Summary Table of Changes to Drawing R86000 Rev L to Rev M

Change Location	Summary Change	Change Reportable Pursuant to 71.95	Impact of Change on Units Previously or Currently in Use under the Certificate	Action Taken By QSA Regarding Affected Units
Sheet 1	Added clarification for the cover bracket to list this item as "optional" and to indicate that the Model 867 uses 2 cover brackets instead of the 1 bracket used on Sentry 110 and 330 packages.	No	No change to package construction or design. Detail added for clarity. The cover bracket is present to serve as an operational convenience when the unit is not in transport. Whether the cover bracket is attached to the packages or not has no impact or importance to safety from a transport standpoint.	None. Not applicable.
Sheets 5 & 6	Added port tube pictorial to sheet in primary and section views A5-A5, B5-B5, A6-A6 and B6-B6. Reference to details for port tube added in Section A5-A5 and A6-A6 views respectively (e.g. see sheet 3).	No	No change to package construction or design. Detail added for clarity and reference in dimensioning of dust cover assembly in relation to port tube.	None. Not applicable.
Sheet 5	Added dimension for the dust cover protruding beyond the port tube in detail A5-A5 Also added dimension for thickness of dust cover located directly above the source assembly when the cover assembly is installed.	No	No change to package construction or design. Detail added for clarity.	None. Not applicable.
Sheet 5	Removed reference to • cover roll pins, • cover screws, • 0.62 lock cover assembly thickness This information was removed from sheet 5 because it is already shown on sheet 10.	No	No change to package construction or design. Change for simplification and clarity.	None. Not applicable.
Sheets 5 & 6	Combined the rear plate diameter call out (⌀5.75) from the primary view with the rear plate thickness dimension shown in	No	No change to package construction or design. Change for simplification and clarity.	None. Not applicable.

Change Location	Summary Change	Change Reportable Pursuant to 71.95	Impact of Change on Units Previously or Currently in Use under the Certificate	Action Taken By QSA Regarding Affected Units
	Section A5-A5 and A6-A6 respectively.			
Sheets 5 & 6	Moved the Dust Cover Assembly callout on sheet from primary view to Section A5-A5 and A6-A6 respectively.	No	No change to package construction or design. Change for simplification and clarity.	None. Not applicable.
Sheets 5 & 6	Changed reference in view A5-A5, A6-A6 and in bill of material table for source wire assembly to read "Flexible Source Assembly". Added "TYP" to the material description for this item in bill of material.	No	None. Revision is equivalent to existing specification but with slightly more flexibility in reference to these assemblies. Change will also allow shipment of additional, compatible flexible source assemblies utilizing approved special form capsules specified in SAR Section 2.10.	None. Not applicable.
Sheet 6	Added dimension for the dust cover protruding beyond the port tube in detail A6-A6, added dimension for thickest portion of the dust cover assembly over the lock cover assembly and added dimension from the bottom of the cover shield to outside of dust cover when the cover assembly is installed.	No	No change to package construction or design. Detail added for clarity.	None. Not applicable.
Sheet 6	Removed reference to cover screws and cover roll pins. Relocated call out for Lock Cover Assembly from Section B6-B6 to A6-A6. Added reference to sheet 10 for Lock Cover Assembly details. This information was removed from sheet 6 because it is already shown on sheet 10.	No	No change to package construction or design. Change for simplification and clarity.	None. Not applicable.

Summary Table of Changes to Drawing R86000 Rev L to Rev M

Change Location	Summary Change	Change Reportable Pursuant to 71.95	Impact of Change on Units Previously or Currently in Use under the Certificate	Action Taken By QSA Regarding Affected Units
Sheet 6	Added reference to Lock Pin springs with the Lock Pin call out in Section A6-A6.	No	No change to package construction or design. Change for clarity as lock pin springs had been listed in bill of material on sheet 6 but not shown on the assembly depictions.	None. Not applicable.
Sheet 10	Added outer diameter and thickness dimensions for the lock covers for Model 867 and Sentry 110/330 version under the Lock Cover description shown. Added Outer diameter for the dust cover under the assembly description shown.	No	No change to package construction or design. Change for simplification and clarity.	None. Not applicable.
Sheet 11	Corrected typographical error in the first appearance of the word "weight" occurring in Note 8.	No	No change to package construction or design. Change for accuracy.	None. Not applicable.

Revision 3 to the Sentry 110, Sentry 330 and 867 SAR changes are described as follows and listed under the SAR Section in Revision 3 where the change occurs.

Section Location	Summary Change	Change Reported Pursuant to 71.95	Impact of Change on Units Previously or Currently in Use under the Certificate	Action Taken By QSA Regarding Affected Units
Figure 1.2e	Figure updated to show cover shield component added to Model 867 dust cover assembly.	No	No impact. Addition of cover shield will only impact units transported after approval of NRC CoC amendment.	None. Not applicable
1.2.1.3	Added reference to addition of cover shield in description of the dust cover for the Model 867.	No	No impact. Addition of cover shield will only impact units transported after approval of NRC CoC amendment.	None. Not applicable.
1.3	Appendix drawings updated to reflect revision to drawing R86000 Revision M.	Changes made are described in separate drawing table summary included with our submission letter. None of the changes are reportable under 71.95.		
Table 2.2a	Revised condition for Tungsten in table to apply to any Class of tungsten not just Class 1.	No	Notation correction made to address other tungsten classes used on the package for accuracy only. Mechanical properties listed applicable to all tungsten classes.	None. Not applicable.
2.6.3, 2.6.4	Updated ISO reference to latest 2012 version of standard.	No.	No change to package construction or design. Changes made for relevancy only.	None. Not applicable.
2.6.7, 2.6.7.6, 2.6.7.7, 2.7, 2.7.1.1.f, 2.7.1.5, 2.7.3, 2.7.3.4, 2.7.4.5, 2.7.4.5.c, 3.5.2, 4.2, 4.3, 5.1	Section updated to reflect additional testing under Test Plan 213.	No	No impact on units previously manufactured. Application of design change will only impact units transported after approval of NRC CoC amendment.	None. Not applicable.

