured with four 5/16-18 hex head stainless steel through-bolts. The voids between the depleted uranium shield and the inner and outer shells are filled with a rigid 8 pound Polyurethane foam.

- Protective Lid: During transport, the locking assembly is protected by a 0.135" thick, Carbon Steel lid. The lid is secured to the top plate by four 3/8-16 hex head strain-hardened stainless steel bolts.

- Source Locking Assembly: Model 650L has two Stainless Steel locking assemblies that keep the source inside the Titanium "U" tube. Each locking assembly is secured to the top plate by four ¼-20 Stainless Steel screws.

The 650L package is shown below in Figure 1.

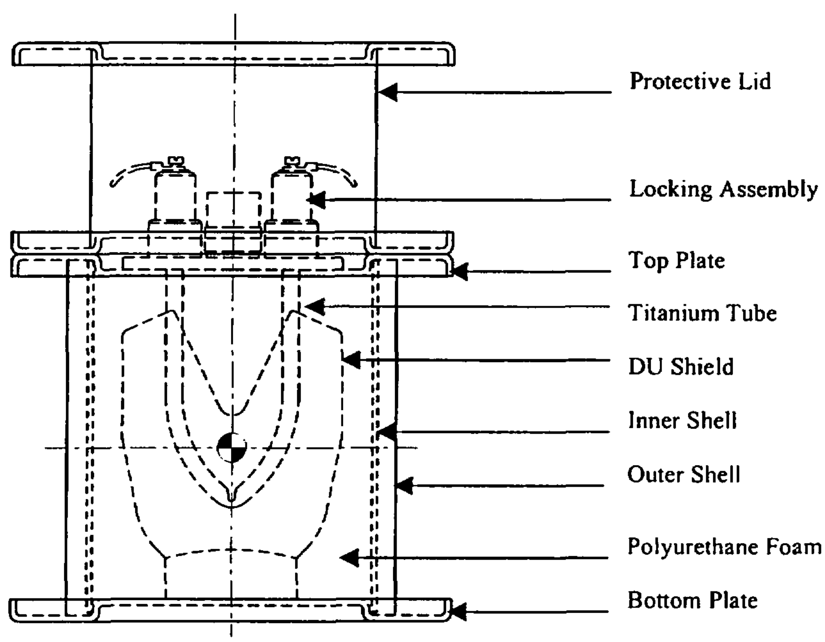


Figure 1. Side View of Model 650L Package

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 650L Source Changer shown in the descriptive drawing provided in Appendix A meets the Type B(U) 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 650L 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.

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 location of the source relative to its stored position in the shield is an important safety element. Displacement of the source and/or shield from its original stored position could elevate the dose rate at the surface of the package above regulatory limits. Tests in this plan focus on damaging those components of the package which could cause displacement of the source, relative to its stored position, within the shield and which affect the integrity of the shield itself.

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

- Oxidation of DU Shield during the thermal test could occur if either distortion/local buckling of the inner and outer shells, or failure of the through-bolts during drop testing results in a large, open path to the DU shield.

- Source Pull-Out from Shield could occur if there is significant relative displacement between the shield and the top cover plate penetration and locking assembly.

Three orientations are considered most likely to cause damage during the 1.2 meter and 9 meter 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, Long-Side Down: The DU shield could move through the foam during impact, which could result in source pullout from titanium tubes. Also, due to the low testing temperature, brittle failure of the inner and outer shells could occur. The failure(s) may be sufficient to open a significant path to the depleted uranium shield during thermal test and cause burning of the DU shield. The Long-Side Down orientation is selected because the long side of the package has a stiffer configuration than the short side, which will result in a shorter deceleration and a higher impact load.

- Case 2, Vertical, Upside Down: Deformation of the lid weldment, crushing of the foam between the depleted uranium shield and top plate, deformation (bowing upward) of the top plate due to the impact load of the DU shield applied through titanium source tubes and foam, failure of the through-bolts, and failure of the locking assembly could occur. When the package is turned upright for the thermal test, the DU shield and its integral titanium tubes could drop down to their original positions while the source is pulled out of the tubes by the bowed top plate or failed locking assembly. Also, a lead shim (which will melt during thermal testing) under the DU shield could cause additional source pullout.

- Case 3, Vertical, Top Corner Down: Failure of lid or lid closure bolts could expose the locking assembly to damage during the puncture bar test. Failure of the locking assembly could result in source pullout. Additionally, this orientation will load the through-bolts in tension, and could cause them to fail.

The following orientations are planned for the puncture tests. These orientations will be modified, if necessary, based on the results of the engineering assessments conducted after the 9 meter drop tests. The puncture test orientations will be selected to maximize damage to the test specimens.

- Case 1, Horizontal, Long-Side Down: This orientation is the same as for the Case 1, 1.2 meter and 9 meter drop tests.

- Case 2, Underside of Top Plate at Lid Bolt: The top plate could be pried up, and, as a minimum, load the through-bolts in tension. The impact on the lid bolt rivnut could damage the lid bolt connection.

- Case 3, Bottom of Package: Impact on the four Stainless Steel rivnuts could damage the through-bolt connection. If the lid is removed during the Case 3 9 meter drop, the test specimen will be dropped upside down such that the lock assemblies strike the puncture bar.

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

5.0 Assessment of Package Conformance

The Model 650L Source Changer must meet the Type B(U) transport package requirements of 10 CFR 71. The conformance criteria are detailed in the following two sections.

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 1 meter from the external surface when the package contains its maximum design radioactive contents.

5.2 Test Package Contents

The Model 650L is designed to carry Special Form Sources. Containment of the radioactive source is tested at manufacture. The source capsules have been certified by the Competent Authority in accordance with the performance requirements for Special Form as specified in 10 CFR Part 71 and 49 CFR.

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 capsule remains contained within the source changer.

A simulated source will be used during testing of the package. The radiation levels after the test will be monitored by replacing the simulated source with an active source.

6.0 Construction and Condition of Test Specimens

The Test Plan 80 (TP 80) test specimens will be Model 650L units constructed in accordance with AEAT/QSA Drawing R-TP80, Revision D.

Drawing TP650L specifies the Model 650L package in its worst case transport conditions, which vary depending on the Test Case. Lead shielding placement should be as described below:

Test Case	Lead Shielding Placement	Rationale
1—Horizontal, Long-Side Down Specimen TP80(A)	No lead between DU shield and long side of inner shell.	Lead between DU and shell or through-bolts might stop DU from travelling through foam during drop impact.
2—Vertical, Upside Down Specimen TP80(B)	Thickest lead under DU shield, use heavy package.	Lead under DU may melt during thermal test and could allow DU to settle, which could allow source pullout. Impact force will be larger for heavier packages, which would result in larger top plate deflection.
3—Top Corner Down Specimen TP80(C)	Any location, use heavy package.	Lead placement will not affect lid failure, and impact force will be larger for heavier packages.

For all Drop Test Cases the temperature of the specimen must be below -40°C 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 the shield and Carbon Steel lid.

7.0 Material and Equipment List

The equipment checklists, test worksheets, 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 8.12.1)
10. Final test inspection

Each specimen must be put through the entire test sequence, unless the thermal test is considered unnecessary based on the test specimen condition after the puncture test and the assessment by Engineering, Quality Assurance and Regulatory Affairs. If test conditions such as the orientation at impact are not met during the test of a particular specimen, it may be replaced with a specimen of equivalent construction. The replacement must go through the entire test sequence.

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 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.

8.2 Specimen Temperature Measurement

The penetration, drop, and puncture tests are to be carried out while the package is at or below -40°C. Temperature measurements will be made by positioning thermocouples on the package surface and the shield (inside the source tube).

8.3 Test Specimen Preparation and Inspection

Refer to the *Specimen Preparation List* in Section 9.0 to ensure that 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-TP80, Revision D.

2. Weigh the test package, including the lid.

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

4. **Quality Control, Engineering, Regulatory Affairs,** and **Quality Assurance** will jointly verify that the test specimens comply with Drawing R-TP80, Revision D, and the AEAT/QSA Quality Assurance Program.

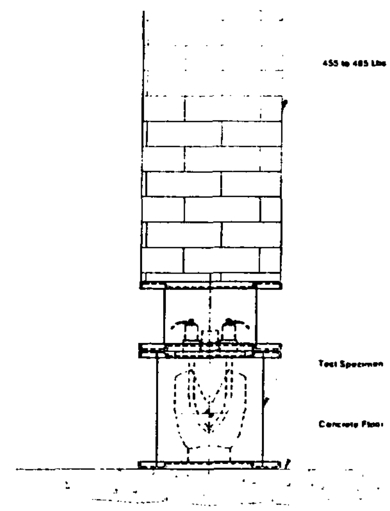
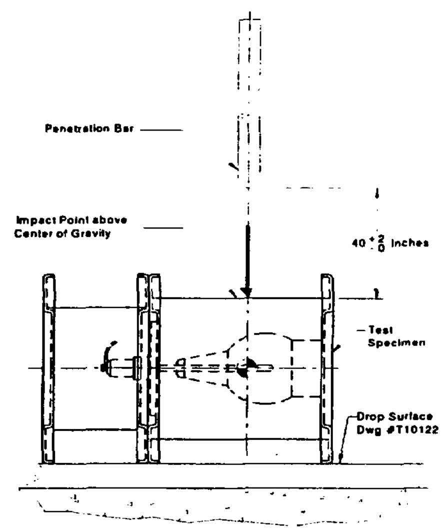
5. Measure and record the location of the simulated source.

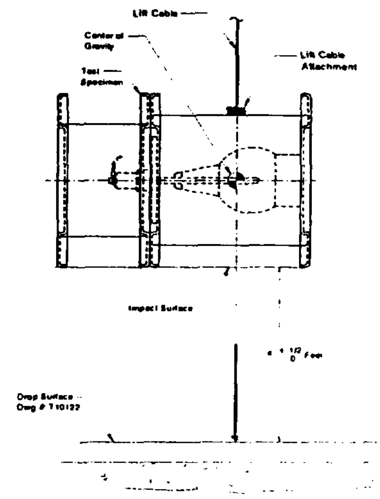
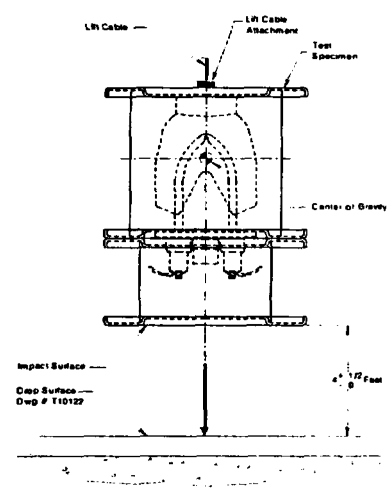
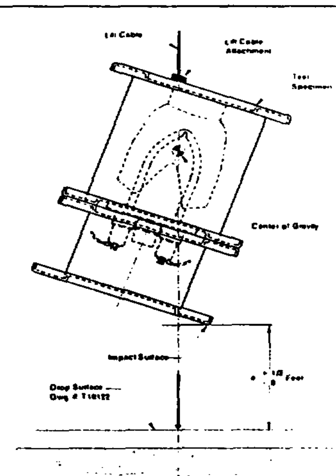
6. Place thermocouples on package surface and inside one of the source tubes.

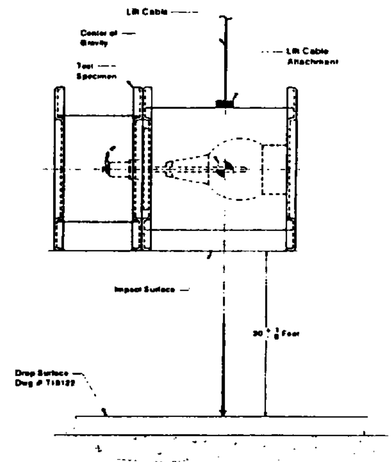
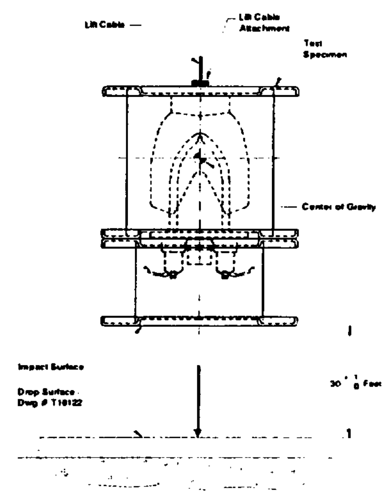
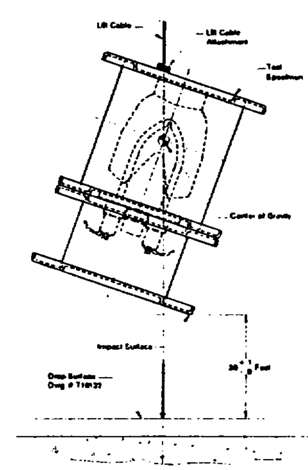
7. Prepare the package for transport.

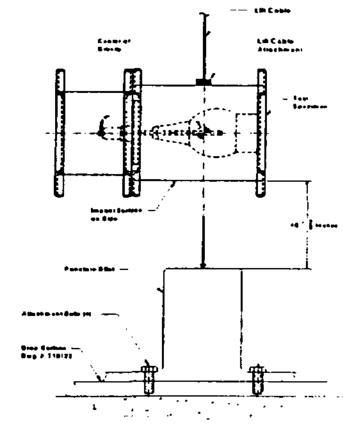
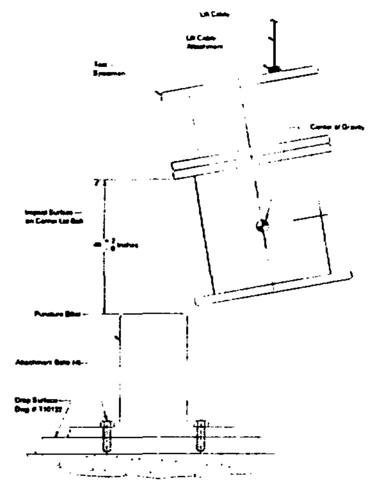
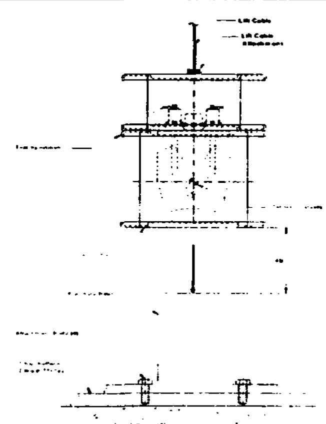
8. Clearly and indelibly mark the units with identification.

8.4 Summary of Test Schedule

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

Test	Paragraph	Specimen	Diagram
1.2 Meter (4 Foot) Free Drop, Case 1, Horizontal, Long Side Down	71.71(c)(7)	TP80(A)	
1.2 Meter (4 Foot) Free Drop, Case 2, Vertical, Upside Down	71.71(c)(7)	TP80(B)	
1.2 Meter (4 Foot) Free Drop, Case 3, Top Corner Down	71.71(c)(7)	TP80(C)	

Test	Paragraph	Specimen	Diagram
9 Meter (30 Foot) Free Drop, Case 1, Horizontal, Long Side Down	71.73(c)(1)	TP80(A)	
9 Meter (30 Foot) Free Drop, Case 2, Vertical, Upside Down	71.73(c)(1)	TP80(B)	
9 Meter (30 Foot) Free Drop, Case 3, Top Corner Down	71.73(c)(1)	TP80(C)	

Test	Paragraph	Specimen	Diagram
Puncture, Case 1, Horizontal, Long Side Down	71.73(c)(3)	TP80(A)	
Puncture, Case 2, Underneath Corner of Top Plate	71.73(c)(3)	TP80(B)	
Puncture, Case 3, Vertical Upright	71.73(c)(3)	TP80(C)	
Thermal	71.73(c)(4)	ALL	Requirement for thermal test to be determined for each unit following completion of drop and puncture tests.

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 455 pounds which is greater than five times the maximum package weight and greater than 2 lbf/in^2 multiplied by the vertically projected area:

5 x 90 lbf = 450 lbf

8 ¼" wide x 10" long x 2 lbf/in^2 = 165 lbf

Refer to *Equipment List 1* for information about required tools. Use *Checklist 1* to ensure that the 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 a specimen for the compression test:

1. Review the setup shown in Figure 2.
2. Place the specimen on a concrete surface oriented in its normal, upright transport position.
3. Gradually place 455 to 465 pounds uniformly distributed onto the specimen as shown in Figure 2.
4. Test specimen in accordance with *Checklist 1*.

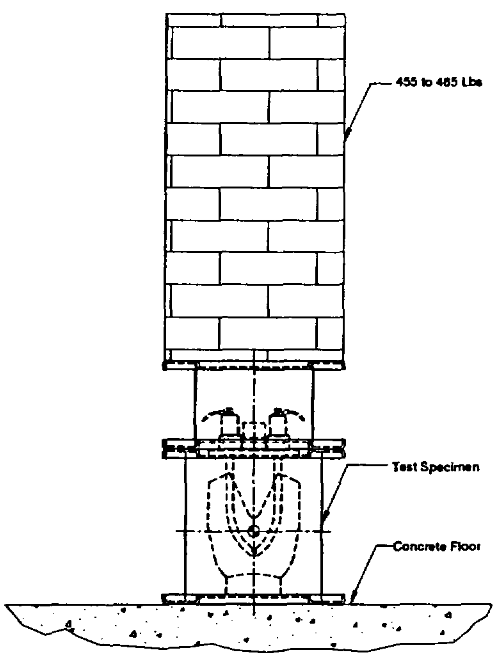


Figure 2. Compression Test Setup

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.

2. Make a preliminary evaluation of the specimen relative to the requirements of 10 CFR 71.

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

4. 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 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 a package 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. Use shims to position the package, if necessary.

2. Position the penetration bar shown in Drawing BT10129, Revision B, directly above the specified point of impact, and raise the bar 40 to 42 inches above the target.

3. Measure the specimen's internal and 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

The 650L package is placed horizontally, long side down on the drop surface specified in Drawing AT10122, Revision B. The orientation of the package is shown in Figure 3. The desired impact point is on the long side of the outer shell, directly above the center of gravity of the package, to try to penetrate the shells.

Other orientations for this specimen were considered including the normal transport position. In the normal transport orientation, the lock assembly is protected by the 0.135" thick steel outer lid. The penetration bar dropped from four feet would cause only minor damage to the outer lid.

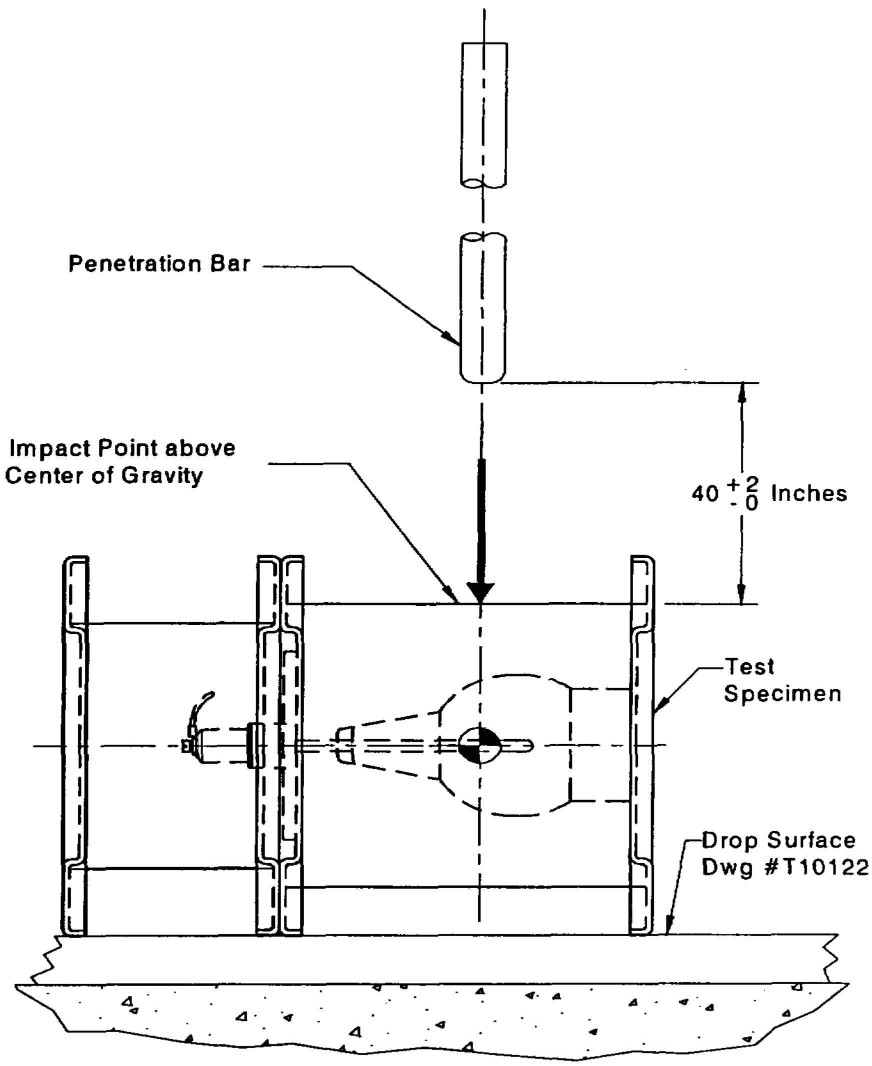


Figure 3. Penetration Test Orientation

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.

2. Make a preliminary evaluation of the specimen relative to the requirements of 10 CFR 71.

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

4. 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 inspections 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, the package is released from a height of four feet and lands on the steel drop surface specified in Drawing AT10122, Revision B.

This test requires that all 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 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 appropriate orientation:

   - Refer to Figure 4 for the Specimen TP80(A) package orientation

   - Refer to Figure 5 for the Specimen TP80(B) package orientation

   - Refer to Figure 6 for the Specimen TP80(C) package orientation

4. Align the selected center-of-gravity as shown in the referenced drawing.

5. Raise the package so that the impact target is 4.0 to 4.5 feet above the drop surface.

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

8.7.2 1.2 Meter (4 Foot) Free Drop Test Orientation, Specimen TP80(A)

The impact surface of Specimen TP80(A) is horizontal, long-side down.

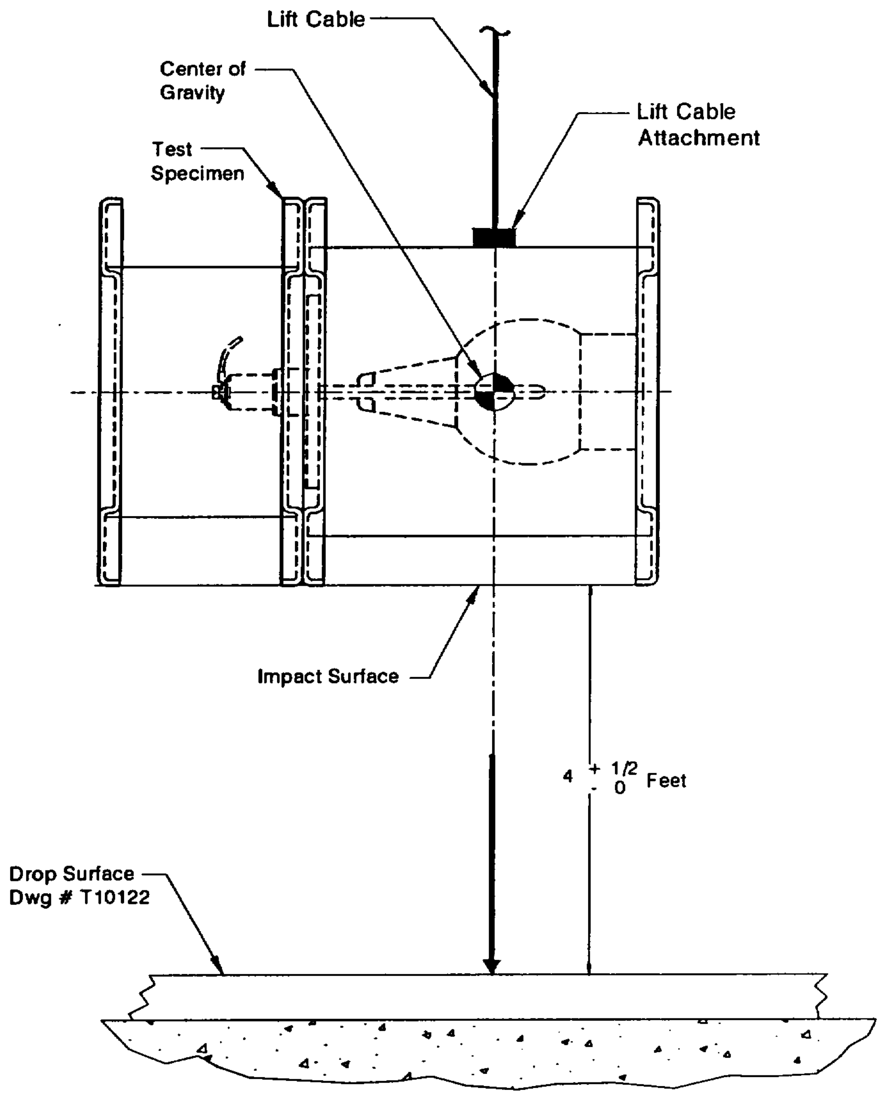


Figure 4. 1.2 Meter (4 Foot) Free Drop Orientation, Specimen TP80(A)

8.7.3 1.2 Meter (4 Foot) Free Drop Test Orientation, Specimen TP80(B)

The impact surface for Specimen TP80(B) is vertical, upside down.

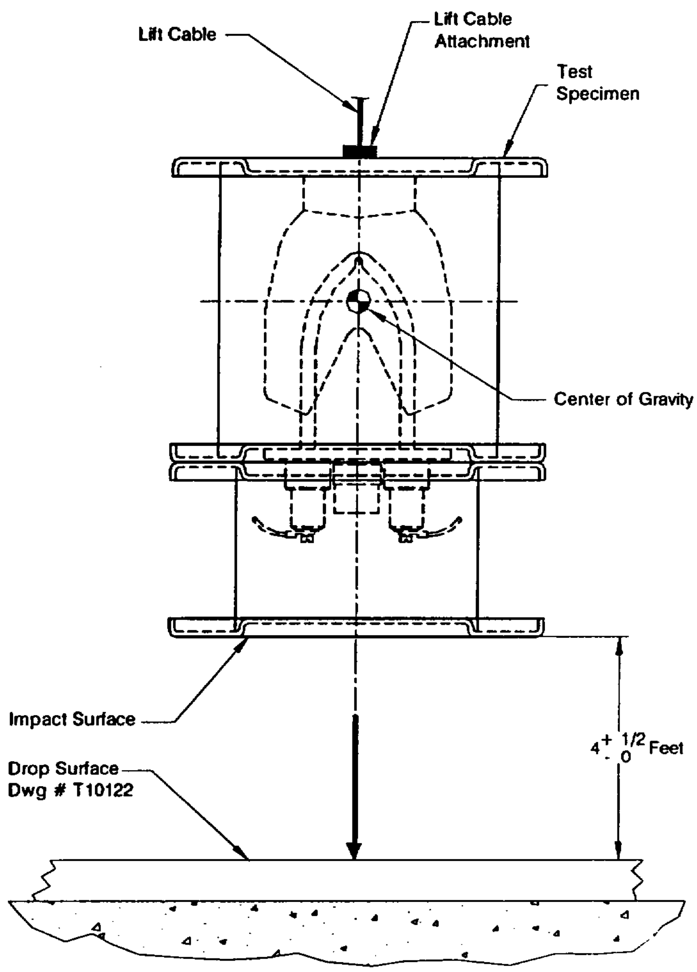


Figure 5. 1.2 Meter (4 Foot) Free Drop Orientation, Specimen TP80(B)

8.7.4 1.2 Meter (4 foot) Free Drop Test Orientation, Specimen TP80(C)

The impact surface for Specimen TP80(C) is the top (lid) corner.

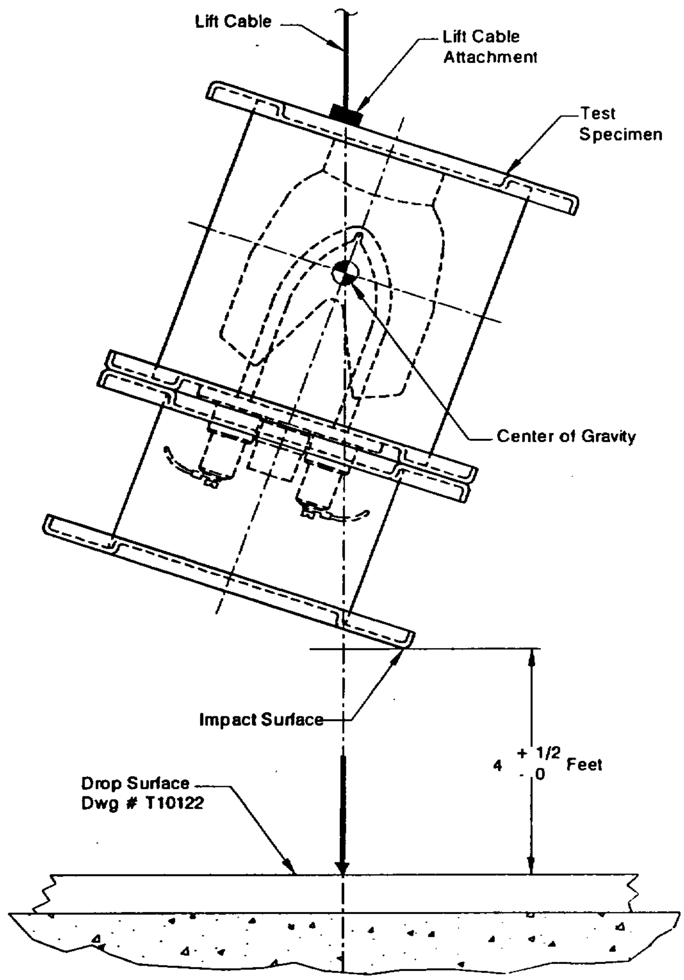


Figure 6. 1.2 Meter (4 Foot) Free Drop Orientation, Specimen TP80(C)

8.7.5 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. Make a preliminary evaluation of the specimen relative to the requirements of 10 CFR 71.71.

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

4. Evaluate the condition of the specimen to determine if changes are necessary in package orientation for the 9 meter (30 foot) free drop to achieve maximum damage.

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

6. Measure and record a radiation profile of the test specimen 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 71.71.

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). This drop uses the same orientations as the 1.2 meter (4 foot) free drop and compounds any damage caused in that test.

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 thirty feet and lands on the steel drop surface specified in Drawing AT10122, Revision B.

This test requires that 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 7 for the Specimen TP80(A) package orientation
   - Refer to Figure 8 for the Specimen TP80(B) package orientation
   - Refer to Figure 9 for the Specimen TP80(C) package orientation

4. Align the selected center-of-gravity marker as shown in the referenced drawing.

5. Raise the package so that the impact target is 30 to 31 feet above the drop surface.

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

8.9.2 9 Meter (30 Foot) Free Drop Test Orientation, TP80(A)

The impact surface for Specimen TP80(A) is horizontal, long-side down. This orientation is the same as the orientation for the 1.2 meter (4 foot) drop for Specimen TP80(A).

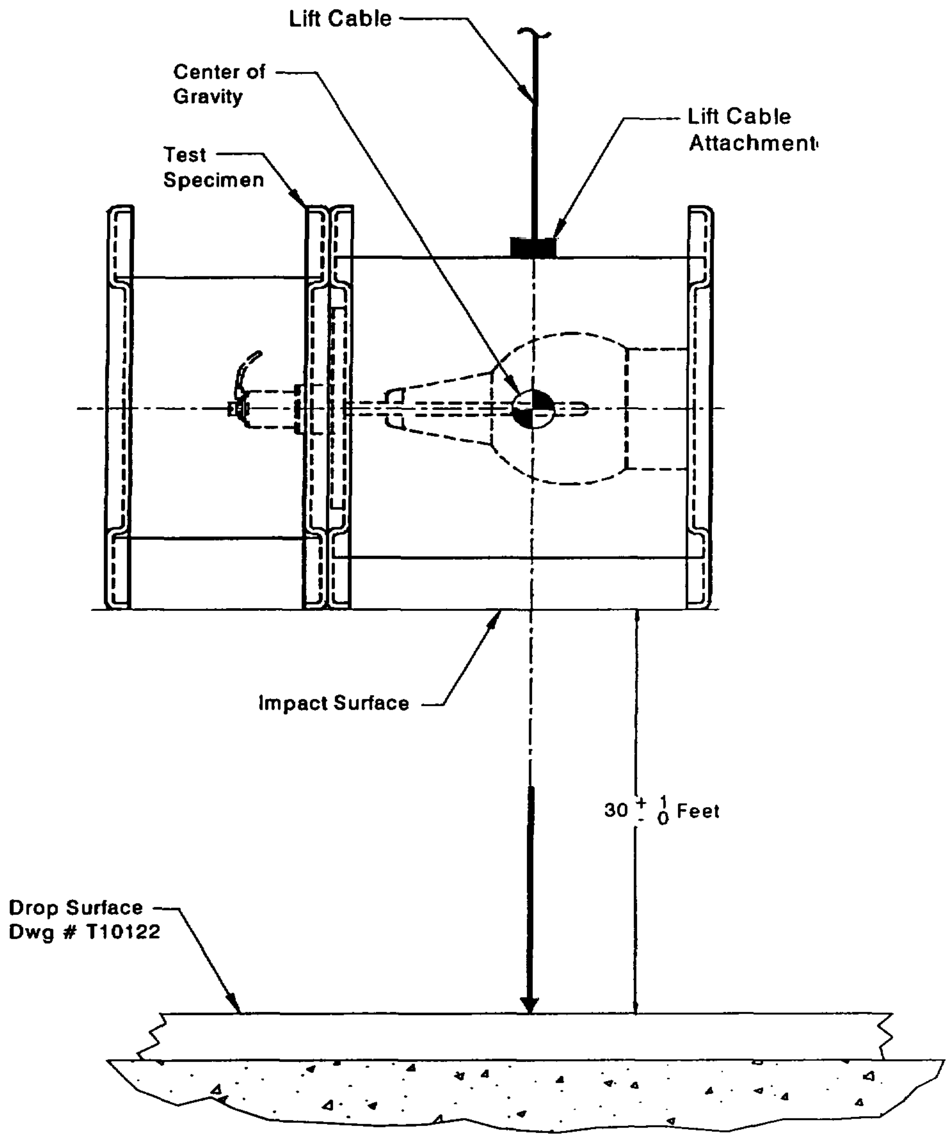


Figure 7. 9 Meter (30 Foot) Free Drop Orientation, Specimen TP80(A)

8.9.3 9 Meter (30 Foot) Free Drop Test Orientation, Specimen TP80(B)

The impact surface for Specimen TP80(B) is vertical, upside down. This orientation is the same as the orientation for the 1.2 meter (4 foot) drop for Specimen TP80(B).

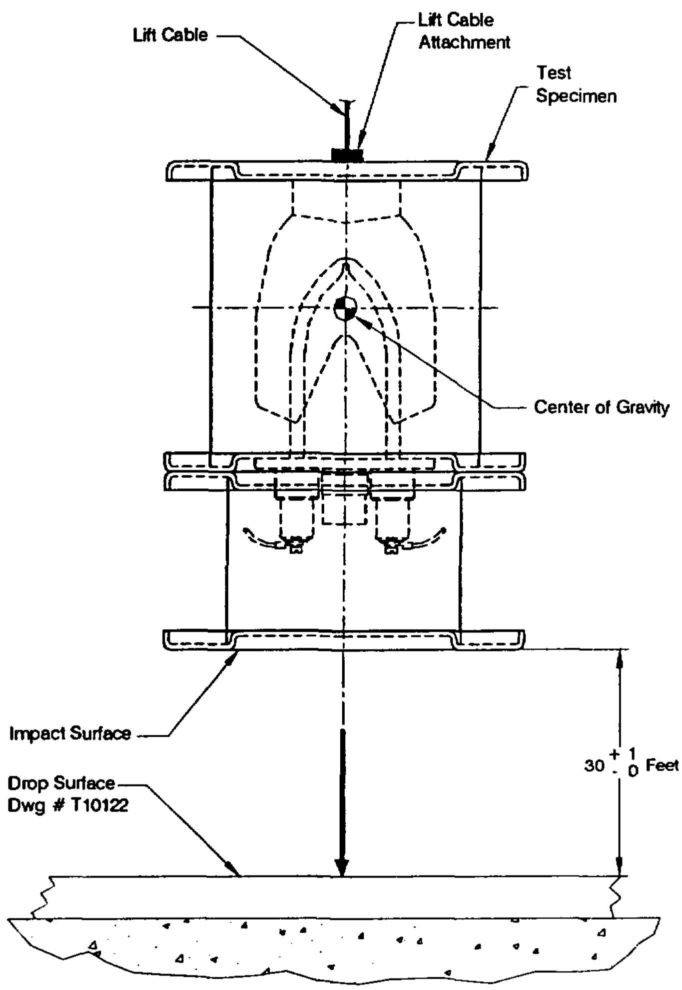


Figure 8. 9 Meter (30 Foot) Free Drop Orientation, Specimen TP80(B)

8.9.4 9 Meter (30 Foot) Free Drop Test Orientation, Specimen TP80(C)

The impact surface for Specimen TP80(C) is the top (lid) corner. This orientation is the same as the orientation for the 1.2 meter (4 foot) drop for Specimen TP80(C).

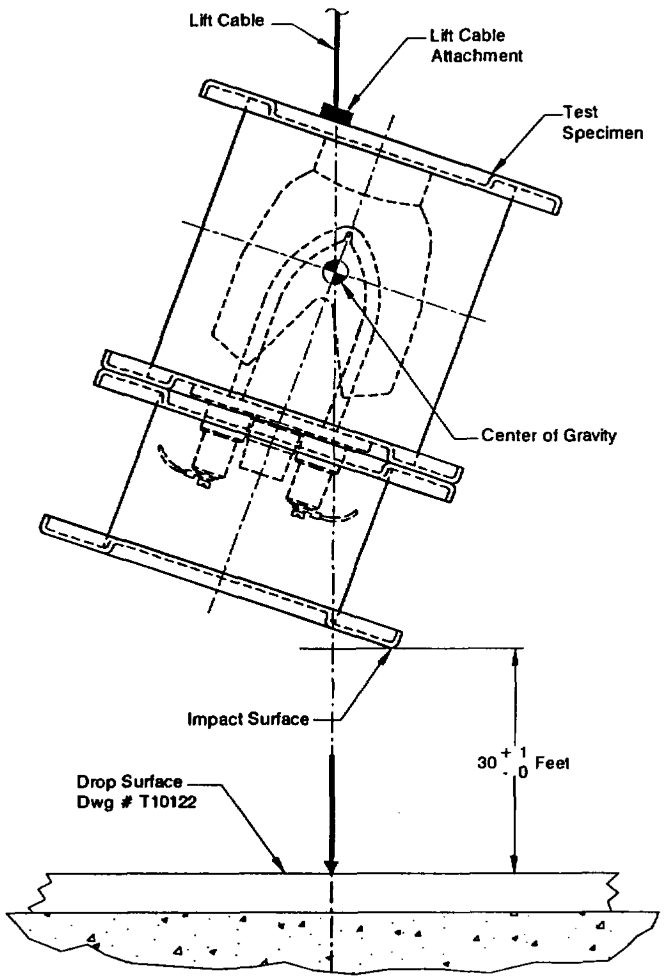


Figure 9. 9 Meter (30 Foot) Free Drop Orientation, Specimen TP80(C)

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. Make a preliminary evaluation of the specimen relative to the requirements of 10 CFR 71.73.

3. Perform an assessment to determine if any change in puncture test orientation is necessary in order to sustain maximum specimen damage during the Puncture Test, and document.

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 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 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. Place the specimen on the drop surface and position it according to the appropriate orientation (unless the 9 meter Test Assessment selects different orientations):

   - Refer to Figure 10 for the Specimen TP80(A) package orientation

   - Refer to Figure 11 for the Specimen TP80(B) package orientation

   - Refer to Figure 12 for the Specimen TP80(C) package orientation

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

4. Raise the package so that there are 40 to 42 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 TP80(A)

The impact surface for Specimen TP80(A) is the horizontal, long-side of the outer shell.

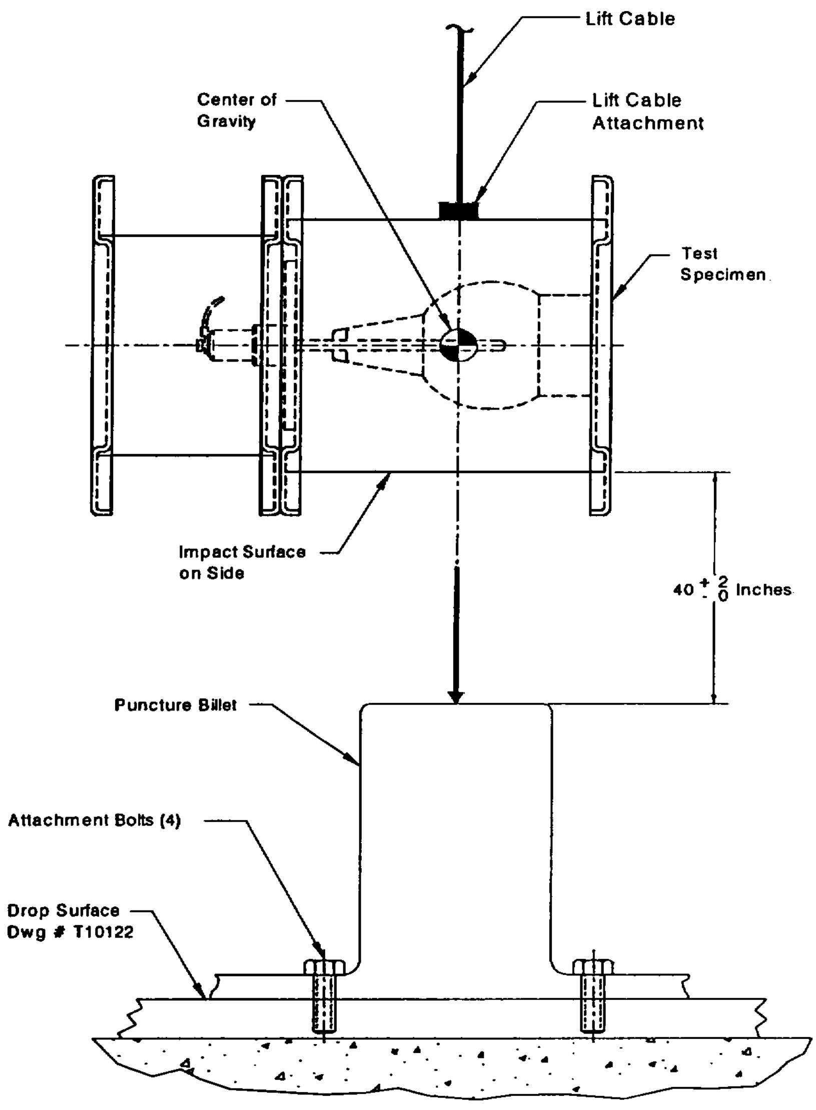


Figure 10. Puncture Test Orientation, Specimen TP80(A)

8.10.3 Puncture Test Orientation, Specimen TP80(B)

The impact surface for Specimen TP80(B) is the underside of the top plate. The puncture bar should impact the corner of the plate on the lid bolt.

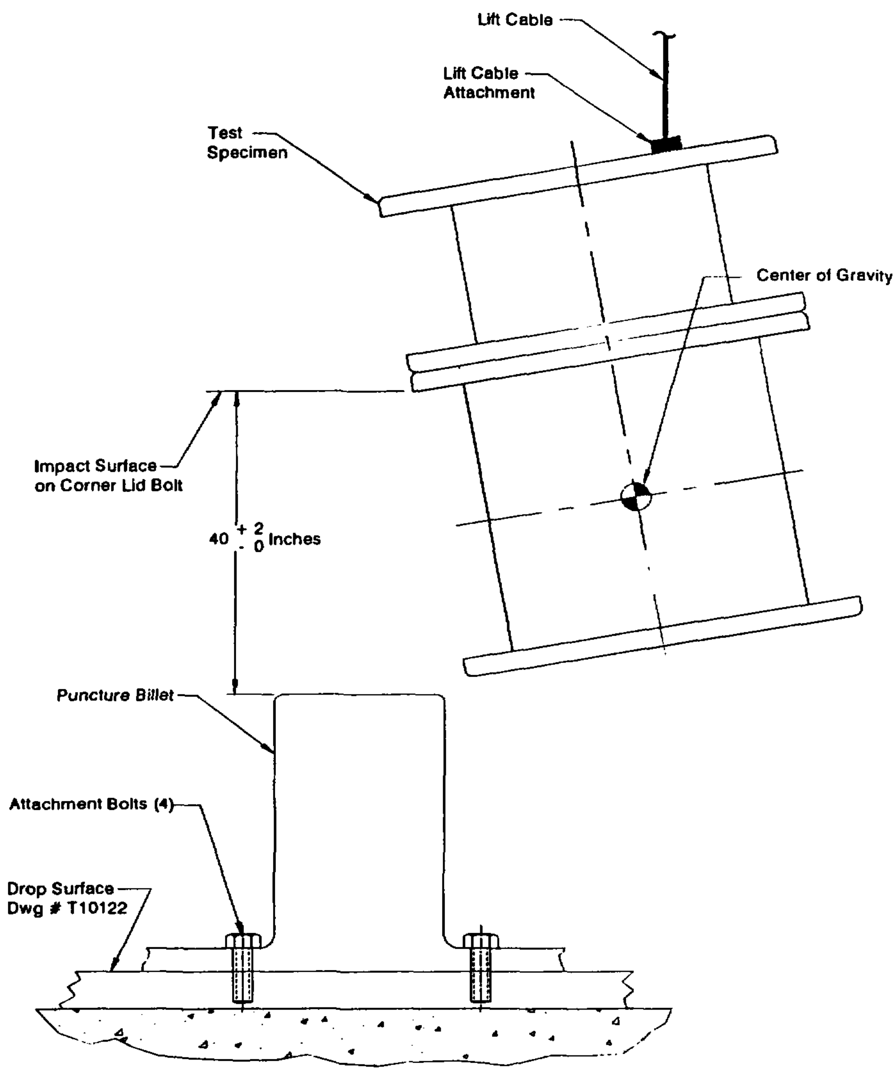


Figure 11. Puncture Test Orientation, Specimen TP80(B)

8.10.4 Puncture Test Orientation, Specimen TP80(C)

The impact surface for Specimen TP80(C) is the bottom of the package.

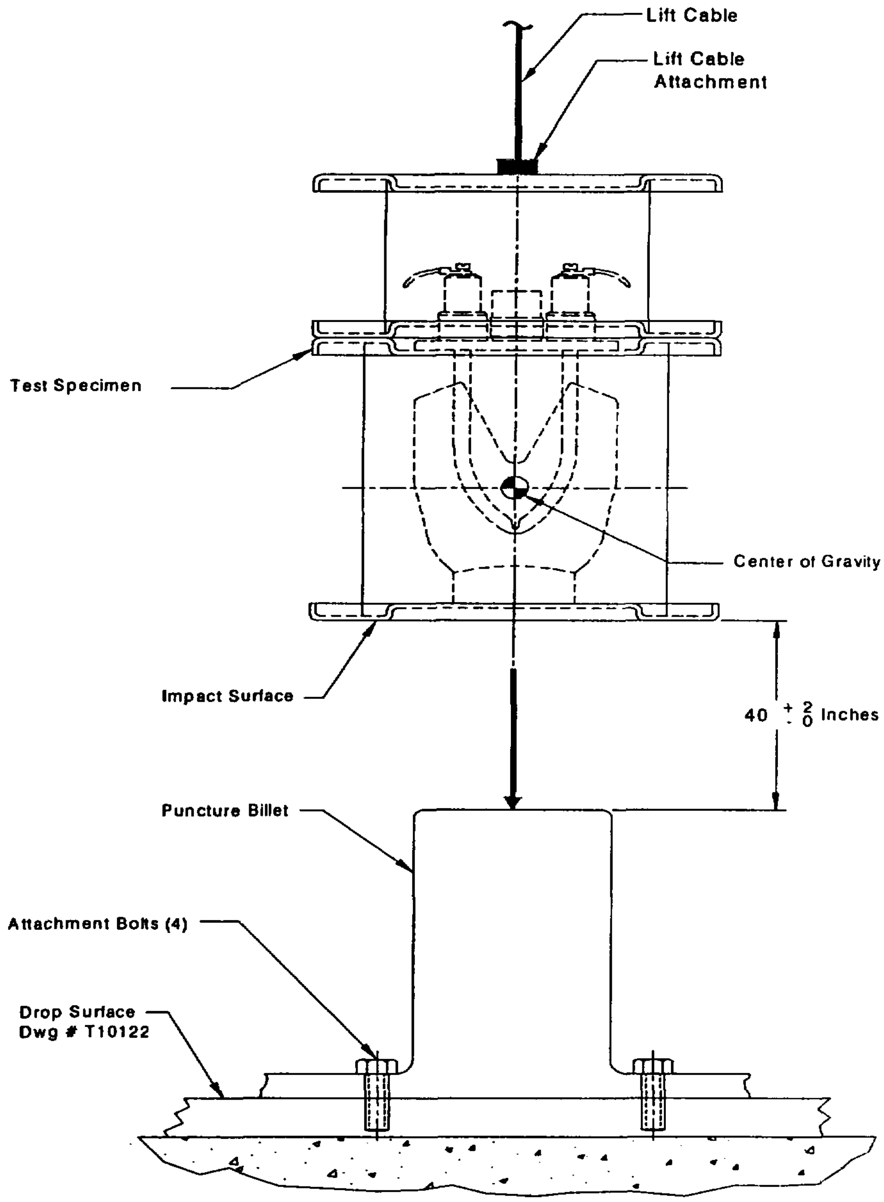


Figure 12. Puncture Test Orientation, Specimen TP80(C)

8.10.5 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. Make a preliminary evaluation of the specimen relative to the requirements of 10 CFR 71.73.

3. 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 all specimens after the puncture test and before the thermal test.

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

2. Determine and record the location of the source.

3. Remove and assess the condition of the simulated source.

4. Reassemble the package using an active source, making sure that the source wire position and the package configuration are the same as they were immediately after the puncture test.

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

6. Reassemble the package using the same simulated source used in the specimen during the previous tests.

7. Make sure that the source wire position and the package configuration are the same as they were immediately after the puncture test.

8. Weigh package.

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).

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 Selection

The specimen(s) selected for thermal testing will be based on an assessment of the damage sustained by the packages following the puncture test. The selected package testing orientation will also be determined based on an assessment of the test specimen condition. As a minimum requirement, the vertical, upside down drop orientation (TP80(B)) will be tested in a vertical, right

side up orientation for the thermal test. The TP80(B) specimen is most likely to have the source pull out from its shielded position due to deflection of the top plate during the drop tests and melting of lead shielding/shims below the DU shield during the thermal test.

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. This temperature, above the required 800°C, includes an allowance for measurement uncertainty.

The test environment is a vented electric oven capable of creating a time weighted average temperature of 800°C.

Thermocouples will be attached to the specimen top, bottom, and 2 side surfaces. The 2 side surface thermocouples will be positioned 180° apart, facing the front and back of the oven. A fifth thermocouple will be inserted into one of the source tubes to measure source changer internal temperature. The external thermocouples will be shielded from the radiant heat of the oven so that the surface temperature of the source changer can be accurately measured.

When the oven has been pre-heated to 810°C, the package will be placed in the oven in the orientation determined to be worst case, per Section 8.10.2. When the temperature of the source changer surface has risen to no less than 810°C, 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 of the foam during the thermal test, 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 cooldown, such a reduction in cooldown rate is considered to have a negligible effect on the package compared with the 30 minutes of exposure to 810°C. This test plan, therefore, does not require insolation effects to be explicitly modeled during package cooldown. 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. Attach the thermocouples to the test specimen's measurement locations.

2. Preheat the oven temperature to not less than 810°C.

3. When the oven temperature is stable at above 810°C, place the specimen in the oven, and partially close the door.

4. When the temperature of the surface of the specimen rises above 810°C, start the 30-minute time interval.

5. Throughout the test, measure and record the oven and the test specimen temperatures.

6. At the end of the 30 minute time interval, open the oven door and shut off the oven.

<u>WARNING:</u> **If the package is burning, appropriate safety measures must be in place to avoid the risks associated with burning polyurethane foam and/or depleted uranium. Consult with the oven operator and other appropriate personnel.**

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

8. 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.

2. Make a preliminary evaluation of the specimen relative to the requirements of 10 CFR 71.73.

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. Determine and record the location of the source.

3. Remove and assess the condition of the simulated source.

4. Reassemble the package using an active source, making sure that the source wire position and the package configuration are the same as they were immediately after the thermal test.

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

6. Document and assess the radiation level at one meter from the surface of the package.

7. Determine whether it is necessary to dismantle the test specimen for inspection of hidden component damage or failure.

8. If proceeding with the inspection, record and photograph the process of removing any component.

9. 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 testing 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.

Specimen Preparation List

Step	TP80(A)	TP80(B)	TP80(C)
1. Serial Number:			
2. Total weight of package (lb):			
3. Location of simulated source from top plate (in):			
4. Location of lead shielding:			
5. All fabrication and inspection records documented in accordance with the AEAT QA Program?			
6. Does the unit comply with the requirements of Drawing R-TP80, Revision D?			
7. Has the radiation profile been recorded in accordance with AEAT QSA Work Instruments WI-Q09?			
8. 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	TP80(A)	TP80(B)	TP80(C)
1. Position the specimen on concrete surface, per the appropriate drawing.	Figure 2	Figure 2	Figure 2
2. Measure the ambient temperature.			
Note the instrument used:			
3. Apply a uniformly distributed weight of 455 to 465 pounds on the top of the lid 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 relative to 10 CFR 71. 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:
Test Date:	Test Time:	Test Plan 80 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:

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

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		
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	TP80(A)	TP80(B)	TP80(C)
1. Immerse the test specimen in dry ice or cool in freezer as needed to bring specimen temperature below –40°C.			
2. Position the package as shown in the referenced figure, or by Step 7, Checklist 1.	Figure 3	Figure 3	Figure 3
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's internal and surface temperatures. Ensure that the specimen is at the specified temperature.			
Record the ambient temperature:			
Note the instrument used:			
Record the specimen's internal temperature:			
Note the instrument used:			
Record the specimen's surface temperature:			
Note the instrument used:			
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 relative to 10 CFR 71. 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:
Test Date:	Test Time:	Test Plan 80 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:		
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		
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	TP80(A)	TP80(B)	TP80(C)
1. Immerse specimen in dry ice or cool in freezer to bring 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 internal and surface temps. Ensure specimen is at specified temp.			
Record the specimen's internal temperature:			
Note the instrument used:			
Record the specimen's surface temperature:			
Note the instrument used:			
6. Lift and orient the test specimen as shown in the specified referenced figure.	Figure 4	Figure 5	Figure 6
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 internal and surface temps. Ensure specimen is at specified temp.			
Record the specimen's internal temperature:			
Note the instrument used:			
Record the specimen's surface temperature:			
Note the instrument used:			
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 relative to 10 CFR 71, and record on Data Sheet 3. Determine package orientation for the 9 meter 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:
Test Date:	Test Time:	Test Plan 80 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:		
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		
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	TP80(A)	TP80(B)	TP80(C)
1. Immerse test specimen in dry ice or cool in freezer to bring specimen temperature 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's internal and surface temps. Ensure specimen is at the specified temperature.			
Record the specimen's internal temperature:			
Note the instrument used:			
Record the specimen's surface temperature:			
Note the instrument used:			
6. Lift and orient the test specimen as shown in the specified referenced figure.	Figure 7	Figure 8	Figure 9
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's internal and surface temps. Ensure specimen is at specified temperature.			
Record the specimen's internal temperature:			
Note the instrument used:			
Record the specimen's surface temperature:			
Note the instrument used:			
11. Photograph the test specimen and record any damage on Data Sheet 4.			
12. **Engineering, Regulatory Affairs and Quality Assurance** make a preliminary assessment relative to 10 CFR 71. 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:
Test Date:	Test Time:	Test Plan 80 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:

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		
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	TP80(A)	TP80(B)	TP80(C)
1. Immerse specimen in dry ice or cool in freezer to bring specimen temp. 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's internal and surface temps. Ensure that specimen is at specified temp.			
Record the specimen's internal temperature:			
Note the instrument used:			
Record the specimen's surface temperature:			
Note the instrument used:			
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 10	Figure 11	Figure 12
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 the specimen's internal and surface temperatures.			
Record the specimen's internal temperature:			
Note the instrument used:			
Record the specimen's surface temperature:			
Note the instrument used:			
11. Photograph the test specimen and record any damage on Data Sheet 5.			
12. **Engineering, Regulatory Affairs and Quality Assurance** make a preliminary assessment relative to 10 CFR 71. 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:
Test Date:	Test Time:	Test Plan 80 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:		
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
Bottom Surface Thermocouple 1		
Top Surface Thermocouple 2		
Side Surface Facing Oven Front Thermocouple 3		
Side Surface Facing Oven Rear Thermocouple 4		
Source Tube Thermocouple 5		
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	TP80(A)	TP80(B)	TP80(C)
1. Record Test Specimen Serial Number.			
2. Preheat the oven to 810°C.			
3. Attach the thermocouples as described in Equipment List 6. 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, 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			
7. At the end of the 30-minute test period, shut off the oven and open the door. Record the time.			
8. Describe combustion when door is opened.			
9. Allow the specimen to cool, then remove the specimen from the oven. Record the time.			
NOTE: If specimen continues to burn, let it self-extinguish and cool naturally.			
10. Measure and record the ambient temperature.			
11. Photograph the test specimen and record any damage on data sheet 6.			
12. Radiograph the unit to determine the shield location.			
13. Measure and record the source location.			
14. **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 80 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:		
Describe results of any pre- or post-test radiography:		
Completed by:		Date:

Appendix A: Drawing R-TP80, Revision D

FIGURE WITHHELD UNDER 10 CFR 2.390

AEA TECHNOLOGY QSA 40 NORTH AVE, BURLINGTON, MA 01803	DESCRIPTIVE DRAWING	
TITLE 650L SOURCE CHANGER TEST UNITS		
SIZE A	DWG. NO. R-TP80 SCALE: NONE SHEET 1 OF 2	REV D

FIGURE WITHHELD UNDER 10 CFR 2.390

UNLESS OTHERWISE SPECIFIED: ALL DIMENSIONS ARE REFERENCE			
SIZE A	DWG. NO. R–TP80		REV D
	SCALE: NONE	SHEET 2 OF 2	

Section 2.12.2 Appendix: Test Plan 80 Report Minus Manufacturing Records (Jun 1999).

AEA TECHNOLOGY
QSA

TEST PLAN NO. 80, REV. 1	
TEST PLAN COVER SHEET	
TEST TITLE: TEST PLAN 80, REVISION 1, MODEL 650L SOURCE CHANGER TYPE B TRANSPORT TESTS	
PRODUCT MODEL: 650L	
ORIGINATED BY: [signature] (MPR)	DATE: 12 MAR 99
TEST PLAN REVIEW	
ENGINEERING APPROVAL: [signature]	DATE: 12 MAR 99
QUALITY ASSURANCE APPROVAL: Daniel W. Kurtz	DATE: 12 Mar 99
REGULATORY APPROVAL: Catherine Roughan	DATE: 12 Mar 99
COMMENTS:	
TEST RESULTS REVIEW	
ENGINEERING APPROVAL: [signature]	DATE: 12 JUL 99
QUALITY ASSURANCE APPROVAL: Daniel W. Kurtz	DATE: 13 Jul 99
REGULATORY APPROVAL: C. Roughan	DATE: 13 Jul 99

SENTINEL

TEST PLAN 80 REPORT

MODEL 650L

June 1999

Prepared By: *Laura Ridzon* Date: 28 JUN 99
Laura Ridzon, MPR Associates, Inc.

Reviewed By: *Nicholas J. Marrone* Date: 28 June 99
Nicholas J. Marrone, MPR Associates, Inc.

Approved By: *Caroline S. Schlaseman* Date: 28 JUN 99
Caroline S. Schlaseman, MPR Associates, Inc.

AEA Technology QSA, Inc.
Burlington, MA

TABLE OF CONTENTS

APPENDICES

1. PURPOSE

This report describes the Type B test results for the Model 650L source changer. These tests were performed in accordance with Test Plan 80 and were conducted March 15 through 20, 1999. The Test Plan specified testing necessary to demonstrate compliance with the requirements in 10 CFR Part 71 and IAEA Safety Series No. 6 (1985 as amended 1990) for "Normal Conditions of Transport" and "Hypothetical Accident Conditions." Evaluation of the compliance of the Model 650L with these requirements is provided in the Safety Analysis Report (SAR).

2. SCOPE OF TESTING

Test Plan 80 identified three orientations that could potentially cause the most significant damage to the Model 650L source changer in the 9 meter (30 foot) drop tests. Therefore, the test plan required three test specimens. Each of these test specimens was subjected to the tests described below.

1. Normal Conditions of Transport Tests per 10 CFR 71.71, including the following for each test specimen:

   a) Compression test, with the test specimen under a load greater than or equal to five times the Model 650L maximum weight for at least 24 hours.

   b) Penetration test, in which a 13.4 lb (6.08 kg) penetration bar is dropped from at least 1 meter (40 inches) onto the test specimen in the most vulnerable location.

   c) 1.2 meter (4 foot) drop test, in which the test specimen is dropped in an orientation expected to cause maximum damage.

   Water spray preconditioning of the test specimens prior to testing was not required in the test plan and is evaluated separately.

2. Hypothetical Accident Condition Tests per 10 CFR 71.73, including the following for each of the test specimens:

   a) 9 meter (30 foot) drop test, in which the test specimen is dropped in an orientation expected to cause maximum damage.

   b) Puncture test, in which the test specimen is dropped from at least 1 meter (40 inches) onto a 6 inch (152.4 mm) diameter vertical bar in an orientation expected to compound damage from the 9 meter (30 foot) drop test.

   c) Thermal test, in accordance with 10 CFR71.73(c)(4), in which the test specimen is exposed for 30 minutes to an environment which provides a time-averaged environmental temperature of at least 800°C (1472°F), and an emissivity coefficient of at least 0.9. For the Model 650L, the test plan specified that the thermal test would be performed for only one of the three test specimens, unless other test units suffered significant damage in the drop and puncture tests. This requirement was based on the evaluation of the construction of the unit, and on the potential failure modes, which are discussed in the following section.

   The crush test specified in 10 CFR 71.73(c)(2) was not required because the source capsules are qualified as Special-Form radioactive material.

   The water immersion test specified in 10 CFR 71.73(c)(6) and other tests specified in 10 CFR 71 are evaluated separately.

   For all tests, sufficient margin was included in test parameters to account for measurement uncertainty. These test parameters included test specimen weight, temperature, and drop height.

3. FAILURE MODES

For the Model 650L source changer, the key function important to safety is the positive retention of the radioactive source in its stored position within the depleted uranium shield. Displacement of either the source or the shield from the design position or failure of the shield could cause radiation from the package to increase above regulatory limits. Mechanisms, which could cause these modes of failure, include:

- Oxidation of the DU Shield - During the thermal test, oxidation of the DU shield could lead to reduced shielding effectiveness and higher radiation exposure. This could occur if failure of the inner and outer shells or failure of the through-bolts during drop testing results in a large, open path to the DU shield.

- Source Pull-Out from the Shield - During drop testing or during the thermal test, source pull-out could lead to higher radiation exposure. This could occur if there is significant relative displacement between the shield and the lock assembly on the top cover plate. Such displacement could occur if the top plate is deformed outward, and the shield moves laterally or downward through the polyurethane foam.

The drop orientations for the normal and hypothetical accident tests were selected to challenge the components that are intended to prevent these failures. For the 1.2 meter (4 foot) and 9 meter (30 foot) drop tests, these orientations include the following:

- Horizontal with the long side of the unit down - This orientation could cause movement of the shield or failure of the inner and/or outer shells.
- Vertical upside down - This orientation could cause deformation of the top plate, failure of the through-bolts, or failure of the lock assembly which would all lead to source pull-out from the shield. Additionally, movement of the shield through the foam in the upper part of the unit would put a large lateral load on the upper portion of the inner shell, which is subject to brittle failure.
- Top corner down - This orientation could cause failure of the bolts holding the protective lid in place, exposing the lock assembly to damage during the puncture test. This orientation also loads the through-bolts, top plate, and inner shell similar to the vertical upside down orientation.

Because of the potential for brittle failure of carbon steel components, all test units were packed in dry ice and cooled to less than -40°C (-40°F) (the minimum temperature required by IAEA Safety Series 6) for the penetration, 1.2 meter (4 foot) drop, 9 meter (30 foot) drop, and puncture tests.

In selecting test units for the thermal test, it was concluded that an undamaged unit would not be significantly affected by exposure to the conditions of the thermal test. In particular, the depleted uranium shield is completely enclosed within the inner and outer shells and is supported by foam and a shim of either copper, steel, or lead. Under the thermal test conditions, degradation of the foam and melting of the shim, if it is lead, will allow the shield to move by a

small amount. This could result in limited movement of the source relative to the shield, but not enough to significantly increase radiation levels.

Therefore, the thermal test is only expected to have a significant effect on those units which sustained damage relating to the two modes of failure described above, specifically: (1) an opening in the inner and outer shells to allow oxidation of the shield, or (2) relative displacement of the lock assembly and shield which could be compounded by shield movement during the thermal test. Since relative displacement of the lock assembly was expected in the vertical upside down drop orientation, it was planned to perform the thermal test with the unit dropped in this orientation. The test plan required thermal tests of the other test specimens only if they sustained damage that could lead to failure during the thermal test.

4. TEST UNIT DESCRIPTION

The Model 650L test specimens, identified below, were originally constructed in accordance with drawing C65009 and were prepared for testing in accordance with drawing R-TP80. The manufacturing route cards for the units document the compliance of these units with the AEA Technology QSA QA program (see Appendix B).

Specimen	Serial No.	Total Weight	Lead Configuration
TP80(A)	2243	80.0 lb (36.3 kg)	No lead between DU shield and long side of inner shell.
TP80(B)	182	83.6 lb (37.9 kg)	Thickest lead under DU shield (total 3/8" thick).
TP80(C)	195	89.0 lb (40.4 kg)	Any location.

Important features of the test unit construction include the following:

- The configuration of lead added to each unit for supplemental shielding was specified as shown above to provide the worst case for the each drop orientation.
- For TP80(B), the original steel shim used in the unit was replaced with a solid 3/8" thick lead shim.
- The original carbon steel through-bolts were replaced with stainless steel bolts.
- The original carbon steel lid bolts were replaced with high strength, strain hardened stainless steel bolts.
- The weights of the test specimens are representative of the heaviest 650L units in use. The range of weights of 650L units is 75 lb to 90 lb (34.0 kg to 40.8 kg).

The test specimens were radiographed to document the lead configuration and the position of the internal components. Also, the position of the "dummy" source used in the units was measured prior to testing.

5. SUMMARY AND CONCLUSIONS

All test specimens met the requirements for 10 CFR 71 Type B(U) Transport Testing, as shown in the following table of Radiation Profile results.

Specimen	Specimen Surface	At Surface, Before Test	At One Meter, Before Test	At Surface, After 4 ft Drop Test	At One Meter, After 4 ft Drop Test	At One Meter, After Final Test (Notes 1,2)
	Reg. Limits	200 mR/hr	10 mR/hr	200 mR/hr	10 mR/hr	1000 mR/hr
TP80(A) S/N 2243	Top	84	3.2	94	2.4	2.7
	Right	47	0.6	47	0.7	0.8
	Front	88	0.7	89	0.8	1.0
	Left	56	0.6	65	0.7	0.7
	Rear	74	0.7	89	0.8	0.9
	Bottom	51	0.4	94	0.7	0.6
TP80(B) S/N 182	Top	60	3.1	71	2.0	28
	Right	56	0.4	53	0.6	5.6
	Front	84	0.8	83	0.8	5.6
	Left	88	0.6	83	0.6	7.9
	Rear	79	0.8	77	0.8	7.9
	Bottom	74	0.5	83	0.7	1.1
TP80(C) S/N 195	Top	72	2.2	59	2.0	2.2
	Right	105	0.7	71	0.7	0.9
	Front	50	0.6	47	0.5	0.6
	Left	127	0.7	106	0.8	1.0
	Rear	50	0.6	53	0.6	0.6
	Bottom	61	0.6	59	0.5	0.5

Notes:
1. The final Hypothetical Accident Condition test for test specimens TP80(A) and TP80(C) was the Puncture Test. The final test for specimen TP80(B) was the Thermal Test.
2. Radiation profile at the surface is not required for the Hypothetical Accident Condition test (see 10 CFR 71.51(a)(2)).

Results of each test are summarized in the table below, in the sequence in which the tests were completed. Detailed results are provided in the following sections of this report, test data sheets are in Appendix C, and photographs are included in Appendix D.

Specimen	Test Performed	Test Results (Note 1)
TP80(A)	Compression Test	No damage
	1 meter (40 inch) penetration bar on side	Impact mark; no visible damage
	1.2 meter (4 foot) drop, horizontal on long side	• Impact mark on edge of plates • Small change in radiation profile
	9 meter (30 foot) drop, horizontal on long side	Bent bottom plate flange inward
	1 meter (40 inch) puncture, horizontal on long side (dropped twice to ensure specimen temperature was below-40°C (-40°F))	Shallow dent on outer shell at impact point
	Post-Drop Inspection	• Lid secured in place • Locks undamaged; source secured • No significant change in source position • Small change in radiation profile
TP80(B)	Compression Test	No damage
	1 meter (40 inch) penetration bar on side	Impact mark; no visible damage
	1.2 meter (4 foot) drop, vertical upside down	• Impact mark on top of lid • Small change in radiation profile
	9 meter (30 foot) drop, vertical upside down	• Outer shell split open from top to bottom • Inner shell cracked, creating a 3 inch (76.2 mm) high by 0.5 inch (12.7 mm) wide opening • Small upward deflection of top plate • Everything seemed to be secure (i.e. through bolts, cover bolts, etc.)
	1 meter (40 inch) puncture on crack in shell	Bent shell inward slightly in area of crack

Specimen	Test Performed	Test Results (Note 1)
TP80(B) (con't)	Post-Drop Inspection	• Lid secured in place • Locks undamaged; source secured • Top plate deflection at center about 0.16 inch (4.1 mm). • No damage to through bolts • No significant change in source position. • Outer and inner shells cracked; opening about 3 inch (76.2 mm) by 0.5 inch (12.7 mm).
	Thermal test	• Some oxidation of DU shield near crack in shell • Shield moved down (as expected) • Polyurethane foam burned off, exposing the shield • Some oxidation of shield near crack in shell • Shield self-extinguished after removal from oven • Source pullout less than 0.5 inch (12.7 mm). • Max. radiation level at one meter was 28 mR/hr (which is much less than 1000mR/hr allowable)
TP80(C)	Compression Test	No damage
	1 meter (40 inch) penetration bar on side	Impact mark; no visible damage
	1.2 meter (4 foot) drop on top edge of lid	• Bent corner of lid and cracked top plate of lid (brittle failure) • Small change in radiation profile
	9 meter (30 foot) drop on top edge of lid	• Increased lid top plate crack length in vicinity of impact point • Locks still protected by lid
	1 meter (40 inch) puncture vertical upside down on lid and on underside of top plate	Broke inside of lid top plate (locks still protected)
	Post-Drop Inspection	• Locks undamaged; source secured • No significant change in source position • Small change in radiation profile

Note 1: None of the new stainless steel bolts installed in the test specimens failed.

Specimen TP80(A) was not significantly damaged in the testing. On specimen TP80(C), the top plate of the protective lid was substantially cracked and portions broke away; however, the rectangular tube section which surrounds the locks was undamaged and still attached to the lower portion which in turn was secured to the body of the changer. As such, the locks remained protected. The post-test radiation profiles showed a slight increase in radiation levels for these units, but these radiation levels were well below the allowable values.

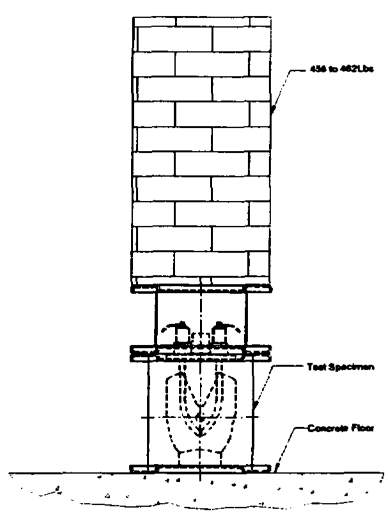
The only significant damage to any unit was the cracked shell in specimen TP80(B). Because of this crack, the depleted uranium shield was exposed to air during the thermal test, and portions of the shield near the crack opening were oxidized. In addition, after the lead shim melted, the shield was free to move downward, pulling the dummy source out of its fully inserted position in the shield. However, even with the oxidized shield and source pull-out, the post-test radiation profile showed a maximum radiation level of 28 mR/hr at one meter. This is well below the maximum allowable level of 1,000 mR/hr at one meter following the hypothetical accident conditions.

6. TP80 NORMAL TESTS

Compression Test

All three test specimens were loaded as shown in the figure below. Lead weights were placed on a steel plate, which was positioned on top of each test specimen.

The vertical projected area of the unit is 8.25 inch (209 mm) x 10 inch (254 mm) or 82.5 square inches (531 square centimeters), yielding a total load of 165 lb (74.8 kg) for an applied pressure of 2 psi. Since the maximum weight of the Model 650L source changer is 90 lb (40.8 kg), a load of 5 times the weight, or 450 lb (204 kg), is more conservative. The total compressive load actually used was 458 lb to 462 lb (208 kg to 210 kg).



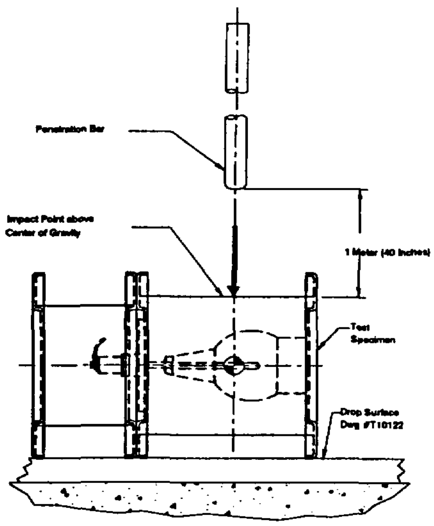
After a period of 24 hours, the weights were removed. No visible deformation or buckling occurred and no other damage was observed for any of the test specimens.

Penetration Test

The three test specimens were subjected to the penetration test. Temperature readings taken just before the test are summarized below.

Specimen	Ambient	Surface	Internal
TP80(A)	10°C (50°F)	-96°C (-141°F)	-95°C (-139°F)
TP80(B)	9°C (48°F)	-93°C (-135°F)	-83°C (-117°F)
TP80(C)	10°C (50°F)	-90°C (-130°F)	-90°C (-130°F)

The penetration bar target was the side of the unit in an attempt to damage the shell. For this test, each specimen was positioned with its horizontal long side down, as shown below.



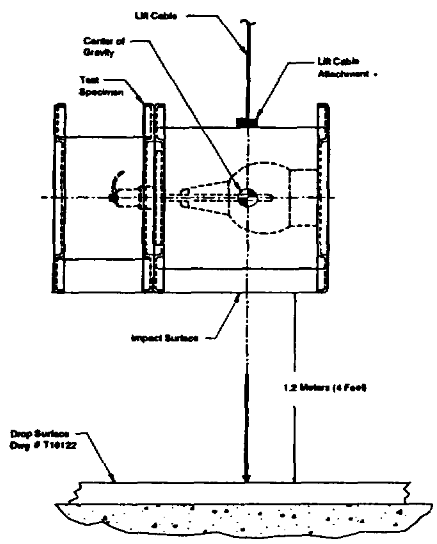
The penetration bar was dropped from a height of at least 1 meter (40 inches) above the impact point. The bar hit as intended on each package, leaving a visible impact mark but no other damage.

1.2 Meter (4 Foot) Drop Test

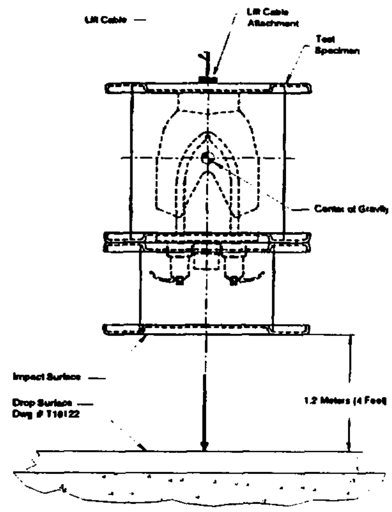
The three test specimens were then subjected to the 1.2 meter (4 foot) drop test. Temperature readings taken just before the test are summarized below.

Specimen	Ambient	Surface	Internal
TP80(A)	13°C (55°F)	-92°C (134°F)	-90°C (-130°F)
TP80(B)	13°C (55°F)	-87°C (-125°F)	-89°C (-128°F)
TP80(C)	13°C (55°F)	-95°C (-139°F)	-92°C (-134°F)

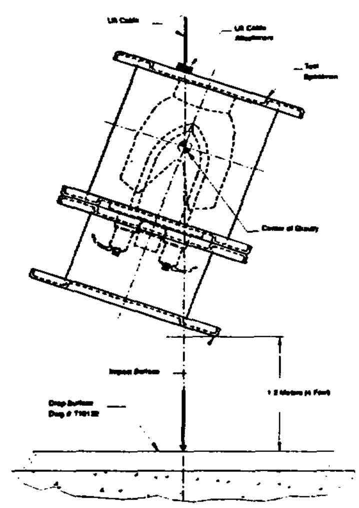
The drop orientations for each unit are shown below and on the next page. These orientations are the same as those used for each specimen in the 9 meter (30 foot) drop tests.



1.2 Meter (4 Foot) Drop Orientation for Specimen TP80(A)



1.2 Meter (4 Foot) Drop Orientation for Specimen TP80(B)



1.2 Meter (4 Foot) Drop Orientation for Specimen TP80(C)

Each test specimen impacted as intended. Visual inspections showed impact marks but no significant damage to either TP80(A) or TP80(B). For TP80(C), a 2 inch (50.8 mm) long crack in the top of the protective lid was observed, and the flange corner was bent.

Post-Test Inspection and Assessment

Results of the first intermediate inspections and assessments are summarized below. The radiation profile of each specimen was measured, and data sheets are provided in Appendices B and C.

Specimen	Damage	Source Movement	Radiation Profile (Note 1)
TP80(A)	No visible damage, locks functional	No significant change observed	Largest change at bottom surface: 51mR/hr to 94 mR/hr (Note 2)
TP80(B)	No visible damage, locks functional	No significant change observed	Largest change at top surface: 60 mR/hr to 71 mR/hr
TP80(C)	Cracked top lid, locks functional	No significant change observed	Largest change at rear surface: 50 mR/hr to 53 mR/hr

Note 1: Radiation levels at one meter were 2.4 mR/hr or less after Normal Condition Tests.

Note 2: All other surfaces measured remained essentially the same, exhibiting no corresponding shift in radiation levels. Additionally, no source movement was measured. Therefore, this change was considered insignificant.

7. TP80 ACCIDENT DROP TESTS – TP80(A)

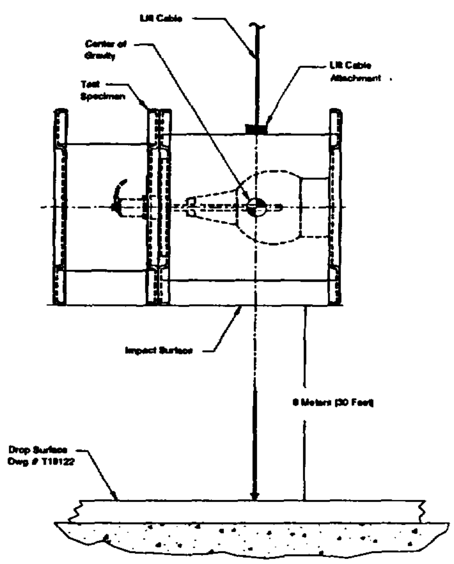
Specimen TP80(A) was subjected to a 9 meter (30 foot) drop test and a puncture test in accordance with Test Plan 80. The results are described below.

<u>9 Meter (30 Foot) Drop Test</u>

Just before the drop test, thermocouple readings for Specimen TP80(A) were as follows:

- Internal (source tube): -93°C (-135°F)
- Surface (shell): -92°C (-134°F)

The orientation for Specimen TP80(A), shown below, was the same as for the 1.2 meter (4 foot) drop. The intention was to cause the shield to move relative to the lock assembly and/or to cause failure of the inner and outer shells.

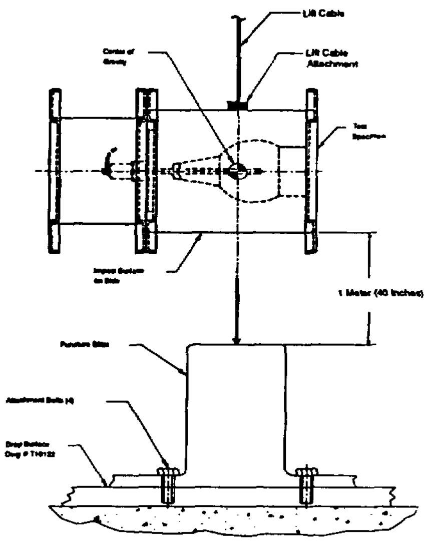


9 Meter (30 Foot) Drop Orientation for Specimen TP80(A)

The package rotated very slightly causing the edge of the bottom plate to impact first. However, the impact was sufficiently close to ideal as to impart the desired force into the package. Visual inspections showed that the edge of the bottom plate had bent inward to the point where it contacted and dented the outer shell. The edge of the top plate of the lid also bent inward slightly.

Puncture Test

For the puncture test, TP80(A) was dropped, as planned, on its side with the center of gravity over the impact area, as shown below. The intention of this orientation was to inflict further damage to the shell. The thermocouple reading on the surface of the unit before the puncture test was -69°C (-92°F) but warmed to -26°C (-15°F) just after the test due to delays in rigging the unit for the drop. Consequently, the unit was cooled again and dropped a second time. For the second test, the surface temperature was -46°C (-51°F) before the test and -42°C (-44°F) after the test.



Puncture Drop Orientation for Specimen TP80(A)

For both drops, the unit impacted on its side as intended. Each impact caused the side of the shell to deform inward slightly, but no significant damage was observed.

Post-Test Inspection and Assessment

Following the test, the protective lid was removed and the unit was inspected. No damage to the lock assembly was observed, and no significant source movement was measured. Radiographs of the unit showed no discernable change in the position of the shield. The post-test radiation profile showed no significant change in radiation levels from the pre-test profile (see Appendices B and C). Because no significant damage occurred to the unit, the thermal test was not considered necessary (see Section 3) as Specimen TP80(B) was concidered worst case.

8. TP80 ACCIDENT DROP TESTS – TP80(B)

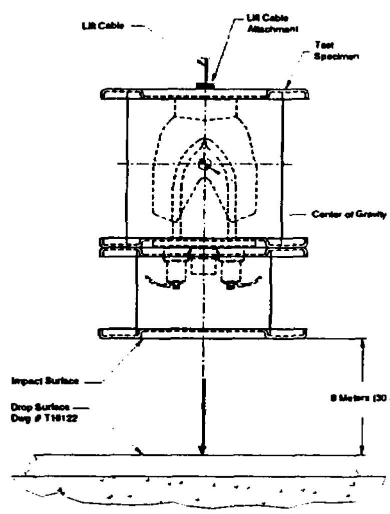
Specimen TP80(B) was subjected to a 9 meter (30 foot) drop test and a puncture test in accordance with Test Plan 80. The results are described below.

<u>9 Meter (30 Foot) Drop Test</u>

Just before the drop test, thermocouple readings for Specimen TP80(B) were as follows:

- Internal (source tube): -94°C (-137°F)
- Surface (shell): -93°C (-135°F)

The package orientation for Specimen TP80(B), shown below, was the same as for the 1.2 meter (4 foot) drop. The intention was to cause deformation of the top plate, failure of the through-bolts, and failure of the lock assembly, leading to source pull-out from the shield.



9 Meter (30 Foot) Drop Orientation for Specimen TP80(B)

The package impacted as intended. The impact caused the depleted uranium shield to move into the foam below the top plate, putting a large lateral load on the inner shell, and causing the shell to crack. The cracking of the inner shell resulted in a transfer of the lateral load to the outer shell, breaking the spot welds that hold the outer shell together. The outer stainless steel wrap also failed and sprung open. One of the rivnuts in the top plate broke, but its associated bolt and the all the other lid bolts were undamaged and the lid remained secured to the pakage.

Puncture Test

For the puncture test, the planned oreintation was changed in order to inflict greated damage based on the on-site assesment of Engineering, Regulatory and QA. As such, TP80(B) was dropped so that the cracked shell was aligned with the top edge of the puncture bar. The intention was to open up the crack or cause additional cracking in the damaged area. The thermocouple reading on the outside surface of the unit was -57°C (-71°F) before the puncture test and -44°C (-47°F) after the test.

The unit impacted directly on the crack. The outer shell was deformed inward at the impact area, but additional cracking was not observed.

Post-Test Inspection and Assessment

Following the test the protective lid was removed and the unit was inspected. The through-bolts were all intact. One of the locks had broken out, but the dummy source remained securely retained (i.e. the lock slide was still secure). The top plate (with the lock assembly) deflected outward by about 0.16 inch (4.1 mm). The resulting source pull-out was measured to be 0.027 inch (0.69 mm) in one side and 0.064 inch (1.6 mm) in the other side. Radiographs showed the crack in the inner shell extended from the top plate to the bottom plate.

9. TP80 ACCIDENT DROP TESTS – TP80(C)

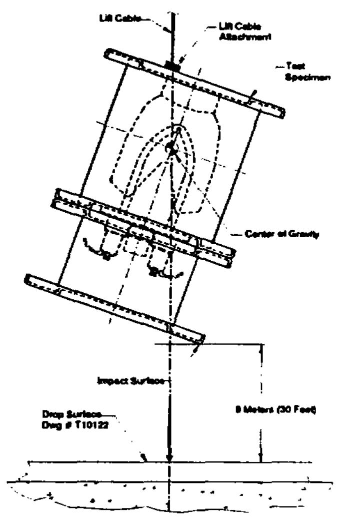
Specimen TP80(C) was subjected to a 9 meter (30 foot) drop test and a puncture test in accordance with Test Plan 80 and results are described below.

9 meter (30 Foot) Drop Test

Just before the drop test, thermocouple readings for Specimen TP80(C) were as follows:

- Internal (source tube): -97°C (-143°F)
- Surface (shell): -98°C (-144°F)

The package orientation for Specimen TP80(C), shown below, was the same as for the 1.2 meter (4 foot) drop. The intention was to fail the bolts holding the protective lid to the rest of the unit. This would expose the lock assembly to further damage during the puncture test.



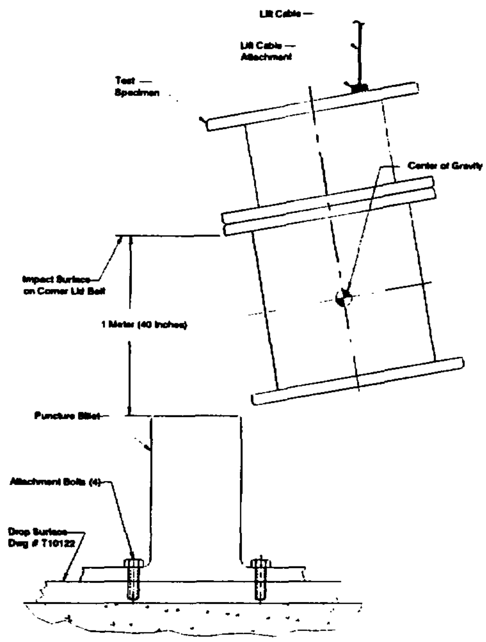
9 Meter (30 Foot) Drop Orientation for Specimen TP80(C)

The package impacted as intended. Visual inspections showed that none of the lid bolts failed, but the lid crack initiated in the 1.2 meter (4 foot) drop increased in both directions. The crack went around the top plate at its interface with the rectangular tube section that protects the locks. The crack went about halfway around the lid, and the top plate was deflected downward about 0.5 inch (13 mm). Portions of the top plate flange also broke off.

Puncture Test

Specimen TP80(C) was subjected to two puncture tests. An additional puncture drop was added as two possible orientations were deemed "worst case". In the first, the unit was dropped vertically upside down, with the intention of breaking through the lid and damaging the locks. The thermocouple reading on the surface of the unit was -53°C (-63°F) before the puncture test and -50°C (-58°F) after the test.

For the second test, the unit was dropped such that the impact was on the underside of the top plate, as shown below. The objective of this drop was to damage the rivnuts, which hold the lid to the top plate, and to pry the top plate off of the unit by overloading the through-bolts. The initial surface temperature was -47°C (-53°F).



Second Puncture Drop Orientation for Specimen TP80(C)

The unit impacted as intended in both drops. In the first drop, the top of the lid was damaged further, however, the lid remained intact and the puncture bar did not impact the lock assembly. In the second drop, the top plate deformed slightly, but no significant damage was observed.

Post-Test Inspection and Assessment

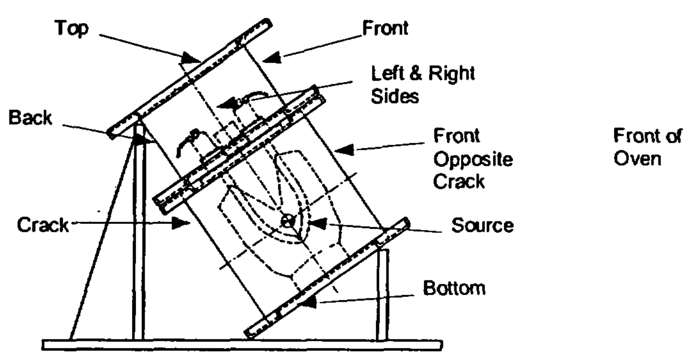
Following the test, the protective lid was removed and the unit was inspected. No damage to the locks was observed and no significant movement of the source was measured. The post-test radiation profile showed no significant change in radiation levels from the pre-test profile (see Appendix B). Because no significant damage occurred to the unit, the thermal test was not considered necessary (see Section 3) as Specimen TP80(B) was concidered worst case..

10. TP80 THERMAL TEST – TP80(B)

Based on the results of the drop tests, a thermal test was performed with specimen TP80(B). The damage to this unit was such that the maximum source pull-out, as well as oxidation of the depleted uranium shield, could occur during the thermal test. The thermal test was not considered necessary for the other test specimens since the results are bounded by those for TP80(B).

Orientation and Setup

Based on the damage observed in the drop tests, it was concluded that worst orientation for the thermal test was to have the unit at an angle such that the center of gravity of the shield was over the bottom corner edge of the inner shell. The cracked side of the unit was oriented downward, so that the shield would move toward the crack as the lead shim melted and the shield dropped down. The worst case angle was determined to be 53° based on the internal geometry of the unit. This would allow the maximum amount of shield movement relative to the top plate, pulling the source out of position. To hold the specimen in this orientation, a steel jig was constructed as shown below.



TP80(B) Orientation and Thermocouple Locations

Seven thermocouples were attached to the specimen on the top, bottom, and four side surfaces (two thermocouples on the front side). An eighth thermocouple was inserted into one of the source tubes to measure the internal temperature. A ninth thermocouple was used to measure the ambient oven temperature.

To allow for combustion during the thermal test, the oven door was blocked open with a gap of 1 inch (25.4 mm) at the top and bottom of the door, permitting airflow into the oven while allowing the oven to maintain its temperature. Since the oven door is 36 inches (914 mm) long, each opening was approximately 36 square inches (232 square centimeters).

Test Chronology

Temperatures were recorded from the time the specimen was inserted in the oven until after it had cooled and was moved to a temporary storage area. The total duration of this period was about 1,000 minutes (16 hours). Plots of the temperature data are included in Appendix C. The overall test chronology is as follows:

- Zero to 32 minutes – heat up of the specimen from ambient to over 810°C (1490°F). The 30 minute test started when all surfaces of the specimen exceeded 810°C (1490°F). The thermocouple on the bottom of the unit was the last to reach the target temperature, and the test was started when it reached 813°C (1495°F).

- 32 to 64 minutes – thirty minute test period, with all temperatures maintained above 810°C (1490°F). The maximum temperature was 996°C (1825°F) on the side of the unit facing the rear of the oven, while the minimum temperature was 813°C (1495°F) on the bottom of the unit. The initial and final temperatures of all thermocouples over the 30 minute period are shown below. Flames due to combustion of the foam were observed, however these diminished and stopped before the end of the 30 minute test.

Location	Initial Temp.	Final Temp.	Average Temp.
Bottom	813°C (1495°F)	861°C (1582°F)	872°C (1602°F)
Top	980°C (1796°F)	879°C (1614°F)	913°C (1675°F)
(Lid) Front Oven	934°C (1713°F)	848°C (1558°F)	879°C (1614°F)
(Lid) Back Oven	995°C (1823°F)	884°C (1623°F)	923°C (1693°F)
(Lid) Left Side	949°C (1740°F)	865°C (1589°F)	899°C (1650°F)
(Lid) Right Side	979°C (1794°F)	872°C (1602°F)	909°C (1668°F)
Side (Opposite Crack)	830°C (1526°F)	810°C (1490°F)	823°C (1513°F)
Source Tube	906°C (1663°F)	865°C (1589°F)	886°C (1627°F)
Oven/Ambient	940°C (1724°F)	839°C (1542°F)	877°C (1611°F)

- 64 minutes – removal from oven. The depleted uranium shield was visible, with a slightly red glow in areas. Some depleted uranium oxide (black power) was observed coming out of the crack and onto the surface below, indicating the shield was oxidizing.

- 64 to 700 minutes – cool down to below 100°C (212°F). During this time, the shield was allowed to self-extinguish.

During the cool down period, the unit was allowed to cool via natural convection with no additional heat input. The hypothetical accident conditions specified in the IAEA Safety Series 6 regulations include a requirement to account for heat input due to insolation during the cool down period. This heat input could reduce the cool down rate. However, the reduction was not considered to have any effect on the damage sustained by the test specimen, particularly compared with the 30 minute exposure to 810°C (1490°F) in the oven.

Post-Test Inspection and Assessment

The initial on-site assessment of the test specimen included the following observations:

- A cracked piece of the inner shell was dislodged and had dropped out of position.
- Most paint had vaporized. Radiation labels were still legible.
- All the foam had burned off, leaving a small amount of carbon char.
- The lead shielding and shim melted and some lead had dripped out the bottom of the unit.
- Radiography showed the shield moved laterally and downward as expected. The resulting source pull-out was measured to be 0.436 inch (11.1 mm) on one side and 0.480 inch (12.2 mm) on the other side.
- The lock assemblies were functional; however, the source tubes had completely pulled out of the top plate and had shifted laterally. This caused an interference between the source wire and the top plate, and required that the top plate be machined to enlarge the holes before the unit could be profiled.

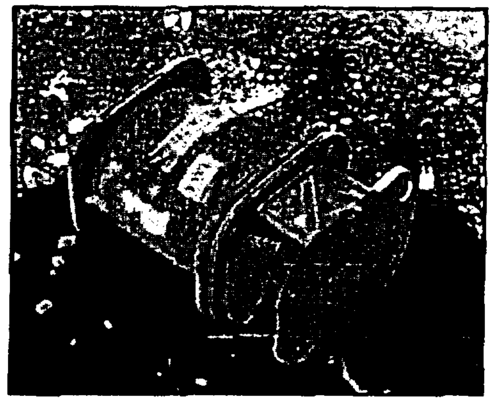
Visual obsevations indicated that the shield was not moving during inspections after the thermal testing (i.e. heldi in place by through bolts and source wires). However to securely fix the shield in position for shipping and extensive handling, holes were drilled in the shell of the unit so that foam could be poured in, and the shield was foamed in place to prevent shield movement. A radiation profile was then done on site with the source located to replicate the amount of observed source pull-out. The highest radiation measurement was 28 mR/hr at one meter (when scaled to the 240 Ci licensed capacity of the unit) at the top of the unit. The small amount of shield oxidation experienced in the test had a minimal effect on the overall effectiveness of the shielding.

APPENDIX D

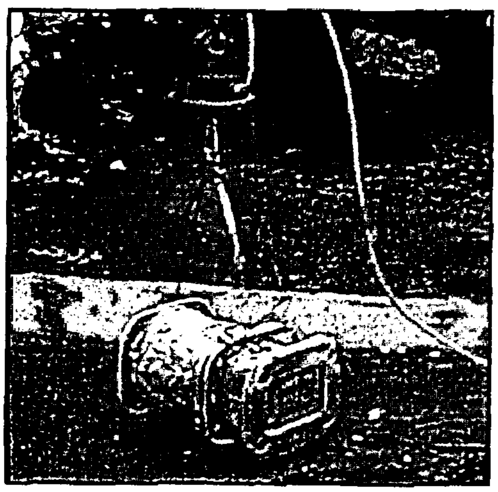
TEST PHOTOGRAPHS

Test Plan 80 Photographs

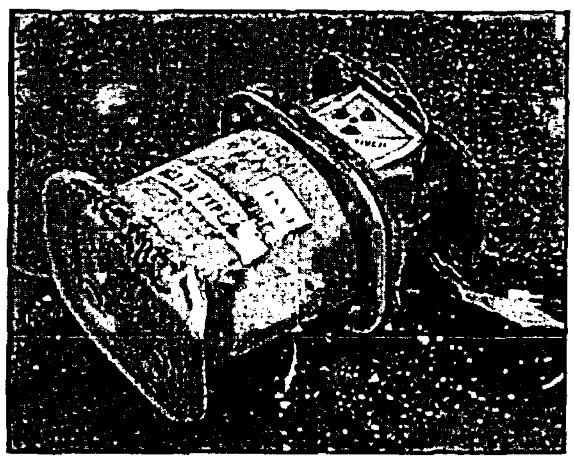
TP80(A) 4 Foot Drop Setup



TP80(A) 4 Foot Drop Results

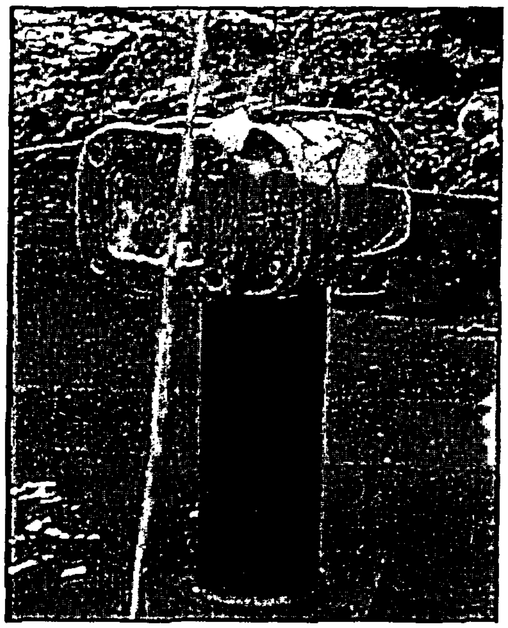


TP80(A) 30 Foot Drop Setup

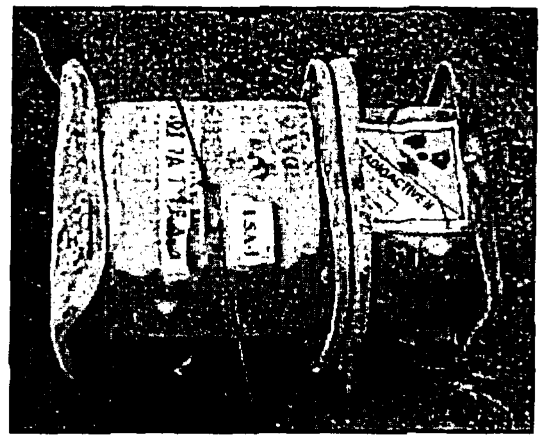


TP80(A) 30 Foot Drop Results

Test Plan 80 Photographs



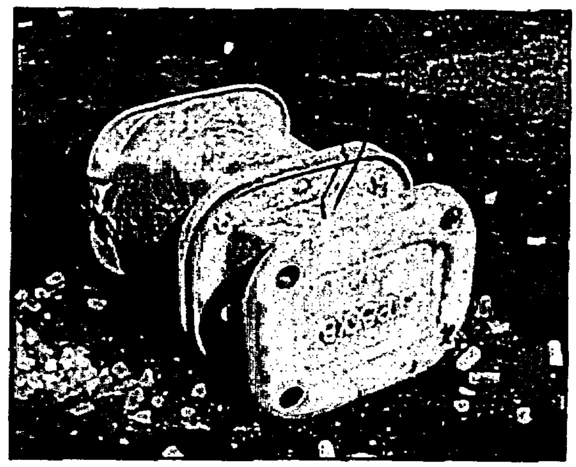
TP80(A) Puncture Test Setup



TP80(A) Puncture Test Results

Test Plan 80 Photographs

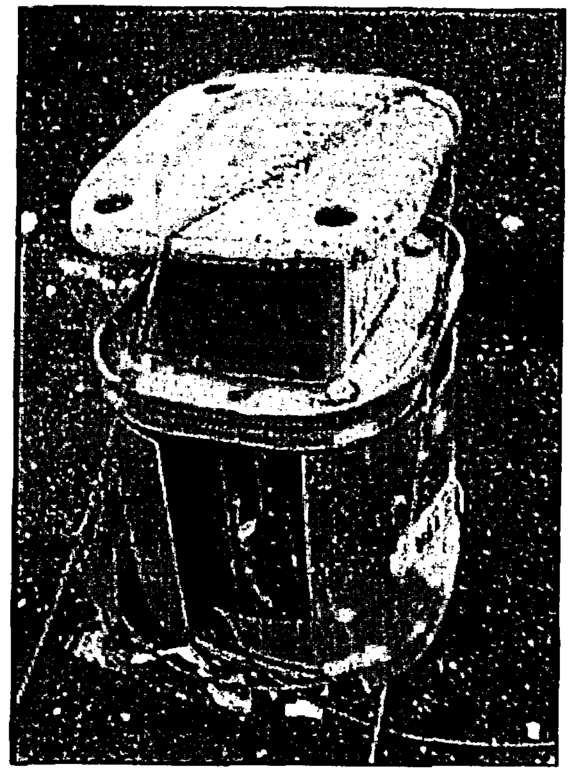
TP80(B) 4 Foot Drop Setup



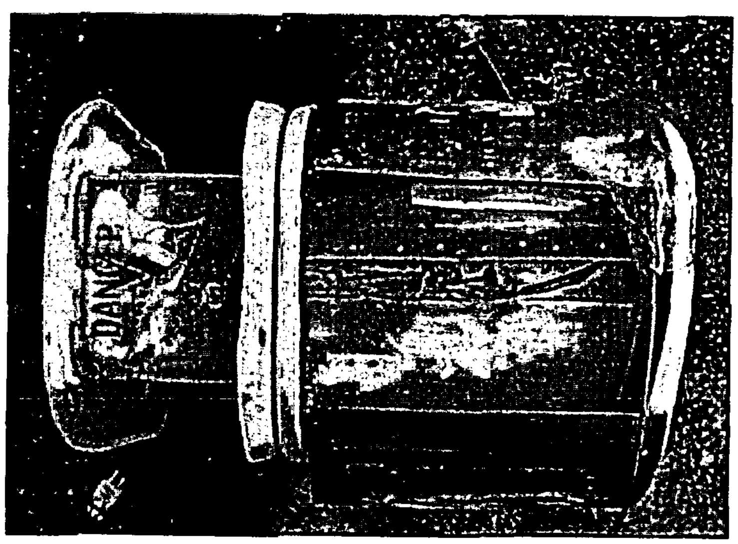
TP80(B) 4 Foot Drop Test Results

Test Plan 80 Photographs

TP80(B) 30 Foot Drop Setup

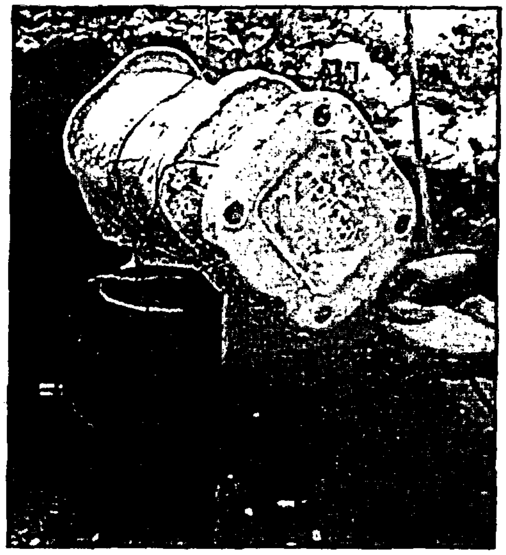


TP80(B) 30 Foot Drop Results

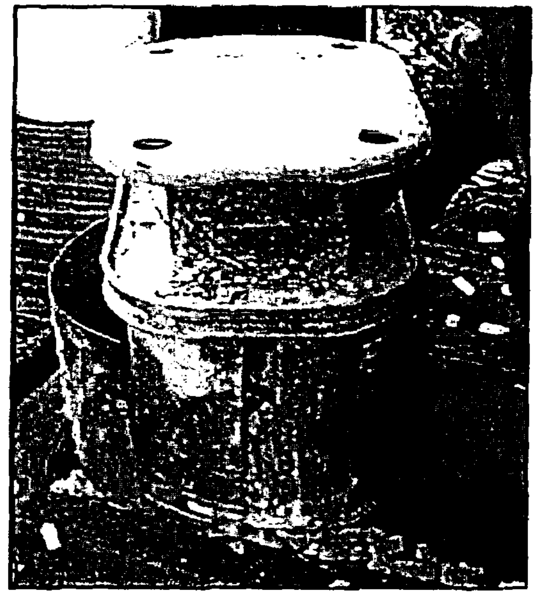


TP80(B) 30 Foot Drop Results

Test Plan 80 Photographs

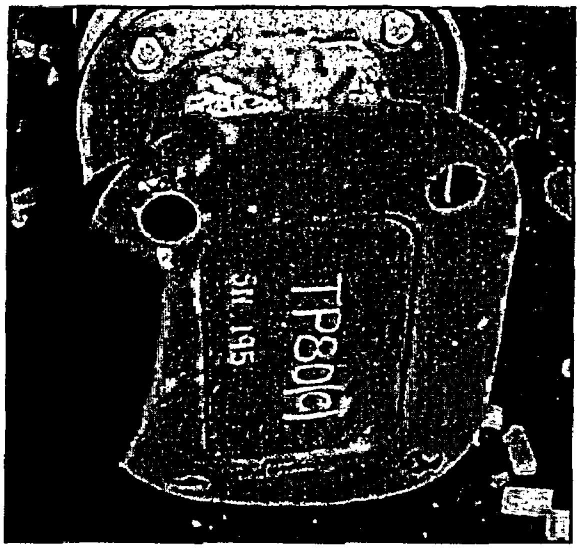


TP80(B) Puncture Test Setup

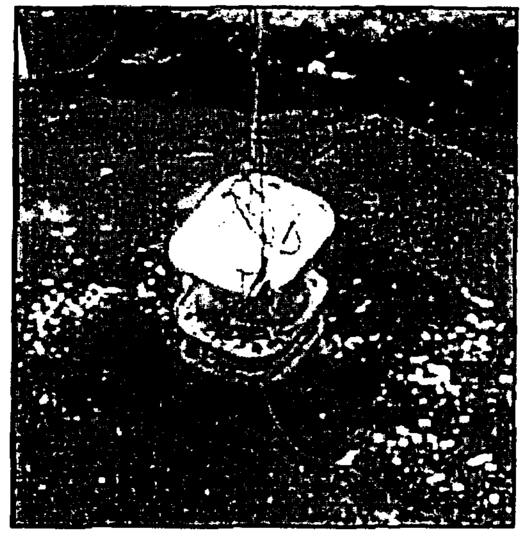


TP80(B) Puncture Test Results

Test Plan 80 Photographs



TP80(C) 4 Foot Drop Test Results



TP80(C) 30 Foot Drop Setup

TP80(C) 30 Foot Drop Results

TP80(C) 30 Foot Drop Results

Test Plan 80 Photographs

TP80(C) Puncture Drop 1 Setup

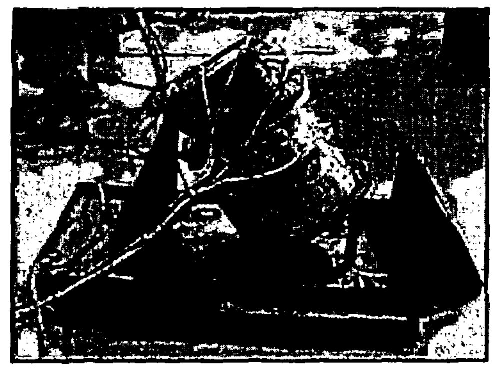
TP80(C) Puncture Drop 1 Results

TP80(C) Puncture Drop 2 Setup

TP80(C) Puncture Drop 2 Results
Showing Closeup of Rivnut

Test Plan 80 Photographs

TP80(B) Thermal Test Setup



TP80(B) Thermal Test Setup

TP80(B) Thermal Test
After Removal From Oven

TP80(B) Thermal Test After
Removal From Oven

Test Plan 80 Photographs

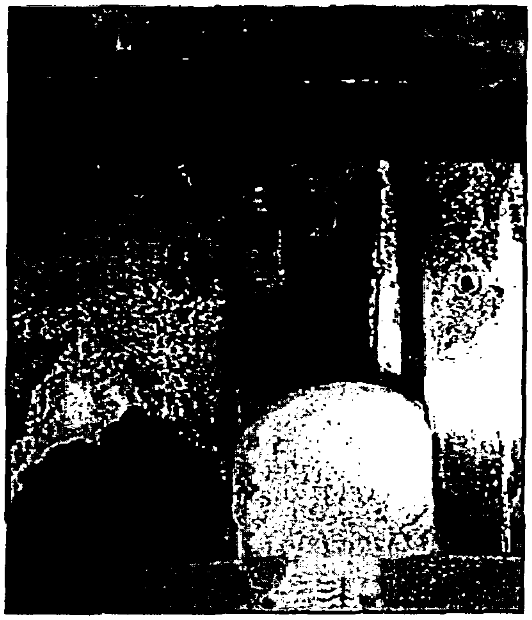
TP80(B) Thermal Test After Removal From Oven

TP80(B) Detail of Cracked Shell

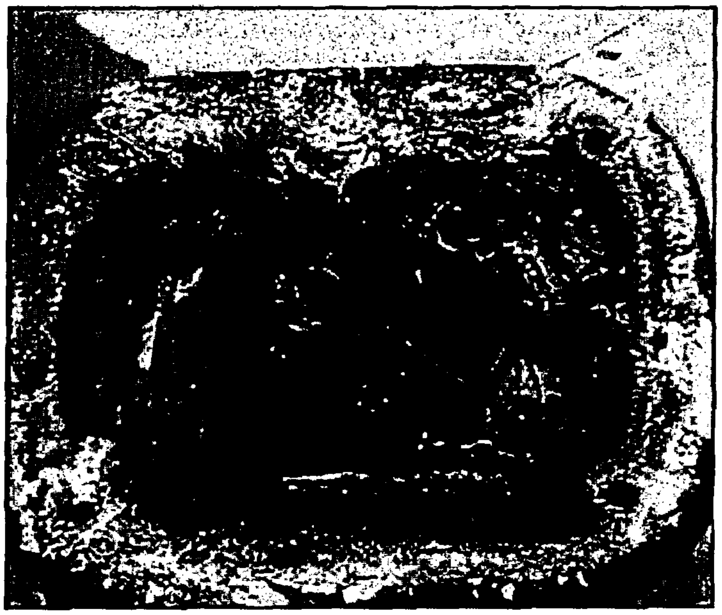
TP80(B) Detail of Uranium Oxide Residue

TP80(B) Detail of Uranium Oxide Residue

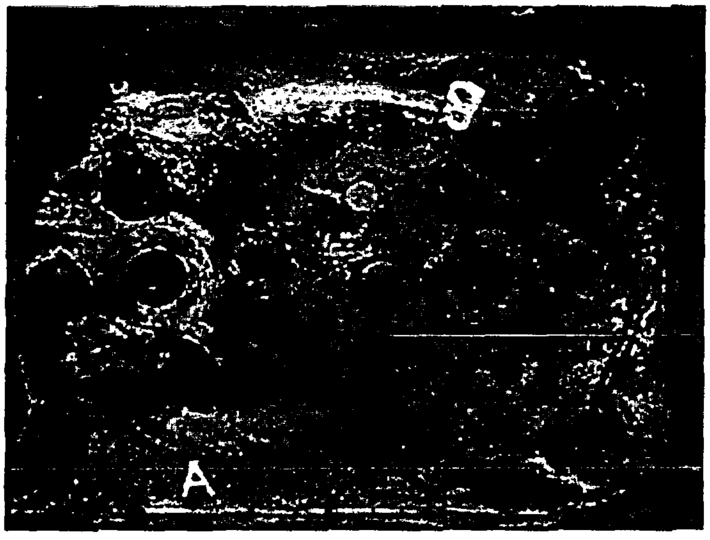
Test Plan 80 Photographs



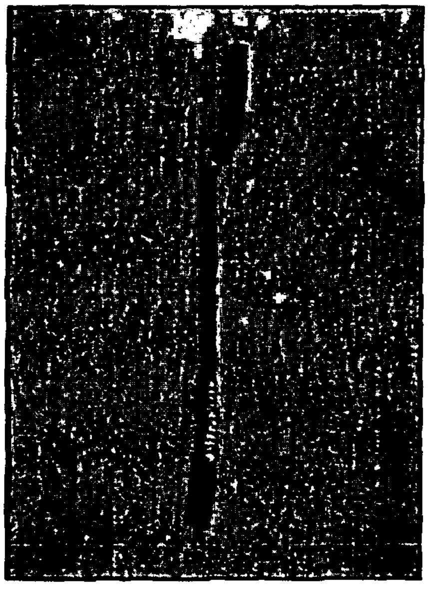
TP80(B) Thermal Test After Removal From Oven--Detail of Crack After Foaming to Stabilize Shield



TP80(B) Thermal Test After Removal From Oven—Lid Removed



TP80(B) Thermal Test After Removal From Oven--Detail of Source Tube Displacement After Removal of Lock Assemblies



TP80(B) Thermal Test After Removal From Oven--Dummy Source Wire--White Mark Shows Top of Source Tube Position

Section 3 - THERMAL EVALUATION

3.1 Description of Thermal Design

(Reference:

- *USNRC, 10 CFR 71.33(a)(5)(v) and 71.33(b)(7)*
- *IAEA TS-R-1, paragraphs 651(b) and 655)*

The Model 650L transport package is a completely passive thermal device having no mechanical cooling system or relief valves. Cooling of the package is through free convection and radiation. There are no specific cooling or insulating design features. Pressure relief of the container is not necessary during the thermal test as the construction is not air tight and will allow venting to the atmosphere.

The maximum activity for this package is 240 Ci of Ir-192 or 300 Ci of Se-75. Accounting for self absorption in the source, this equals a maximum content activity of 552 Ci of Ir-192. The corresponding decay heat generation rate for the content activity is approximately 4.8 Watts (See Table 1.2a). The thermal evaluations are based on the decay energy of Ir-192 as this is greater than Se-75.

3.1.1 Design Features

The Model 650L transport package is described in Section 1. The containers use depleted uranium shielding. The depleted uranium is fully enclosed in the steel structure and endplates which are attached by screws. This construction prevents oxidation by severely limiting oxygen from reaching the depleted uranium shield.

3.1.2 Content's Decay Heat

From Table 1.2a, a maximum of 4.8 Watts of decay energy is available to be absorbed by the package.

3.1.3 Summary Tables of Temperatures

Table 3.1a: Summary Table of Temperatures

Surface Temperature Condition	Model 650L Packages	Comments
Insolation (38°C in full sun)	70°C (158°F)	Section 3.4.1.1
Decay Heating (38°C in shade)	46°C (115°F)	Section 3.4.1.2
Fire Test During	996°C (1,825°F)	
Post-Fire (Maximum Temperature)	884°C (1,623°F)	

3.1.4 Summary Tables of Maximum Pressures

All Model 650L containers are vented to atmosphere. As such, no pressure will build up in the units under either Normal or Hypothetical Accident conditions.

Table 3.1b: Summary Table of Maximum Pressures

Package Configuration	Void Volume IN^3	Normal Conditions 88°C (190°F) Pressure Developed	Fire Conditions 800°C (1,472°F) Pressure Developed	Comments
650L	0	0 psig	0 psig	

3.2 Material Properties and Component Specifications

3.2.1 Material Properties

Table 3.2a 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 3.2a: 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
Lead	0.41	327°C (620°F)	29.3μin/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
Titanium	0.18	1,704°C (3,100°F)	5.2μin/in°F	Reference #1, p. 6-11
Polyurethan Foam	8 lb/ft^3	--	150μin/in°C	Reference #1, p. 6-199

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.

3.2.2 Component Specifications

All components are specified and described on the drawings included in the Section 1.4.

3.3 General Considerations

3.3.1 Evaluation by Analysis

Evaluations by analysis are described in the section they apply to in this Safety Analysis Report or when applicable in the Test Plans contained in Section 2.12.

3.3.2 Evaluation by Test

Evaluations by direct testing are documented in the Test Plans contained in Section 2.12.

3.3.3 Margins of Safety

Margins of safety are discussed in each section as appropriate. All testing and analysis resulted in no loss of source containment or securement in the transport package. Though this demonstrates package compliance, it is difficult to quantify the margin related to these results. All physical testing used multiple specimens, with demonstrated results well within the regulatory requirements. Based on the results of the physical testing and the related analyses, we estimate the margin of safety for the Model 650L package as high.

3.4 Thermal Evaluation for Normal Conditions of Transport

3.4.1 Heat and Cold

3.4.1.1 <u>Insolation and Decay Heat</u>
(Reference:

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

This analysis determines the maximum surface temperature produced by solar heating of the Model 650L transport package loaded at maximum activity with the contents that produce the highest energy input in accordance with 10 CFR 71.71(c)(1) and IAEA TS-R-1. This will be compared to the Normal Transport test conditions temperature range to determine which is the most onerous for thermal stress considerations.

The model consists of taking a steady state heat balance over the surface of the transport package. The following design analysis calculates the steady state surface temperature of a cylindrical package subjected to insolation and self-heat. The analysis is based on recognized heat transfer theory and specifically, that the total heat input due to the self-heat of the radioactive contents and the insolation energy absorbed must balance the heat loss due to convection and emitted radiation from the package surface. In order to assure conservatism, the following assumptions are made:

a. The transport package is assumed to undergo free convective heat transfer from the top and sides.

b. The inside package faces are considered perfectly insulated so there is no conduction into the package. The faces are considered to be sufficiently thin so that no temperature gradients exist in the faces.

c. The lid of the package is modeled as a rectangular solid, 10 inches (254 mm) long, 8 ¼ inches (210 mm) wide and 5 inches (127 mm) high. The outer shell of the package is modeled as a cylinder, 7 7/16 inches (189 mm) in diameter and 8 ¼ inches (210 mm) long.

d. The decay heat load (4.8 Watts) is added to the solar heat input load.

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

f. The absorptivity coefficient of the steel package is conservatively assumed to be 1.0.

The following heat calculations are based on the steady-state equilibrium relationship between the heat gained by the package and the heat lost.

Heat Input, Q_{IN} = Heat Output, Q_{OUT} in the steady-state.
Q_{IN} = Solar Heat Input + Decay Heat
Q_{OUT} = Heat loss by Radiation and Convection

The solar heat input is the combined solar heating of the top horizontal surface (flat), side vertical surface of the lid (flat) and the side vertical surface of the outer shell (curved). The insolation data, provided in 10 CFR 71.71(c)(1), is found in Table 3.4a.

Table 3.4a: 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

Practically all solid materials are opaque to thermal radiation (even glass is only transparent to a fairly narrow range of wavelengths), and thermal radiation is in fact either reflected or absorbed within a very shallow depth of matter. Thus for solids it is possible to neglect transmissivity and write:

$$\text{reflectivity, } \rho + \text{absorptivity, } \alpha = 1 \text{ where } \rho = 0 \text{ and } \alpha = 1$$

i.e., the sum of the radiation reflected and absorbed by the material is equal to the total incident energy. Since the reflected energy does not contribute to the heat energy contained within the system, or package, it is not necessary to consider it in the analysis. However, the absorptivity of the material is the fraction of the total incident energy entering the system, which in this case is the heat input due to insolation.

Heat input due to insolation falling on top surface, Q_{IT}

$$Q_{IT} = 800 \text{ W/m}^2 \times 0.053 \text{ m}^2 = 42.4 \text{ W}$$

Heat input due to insolation on lid side surfaces (assumed rectangular box), Q_{ILS}

$$Q_{ILS} = 200 \text{ W/m}^2 \times 0.118 \text{ m}^2 = 23.6 \text{ W}$$

Heat input due to insolation on outer shell surface (assumed cylinder), Q_{IOS}

$$Q_{IOS} = 400 \text{ W/m}^2 \times 0.124 \text{ m}^2 = 49.6 \text{ W}$$

Decay Heat Input: $Q_{DT} = 4.8$ W

The total heat input is the sum of the solar heat input multiplied by the absorptive constant α for the material plus the decay heat input.

$$Q_{IN} = \alpha(Q_{IT} + Q_{ILS} + Q_{IOS}) + Q_{DT} = 120.4 \text{ W}$$

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/m² K⁴ (Stefan-Boltzmann Constant)
$E = 0.8$ (emissivity)
$A_{TS} = 0.295$ m² (surface area of the lid top, lid sides and outer shell)
T_W = The maximum surface temperature of the package
$T_A = 38$°C (ambient temperature)

Therefore, $Q_R = 1.34 \times 10^{-8}\,\{(T_W + 273)^4 - 9.36 \times 10^9\}$

Lid top surface convection = $Q_{LT} = H_{LT}A_{LT}(T_W - T_A)$

Where $A_{LT} = 0.053\ m^2$ (lid top surface area) and H_{LT} = the free convection coefficient for a flat horizontal surface. For a heated plate facing up, the free convection coefficient for laminar flow is:

$$H_{LT} = 0.54[(g\ \beta\ (T_W - T_A)\ L^3\ ) / (\nu\ \alpha\ )]^{0.25}\ (K / L)$$

(Reference: Fundamentals of Heat and Mass Transfer, F.P. Incropera, 4th Edition, 1996, Ch. 9)

Where:

$g = 9.8\ m/s^2$
$\beta = 0.00303$ ($1/T_{avg}$ assuming $T_{avg} = 330$ K)
$L = 0.0572$ m (Area/Perimeter)
$\nu = 18.9 \times 10^{-6}\ m^2/s$
$\alpha = 26.9 \times 10^{-6}\ m^2/s$
$K = 28.52 \times 10^{-3}$ W/m K

Therefore, $H_{LT} = 2.75\ (T_W - 38)^{0.25}$

Substituting this into the convection equation for the lid top surface produces:

$$Q_{LT} = 0.146\ (T_W - 38)^{1.25}$$

Lid side surface convection = $Q_{LS} = H_{LS}A_{LS}(T_W - T_A)$

Where $A_{LS} = 0.118\ m^2$ (total surface area of lid sides) and H_{LS} = the free convection coefficient for a vertical surface. For a heated plate, the free convection coefficient for laminar flow is:

$$H_{LS} = [0.68 + 0.67[(g\ \beta\ (T_W - T_A)\ L^3\ ) / (\nu\ \alpha\ )]^{0.25}\ ] / \{1 + (0.492\ \alpha/\nu)^{9/16}\}^{4/9}]\ (K / L)$$

(Reference: Fundamentals of Heat and Mass Transfer, F.P. Incropera, 4th Edition, 1996, Ch. 9)

Where L = 0.056 m (area/perimeter). Therefore:

$$H_{LS} = 0.346 + 2.64\ (T_W - 38) + 0.312\ (T_W - 38)^{1.25}$$

Outer shell surface convection, $Q_{OS} = H_S A_S\ (T_W - T_A)$ where $A_{OS} = 0.124\ m^2$ (total surface area of the outer shell) and H_{OS} = the free convection coefficient for a vertical surface.

For a vertical plate the free convection coefficient for laminar flow is:

$$H_{OS} = [0.68 + 0.67[(g\ \beta\ (T_W - T_A)\ L^3\ ) / (\nu\ \alpha\ )]^{0.25}\ ] / \{1 + (0.492\ \alpha/\nu)^{9/16}\}^{4/9}]\ (K / L)$$

(Reference: Fundamentals of Heat and Mass Transfer, F.P. Incropera, 4th Edition, 1996, Ch. 9)

Where L = 0.077 m (area/perimeter). Therefore:

$$H_{OS} = 0.252 + 2.44\,(T_W - 38)^{0.25}$$

Solving for $Q_{OS} = 0.031\,(T_W - 38) + 0.303\,(T_W - 38)^{1.25}$

Total Heat Output: $Q_{OUT} = Q_R + Q_{LT} + Q_{LS} + Q_{OS}$

Total Heat Input: $Q_{IN} = \alpha(Q_{IT} + Q_{ILS} + Q_{IOS}) + Q_{DT} = 120.4$ W

Setting $Q_{OUT} = Q_{IN}$ and substituting produces:

$$120.4\text{ W} = 1.34 \times 10^{-8}\{(T_W + 273)^4 - 9.36 \times 10^9\} + 0.761\,(T_W - 38)^{1.25} + 0.072\,(T_W - 38)$$

Iteration of this relationship yields a maximum wall temperature (T_W) of 70°C (158°F). This temperature will not adversely affect the package during normal transport since the melting temperatures of all safety critical components are well above this temperature. Additionally, charring of the polyurethane foam will not begin to occur at such low temperatures. Therefore the package satisfies the requirements of 10 CFR 71.71(c)(1) and IAEA TS-R-1, paragraph 651.

3.4.1.2 Still Air (shaded) Decay Heating

(Reference:

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

This analysis calculates the maximum surface temperature of the Model 650L 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).

The same assumptions from Section 3.4.1.1 are used. To assure conservatism, the following additional assumptions are made:

a. The entire decay heat (4.8 W) is deposited in the exterior surfaces of the package.

b. The interior of the package is perfectly insulated and heat transfer occurs only from the exterior surface to the environment.

c. 100% of the total heat is conservatively assumed to be deposited in sides of the package lid.

d. The only heat transfer mechanism is free convection.

Using these assumptions, the maximum wall temperature T_W is found using:

$$T_W = (q/hA) + T_A$$

Where:

q = 4.8 W (heat deposited per unit time on the package surface)
h = 5 W/m^2 K (free convection heat transfer coefficient for air)
(Reference Fundamentals of Heat and Mass Transfer, F.P. Incropera, 4th Edition, 1996)
A = 0.118 m^2 (surface area of the lid sides)
T_A = 311°K (ambient air temperature of 38°C)

Solving for T_W produces a maximum wall temperature (T_W) of 46°C (115°F), which is less than the maximum 50°C (122°F) allowed by 10 CFR 71.43(g).

3.4.1.3 Cold Effected Materials

The carbon steel components of the Model 650L are susceptible to brittle fracture at low temperatures. However, the package successfully met the Normal and Hypothetical accident transport requirements at temperatures below -40°C (-40°F) therefore the package complies with the requirements of this section.

3.4.2 Maximum Normal Operating Pressure

All 650L components are vented to the atmosphere. As such, pressure will not build up in the packages during Normal Transport conditions. Containers will exhibit a pressure differential of 0 psi as they are vented to the atmosphere with no means for creating a pressure differential. No other contributing gas sources are present.

3.4.3 Maximum Thermal Stresses

The temperature and pressure variations described in Sections 3.4.1 and 3.4.2 will not adversely affect the transport package during normal transport since the melting temperatures of all safety critical components are well above these temperatures and the package will experience no pressures to cause package failure. It its therefore concluded that the Model 650L transport packages will maintain their structural integrity and shielding effectiveness under the normal transport thermal stress conditions.

3.5 Thermal Evaluation Under Hypothetical Accident Conditions

3.5.1 Initial Conditions

The thermal test performed and described under Test Plan 80 and Test Plan 80 Report Sections 2.12.1 and 2.12.2 for detailed description of the test specimen initial conditions.

3.5.2 Fire Test Conditions

Sections 2.12.2 for detailed description of the fire test conditions.

3.5.3 Maximum Temperatures and Pressure

Sections 2.12.2 for detailed description of the temperature variations measured in the test specimen during the thermal test. Since the 650L is vented to the atmosphere, no pressures were generated in the package during the thermal test.

3.5.4 Maximum Thermal Stresses

Sections 2.12.2 for a description of the damage induced in the test specimen due to thermal stresses generated in the package during the thermal test.

3.5.5 Accident Conditions for Fissile Material Packages for Air Transport

Not Applicable. This package is not used for transport of Type B quantities of fissile material.

3.6 Appendix

Not Applicable.

Section 4 – CONTAINMENT

4.1 Description of the Containment System

(Reference:
- *USNRC, 10 CFR 71.33(a)(4)*
- *IAEA TS-R-1, paragraph 501(a), 501(b), 639 through 643 and 645)*

4.1.1 Containment Boundary

The containment system consists of the Model 650L transport packages and the radioactive source capsule(s). The source capsule(s) shall be qualified as Special Form radioactive material under 49 CFR 173 and IAEA TS-R-1.

4.1.2 Special Requirements for Plutonium

Not applicable. This package is not used for transport of Type B quantities of Plutonium.

4.2 General Considerations

4.2.1 Type A Fissile Packages

Not applicable. This package is not used for transport of Type A quantities of fissile material.

4.2.2 Type B Packages

(Reference:
- *USNRC, 10 CFR 71.51*
- *IAEA TS-R-1, paragraphs 646 & 656)*

As demonstrated in the Test Plan 80 Report (Section 2.12.2) and supported by assessments when applicable, performance of the normal conditions of transport testing caused no loss or dispersal of radioactive contents, no significant increase in surface radiation levels and no substantial reduction in the effectiveness of the package. The Model 650L packages therefore meets the requirements of this section.

4.3 Containment Under Normal Conditions of Transport (Type B Packages)

(Reference:
- *USNRC, 10 CFR 71.51(a)(1)*
- *IAEA TS-R-1, paragraphs 656(a))*

As demonstrated in the Test Plan 80 Report (Section 2.12.2) and supported by assessments when applicable, performance of the normal conditions of transport testing caused no breach of the source capsules contained in the package. Since the source capsules are the primary containment of the radioactive contents and no release from the source capsules occurred, the Model 650L packages meet the requirements of this section.

4.4 Containment Under Hypothetical Accident Conditions (Type B Packages)

(Reference:
- *USNRC, 10 CFR 71.51(a)(2)*
- *IAEA TS-R-1, paragraphs 656(b))*

As demonstrated in the Test Plan 80 Report (Section 2.12.2) and supported by assessments when applicable, performance of the hypothetical accident conditions of transport testing, the radiation level at one meter from the surface of the package did not exceed 1 R/hr. The Model 650L packages therefore meet the requirements of this section.

4.5 Leakage Rate Tests for Type B Packages

(Reference:
- *USNRC, 10 CFR 71.51*
- *IAEA TS-R-1, paragraphs 656(a))*

The primary containment for the radioactive material in the Model 650L transport package is the radioactive source capsules. All source capsules authorized for Type B transport in the Model 650L package are certified as special form radioactive material under 10 CFR Part 71, 49 CFR Part 173 and IAEA TS-R-1. After manufacture and again once every six months thereafter prior to transport, the source capsule is leak tested in accordance with ISO9978:1992(E) (or more recent editions) to ensure that containment of the source does not allow release of more than 0.005 μCi of radioactive material. These fabrication and periodic tests ensure that contamination release from the package does not exceed the regulatory limits.

Reference : ISO9978:1992(E) – Radiation Protection – Sealed Radioactive Sources – Leakage Test Methods.

4.6 Appendix

Not Applicable.

Section 5 - SHIELDING EVALUATION

5.1 Description of Shielding Design

(Reference:
- *USNRC, 10 CFR 71.31*
- *IAEA TS-R-1, paragraph 701 and 702)*

5.1.1 Design Features

The principal shielding in the Model 650L transport package is the depleted uranium shield assembly. In some cases additional supplemental lead shielding is added to the shield assembly as described in the drawings included in Section 1.4.

5.1.2 Summary Table of Maximum Radiation Levels

The tables in this Section include radiation profile data obtained from the 650L packages that were tested to the Normal and Hypothetical Accident Conditions of Transport under Test Plan 80 Report (see Section 2.12.2). The following notes apply to all tables in this section:

Note 1: Transport Index may not exceed 10. The Transport Index is equivalent to the 1 meter reading in mRem per hour (i.e., 5 mRem per hour at 1 meter = a Transport Index of 5.0).

Note 2: The maximum Transport Index based on the mrem per hour readings at one meter from the surface of this package was 0.8. All packages accepted and released for shipment under this Model designation will have a Transport Index less than or equal to 10.

Table 5.1a: Model 650L Test Unit TP80(A) After Normal Transport Testing Summary Table of External Radiation Levels Extrapolated to Capacity of 240 Ci Ir-192 (Non-Exclusive Use)

Normal Conditions of Transport	Package Surface mSv per hour (mrem per hour)			1 Meter from Package Surface μSv per hour (mrem per hour)		
Radiation	Top	Side	Bottom	Top	Side	Bottom
Gamma	0.94 (94)	0.89 (89)	0.94 (94)	24 (2.4)	8 (0.8)	7 (0.7)
Neutron	NA	NA	NA	NA	NA	NA
Total	0.94 (94)	0.89 (89)	0.94 (94)	24 (2.4)	8 (0.8)	7 (0.7)
10 CFR 71.47(a) Limit	2 (200)	2 (200)	2 (200)	100 (10)	100 (10)	100 (10)

Table 5.1b: Model 650L Test Unit TP80(B) After Normal Transport Testing
Summary Table of External Radiation Levels Extrapolated to Capacity of 240 Ci Ir-192
(Non-Exclusive Use)

Normal Conditions of Transport	Package Surface mSv per hour (mrem per hour)			1 Meter from Package Surface µSv per hour (mrem per hour)		
Radiation	Top	Side	Bottom	Top	Side	Bottom
Gamma	0.71 (71)	0.83 (83)	0.83 (83)	20 (2.0)	8 (0.8)	7 (0.7)
Neutron	NA	NA	NA	NA	NA	NA
Total	0.71 (71)	0.83 (83)	0.83 (83)	20 (2.0)	8 (0.8)	7 (0.7)
10 CFR 71.47(a) Limit	2 (200)	2 (200)	2 (200)	100 (10)	100 (10)	100 (10)

Table 5.1c: Model 650L Test Unit TP80(C) After Normal Transport Testing
Summary Table of External Radiation Levels Extrapolated to Capacity of 240 Ci Ir-192
(Non-Exclusive Use)

Normal Conditions of Transport	Package Surface mSv per hour (mrem per hour)			1 Meter from Package Surface µSv per hour (mrem per hour)		
Radiation	Top	Side	Bottom	Top	Side	Bottom
Gamma	0.57 (57)	1.06 (106)	0.59 (59)	20 (2.0)	8 (0.8)	5 (0.5)
Neutron	NA	NA	NA	NA	NA	NA
Total	0.57 (57)	1.06 (106)	0.59 (59)	20 (2.0)	8 (0.8)	5 (0.5)
10 CFR 71.47(a) Limit	2 (200)	2 (200)	2 (200)	100 (10)	100 (10)	100 (10)

Table 5.1d: Model 650L Test Unit TP80(A) After Hypothetical Accident Transport Testing
(9 meter Drop Test and Puncture Bar Test)
Summary Table of External Radiation Levels Extrapolated to Capacity of 240 Ci Ir-192
(Non-Exclusive Use)

Hypothetical Accident Conditions of Transport	1 Meter from Package Surface mSv per hour (mrem per hour)		
Radiation	Top	Side	Bottom
Gamma	0.027 (2.7)	0.010 (1.0)	0.006 (0.6)
Neutron	NA	NA	NA
Total	0.027 (2.7)	0.010 (1.0)	0.006 (0.6)
10 CFR 71.47(a)(2) Limit	10 (1,000)	10 (1,000)	10 (1,000)

Table 5.1e: Model 650L Test Unit TP80(B) After Hypothetical Accident Transport Testing (9 meter Drop Test, Puncture Bar Test and Thermal Test) Summary Table of External Radiation Levels Extrapolated to Capacity of 240 Ci Ir-192 (Non-Exclusive Use)

Hypothetical Accident Conditions of Transport	1 Meter from Package Surface mSv per hour (mrem per hour)		
Radiation	Top	Side	Bottom
Gamma	27 (2.7)	10 (1.0)	0.006 (0.6)
Neutron	NA	NA	NA
Total	27 (2.7)	10 (1.0)	0.006 (0.6)
10 CFR 71.47(a)(2) Limit	10 (1,000)	10 (1,000)	10 (1,000)

Table 5.1f: Model 650L Test Unit TP80(C) After Hypothetical Accident Transport Testing (9 meter Drop Test and Puncture Bar Test) Summary Table of External Radiation Levels Extrapolated to Capacity of 240 Ci Ir-192 (Non-Exclusive Use)

Hypothetical Accident Conditions of Transport	1 Meter from Package Surface mSv per hour (mrem per hour)		
Radiation	Top	Side	Bottom
Gamma	22 (2.2)	10 (1.0)	0.005 (0.5)
Neutron	NA	NA	NA
Total	22 (2.2)	10 (1.0)	0.005 (0.5)
10 CFR 71.47(a)(2) Limit	10 (1,000)	10 (1,000)	10 (1,000)

Table 5.1g includes radiation profile data used to demonstrate that the Model 650L package configurations will meet the external radiation level requirements for non-exclusive use transport when loaded to capacity for Se-75.

Table 5.1g: Model 650L sn 274 Se-75 Profile Results Summary Table of External Radiation Levels Extrapolated to Capacity of 300 Ci Se-75 (Non-Exclusive Use)

	Package Surface mSv per hour (mrem per hour)			1 Meter from Package Surface mSv per hour (mrem per hour)		
Radiation	Top[1]	Side	Bottom	Top[1]	Side	Bottom
Gamma	190 (19)	120 (12)	120 (12)	0.005 (0.5)	0.005 (0.5)	0.002 (0.2)
Neutron	NA	NA	NA	NA	NA	NA
Total	190 (19)	120 (12)	120 (12)	0.005 (0.5)	0.005 (0.5)	0.002 (0.2)
10 CFR 71.47(a) Limit	2 (200)	2 (200)	2 (200)	0.1 (10)	0.1 (10)	0.1 (10)

[1]Profile results from the top of the 650L were taken without the protective cover installed on the package. Actual surface and one meter readings from the top of the package will be lower than noted in the table.

5.2 Source Specification

5.2.1 Gamma Source

(Reference:
- *USNRC, 10 CFR 71.33(b)(1) & (3))*
- *IAEA TS-R-1, Section IV & paragraph 807(a))*

The gamma sources allowed for transport in the Model 650L transport package are specified in Sections 1.2.3 and 2.10.

5.2.2 Neutron Source

Not Applicable. The Model 650L transport package is not used for the transportation of neutron emitting sources.

5.3 Shielding Model

5.3.1 Configuration of Source and Shielding

A shielding model was not used to justify acceptance of this package. Shielding justification was based on direct measurement.

5.3.2 Material Properties

Not Applicable. A shielding model was not used in the justification of this package. Shielding justification was based on direct measurement.

5.4 Shielding Evaluation

5.4.1 Methods

Shielding justification was based on direct measurement. All packages are profiled prior to final acceptance and shipment. This profile takes into account the maximum capacity of the package. Any package not meeting the required dose rates is rejected.

5.4.2 Input and Output Data

Radiation measurements included in this Section were adjusted to the maximum activity capacity for the package (e.g., activity correction factor). Activity correction factors (CF_A) were obtained by using the following relationship:

$$CF_A = \frac{Maximum Package Activity Capacity\ (A_C)}{Actual\ Profile Activity\ (A_P)}$$

$$For Example,\ if\ A_P = 834\,Ci\ and\ A_C = 1{,}000\,Ci,\ then$$

$$CF_A = \frac{1{,}000\,Ci}{834\,Ci} = 1.2$$

Therefore all original surface and 1 meter profile measurements would be multiplied by a factor of 1.2 for a package profiled using 834 Ci and a package capacity of 1,000 Ci.

5.4.3 Flux-to-Dose-Rate Conversion

Not Applicable. Flux rates were not used to convert to dose rates in any shielding evaluations.

5.4.4 External Radiation Levels

Radiation surveys for the Model 650L showed maximum surface and 1 meter radiation levels from the transport packages within regulatory limits. Radiation surveys of the Model 650L transport packages after undergoing normal and accident condition transport testing were also well within the regulatory limits.

5.5 Appendix

Not Applicable.

Section 6 - CRITICALITY EVALUATION

All parts of this section are not applicable. The Model 650L transport package is not used for shipment of Type B quantities of fissile material.

Section 7 – Package Operations

Operation of the Model 650L transport package must be in accordance with the operating instructions supplied with the transport package, per 10 CFR 71.87 and 71.89.

(Reference:
- *USNRC, 10 CFR 71.87 and 71.89*
- *IAEA TS-R-1, paragraph 501(a), 502(e) and 503)*

7.1 Package Loading

7.1.1 Preparation for Loading

The Model 650L packages must be loaded and closed in accordance with the following (or equivalent) written procedures. Shipment of Type B quantities of radioactive material are authorized for sources specified in Section 7.1.1.1. Maintenance and inspection of the Model 650L packaging is in accordance with the requirements specified in Section 7.1.1.2.

7.1.1.1 Authorized Package Contents

(Reference:
- *USNRC, 10 CFR 71.87(a)*
- *IAEA TS-R-1, paragraph 502(f))*

Table 7.1a: Model 650L Package Information

Nuclide	Form	Maximum Capacity[1]	Maximum DU Weight	Maximum Weight
Ir-192	Special Form Sources	240 Ci	44 lbs (20 kg)	90 lbs (41 kg)
Se-75	Special Form Sources	300 Ci		

7.1.1.2 Packaging Maintenance and Inspection Prior to Loading

7.1.1.2.a Ensure all markings are legible and labels are securely fastened to the container.

7.1.1.2.b Inspect the container for signs of significant degradation. Ensure that the housing integrity is secure and does not have any significant dents, cracks of any type or rust.

7.1.1.2.c Ensure all bolts are present and secured. Assure safety wires are present and intact as noted on the drawings referenced in the Type B certificate.

7.1.1.2.d Assure the locking assemblies allow free movement of the lock slide

[1] Maximum Capacity Activity for Ir-192 is defined as output Curies as required in ANSI N432 and 10 CFR 34.20 and in line with TS-R-1 and Rulemaking by the USNRC and the USDOT published in the Federal Register on 26 January 2004 .

when performing an operational test and that the plunger lock engages and is functional. Assure the shipping caps installs and secures over the source tube on the lock assemblies.

7.1.1.2.e Assure threaded holes used to secure the protective lid to the container body do not have damaged threads and engage the 3/8-16 x 7/8 inch long shipping cover bolts.

7.1.1.2.f If the container fails any of the inspections in steps 7.1.1.2.a-e, remove the container from use until it can be brought into compliance with the Type B certificate.

7.1.2 Loading of Contents

NOTE: ***These loading operations apply to "dry" loading only. The Model 650L package is NOT approved for wet loading.***

7.1.2.1 Prior to transportation, ensure the package and its contents meet the following requirements:

7.1.2.1.a The contents are authorized for use in the package.

7.1.2.1.b The package condition has been inspected in accordance with Section 7.1.1.2.

7.1.2.1.c Ensure that the source(s) are secured into place in the storage position(s) in accordance with the following requirements. Compliance with the following requirements ensures that the source(s) are securely locked in position before shipment.

1. Removal and installation of radioactive material contained within the shield container must be performed in a shielded cell/enclosure capable of holding the maximum isotope capacity of the container, or by using remote transfer operations for wire mounted sources. Container loading can only be performed by persons specifically authorized under an NRC or Agreement State license (or as otherwise authorized by an International Regulatory Authority). All necessary safety precautions and regulations must be observed to ensure safe transfer of the radioactive material.

2. Using remote handling techniques, load the source assembly so that it is fully inserted into the source tube with the inactive end of the source assembly protruding from the top of the source tube. Once loaded, push the lock slide to the "locked" position, depress the plunger lock and remove the key. Install the shipping cap over the source on the lock assembly. Repeat this step for the second source tube if transporting more than one source in the container.

7.1.3 Preparation for Transport

(Reference:
- *10 CFR 71.87*
- *IAEA TS-R-1, applicable paragraphs of Section V)*

7.1.3.1 Ensure that all conditions of the certificate of compliance are met.

7.1.3.2 Perform a contamination wipe of the outside surface of the package and ensure removable contamination does not exceed 0.0001 μCi when averaged over a wipe area of 300 cm^2.

7.1.3.3 Survey all exterior surfaces of the package to assure that the radiation level does not exceed 200 mR/hr at the surface. Measure the radiation level at one meter from all exterior surfaces to assure that the radiation level is less than 10 mR/hr.

7.1.3.4 Ship the container according to the procedure 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 Package Unloading

7.2.1 Receipt of Package from Carrier

7.2.1.1 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.

7.2.1.2 Upon receipt of a transport package of radioactive material:
(Reference:
- *IAEA TS-R-1, paragraph 510 and 511)*

7.2.1.2.a 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.

7.2.1.2.b Record the actual radiation levels on the receiving report.

7.2.1.2.c 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.

7.2.1.2.d Inspect the outer container for physical damage or leaking. If the package is damaged or leaking or it is suspected that the package may have leaked or been damaged, restrict access to the package. As soon as possible, contact the Radiation Safety Office to perform a full assessment of the package condition and take necessary follow-up actions.

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

7.2.2 Removal of Contents

7.2.2.1 Unload the package must be in accordance with the instructions supplied with the package per 10 CFR 71.89.

7.2.2.2 Unloading of the package must also be in accordance with applicable licensing provisions for the user's facility related to radioactive material handling.

7.3 Preparation of Empty Package for Transport

(Reference:
- *IAEA TS-R-1, paragraph 520)*

In the following instructions, an *empty* transport package refers to a Model 650L transport package without an active source contained within the shielded container. To ship an empty transport package:

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

7.3.1.1. Remove the authorized source assembly from the package be in accordance with the instructions supplied with the package per 10 CFR 71.89.

7.3.1.2. After removing the source insert the depth gauge attached to the container into the empty tube(s) of the package. Read the gauge at the top of the outlet fitting.

7.3.1.3. The gauge should bottom out in the empty source tube(s) and indicate a safe condition. The red line should be flush with the top of the outlet fitting. Verify that each empty tube indicates a safe condition.

7.3.1.4. If the gauge indicates an unsafe condition (redline is above the outlet fitting) they may be an obstruction in the tube. Remove the gauge slowly while observing the survey meter. If the radiation levels increase as the gauge is being removed keep the gauge within the source tube, secure the container and contact QSA Global Inc. for further instructions.

7.3.1.5. If radiation levels remain normal as the gauge is being removed, completely remove the gauge.

7.3.2 Assure that the levels of removable radioactive contamination on the outside surface of the transport package does not exceed 4 Bq/cm^2 (when averaged over 300 cm^2).

7.3.3 When it is confirmed that the Model 650L transport package is empty, prepare the transport package for shipment. Survey the assembled package to ensure the external surface radiation level does not exceed 5 µSv/h.

7.3.4 Ship the container according to the procedure for transporting radioactive material as established in 49 CFR 171-178.

7.4 Other Operations

7.4.1 Package Transportation By Consignor

(Reference:

- *IAEA TS-R-1, paragraph 508, 512 through 514)*

Persons transporting the Model 650L transport package in their own conveyances should comply with the following:

7.4.1.1 For a conveyance and equipment used regularly for radioactive material transport, check to determine the level of contamination that may be present on these items. This contamination check is suggested if the package shows signs of damage upon receipt or during transport, or if a leak test on the special form source transported in the package exceeds the allowable limit of 185 Bq.

7.4.1.2 If contamination above 4 Bq/cm^2 (220 dpm/cm^2), when averaged over 300 cm^2, is detected on any part of a conveyance or equipment used regularly for radioactive material transport, or if a radiation level exceeding 5 µSv/h (0.5 mrem/hr) is detected on any conveyance or equipment surface, then remove the affected item from use until decontaminated or decayed to meets these limits.

7.4.2 Emergency Response

(Reference:

- *IAEA TS-R-1, paragraph 308 and 309)*

In the event of a transport emergency or accident involving this package, follow the guidance contained in "2000 Emergency Response Guidebook: A Guidebook for First Responders During the Initial Phase of a Dangerous Goods/Hazardous Materials Incident", or equivalent guidance documentation.

Reference: "2000 Emergency Response Guidebook: A Guidebook for First Responders During the Initial Phase of a Dangerous Goods/Hazardous Materials Incident"

7.5 Appendix

Not Applicable.

Section 8 - ACCEPTANCE TESTS AND MAINTENANCE PROGRAM

8.1 Acceptance Test

8.1.1 Visual Inspections and Measurements

8.1.1.1 Visually inspect each transport package component to be shipped to assure the following:

8.1.1.1.a Remove the authorized source assemblies from the package in accordance with the instructions supplied with the package per 10 CFR 71.89

8.1.1.1.b The transport package was assembled properly to the applicable drawing.

8.1.1.1.c All fasteners as required by the applicable drawings are properly installed and secured.

8.1.1.1.d 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.

8.1.1.2 Evaluate each Model 650L for shielding to ensure the transport dose rate requirements are met when the container is loaded to capacity.

8.1.1.3 Visual inspections and measurements will be performed in accordance with QSA Global Inc.'s USNRC approved Quality Assurance Program No. 0040.

8.1.2 Weld Examinations

Weld examinations will be performed in accordance with the applicable drawings requirements and in accordance with QSA Global Inc.'s USNRC approved Quality Assurance Program No. 0040.

8.1.3 Structural and Pressure Tests

(Reference:
- *10 CFR 71.85(a) and (b))*
- *IAEA TS-R-1, paragraph 501(a))*

Prior to first use as part of a 650L transport package, container structural conformance will be evaluated in accordance with the applicable drawings requirements and in accordance with QSA Global Inc.'s USNRC approved Quality Assurance Program No. 0040. The containment system is not designed to require increased or decreased operating pressures to maintain containment during transport, therefore pressure tests of package components prior to first use is not required.

8.1.4 Leakage 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 ISO9978:1992(E) (or more recent editions). The source capsules are not used if they fail any of these tests.

8.1.5 Component and Material Tests

Component and material compliance is achieved in accordance with the requirements in QSA Global Inc.'s USNRC approved Quality Assurance Program No. 0040.

8.1.6 Shielding Tests

The radiation levels at the surface of the transport package and at 1 meter from the surface are evaluated prior to first transport. 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.

8.1.7 Thermal Tests

Not applicable. The source content of the Model 650L packages has minimal effect on the package surface temperature and therefore no additional testing is necessary to evaluate thermal properties of the packaging.

8.1.8 Miscellaneous Tests

Not applicable.

8.2 Maintenance Program

8.2.1 Structural and Pressure Tests

Not applicable. Material certification, or equivalent dedication process, is obtained for Safety Class A components used in the transport package prior to their initial use. Based on the construction of the design, no additional structural testing during the life of the package is necessary if the container shows no signs of defect when prepared for shipment in accordance with the requirements of Section 7 of the SAR. The 650L packaging system is not designed to require increased or decreased operating pressures to maintain containment during transport, therefore pressure tests of package components prior to individual shipment is not required.

8.2.2 Leakage Tests

As described in Section 8.1.4, "Leakage Tests," the radioactive source assembly is leak-tested at manufacture. In addition, the sources are leak tested in accordance with that Section at least once every six months thereafter if being transported to ensure that removable contamination is less than 0.005 microcuries. Also a contamination wipe is performed of the shield source tubes whenever the shield is returned to the manufacturer (typically the shield is shipped to a customer with new sources and may be returned directly to the manufacturer with decayed sources for disposition).

8.2.3 Component and Material Tests

The transport package is inspected for tightness of fasteners, proper seal wires, and general condition prior to each use as described in Section 7 of this SAR. No additional component or material testing is required prior to shipment.

8.2.4 Thermal Tests

Not applicable. The source content of the Model 650L packages has minimal effect on the package surface temperature and therefore no additional testing is necessary to evaluate thermal properties of the packaging prior to shipment.

8.2.5 Miscellaneous Tests

Inspections and tests designed for secondary users of this transport package under the general license provisions of 10 CFR 71.17(b) are provided in Section 7.

8.3 Appendix

Not applicable.

Section 9 – IAEA TS-R-1 1996 Edition (Revised) Requirements not Otherwise Addressed – Section VI

9.1 General Package Design Requirements

9.1.1 *(Reference: IAEA TS-R-1, paragraph 609)*

As far as practicable, the packaging shall be so designed and finished that the external surfaces are free from protruding features and can be easily decontaminated.

The exterior surface of the 650L package is comprised of steel. The materials and fabrication of the package provides an external surface which is free from protruding features not necessary for use of the package and it can be easily decontaminated if necessary.

9.1.2 *(Reference: IAEA TS-R-1, paragraph 610)*

As far as practicable, the outer layer of the package shall be so designed as to prevent the collection and the retention of water.

The exterior surface of the 650L package is comprised of steel. The materials and fabrication of the package are water resistant and prevent, as far as practicable, the collection and retention of water.

9.1.3 *(Reference: IAEA TS-R-1, paragraph 611)*

Any features added to the package at the time of transport which are not part of the package shall not reduce its safety.

There are no added features to the package other than transport labels, markings, etc. These items are standard in package shipment and will not reduce the package safety due to their presence.

9.1.4 *(Reference: IAEA TS-R-1, paragraph 614)*

All valves through which the radioactive contents could otherwise escape shall be protected against unauthorized operation.

Not applicable. This package does not incorporate the use of valves.

9.1.5 *(Reference: IAEA TS-R-1, paragraph 616)*

For radioactive material having other dangerous properties the package design shall take into account those properties; see paras 109 and 507.

Not applicable. The contents of this package do not have any other dangerous properties other than its radioactivity.

9.2 Requirements for Type A Packages (required by TS-R-1 paragraph 650)

9.2.1 *(Reference: IAEA TS-R-1, paragraph 644)*

All valves, other than pressure relief valves, shall be provided with an enclosure to retain any leakage from the valve.

Not applicable. This package does not incorporate the use of valves.

9.2.2 *(Reference: IAEA TS-R-1, paragraph 647)*

The design of a package intended for liquid radioactive material shall make provision for ullage to accommodate variations in the temperature of the contents, dynamic effects and filling dynamics.

Not applicable. This package is not used for the transport of liquids.

9.3 Requirements for Type B(U) Packages

9.3.1 *(Reference: IAEA TS-R-1, paragraph 659)*

A package shall not include a pressure relief system from the containment system which would allow the release of radioactive material to the environment under the conditions of the tests specified in paras 719-724 and 726-729.

Not applicable. This package does not incorporate a pressure relief system.

9.4 Appendix

Not Applicable.