Section Location	Summary Change	Change Reported Pursuant to 71.95	Impact of Change on Units Previously or Currently in Use under the Certificate	Action Taken By QSA Regarding Affected Units
Section 2 Figures	Figure references updated as necessary based on addition of drop test figure orientations for test specimen TP180J	No	No impact. Administrative change only.	None. Not applicable.
2.6.7.7	Section renumbered due to added testing under Test Plan 213. Section description clarified as based on testing performed under previous test plans.	No	No impact. Change for accuracy only based on other document changes.	None. Not applicable.
2.7.3.6	Section updated to reflect additional testing under Test Plan 213. Section also corrects dimension in inches equivalent to 1 m drop distance and the section reference to 10 CFR 71.73.	No	No impact on units previously manufactured. Application of design change will only impact units transported after approval of NRC CoC amendment. Other changes administrative only.	None. Not applicable.
2.7.8	Section updated to reflect additional testing under Test Plan 195 and 213. Section also corrects Table reference from Table 2.7A to Table 2.7c.	No	No impact on units previously manufactured. Application of design change will only impact units transported after approval of NRC CoC amendment. Other changes administrative only.	None. Not applicable.
Table 2.7c	Updated unit descriptions to differentiate between test specimens manufactured to Sentry 330 construction and specimens manufactured to Sentry 867 construction. Added information related to testing of Test specimen TP180J performed under Test Plan 213.	No	No impact on units previously manufactured. Application of design change will only impact units transported after approval of NRC CoC amendment. Other changes for clarity only.	None. Not applicable.
2.12.7	Updated special form certificate revision from 7 to 8.	No	No impact. Administrative change only.	None. Not applicable.
2.12.13, 2.12.14, 2.12.15	Appendices sections added to include documentation for Test Plan 213, Test Plan 213 Report and Special Form certificate USA/-0603/S-96	No	No impact. Information added to support other document changes.	None. Not applicable.
Table 3.2a	Table updated to include material details for rotor shield, cover shield and fitting as shown on drawing R86000.	No	No impact. Information added to support other document changes.	None. Not applicable.
2.10	Section revised to reflect addition of X2163 capsule as optional special form source. Description modified to list source assemblies as typical for reference purposes.	No	No impact. Application of change will only impact units transported after approval of NRC CoC amendment.	None. Not applicable.

Section Location	Summary Change	Change Reported Pursuant to 71.95	Impact of Change on Units Previously or Currently in Use under the Certificate	Action Taken By QSA Regarding Affected Units
Table 5.1g	Footnote 8 wording revised to reflect "typical" dose rates for transport of alternate wire assemblies and to reference activity of 330 Ci in reference to the A424-13 assembly.	No	No impact. Information added to support other document changes and for accuracy.	None. Not applicable.
7.4.2, 7.5.1	Updated reference to latest 2012 version of standard and included reference for later revisions.	No.	No change to package construction or design. Changes made for relevancy only.	None. Not applicable.

Safety Analysis Report for the Models Sentry 330, Sentry 110 & 867 Transport Packages

List of Affected Pages	
Revision 0, October 2010	Original Submission.
Revision 1, April 2011	Revised to reflect changes made to address issues raised in USNRC RAI letter dated 7 March 2011.
Revision 2, July 2013	Revised drawing R86000 and pages 1-3, 2-42, 5-5, 5-6 and 7-1.
Revision 3, June 2015	Revised in entirety to incorporate testing under Test Plan 213 and drawing revisions.

Safety Analysis Report

QSA Global, Inc.

Models Sentry 110, Sentry 330 and 867
Type B(U) - 96
Transport Package

June 2015

Revision 3

Contents

List of Tables

List of Figures

Section 1 - GENERAL INFORMATION

1.1 Introduction

All versions of the Models Sentry 110, Sentry 330 and 867 are designed as transport packages and storage containers for Type B quantities of special form ^{60}Co radioactive material. They conform to the Type B(U)-96 criteria for packaging in accordance 10 CFR 71, 49 CFR 173, the IAEA Regulations for the Safe Transport of Radioactive Material No. TS-R-1 (ST-1, Revised) 1996 Edition (Revised) and Canadian Nuclear Safety Commission (CNSC) PTNS Regulations SOR/2000-208. This submission is formatted in accordance with NUREG-1886 "Joint Canada – United States Guide for Approval of Type B(U) and Fissile Material Transportation Packages" dated May 2009.

1.2 Package Description

These transport packages are variations of essentially three package designs that share a common structure, but incorporate some variations in the individual designs for functionality as radiography devices. These package designs can be transported in either the "Standard" configuration, shown in Figure 1.2a, or the "Basic" configuration, shown in Figure 1.2b.

The Standard configuration includes the handling rib and link plates not present on the Basic configuration. Otherwise, both the Standard and Basic configurations are identical. The rib/link assemblies do not impair the package's ability to meet the Type B requirements as described in this Safety Analysis Report (SAR). Transport of the package with the rib/link assemblies is the "standard transport configuration" (see Figure 1.2a). When transported without the ribs/link assemblies, this is considered the "basic transport configuration" for these packages (see Figure 1.2b).

These transport packages are constructed in accordance with descriptive drawing R86000 in Appendix 1.3. The external dimensions for all three standard configuration packages are the same. Their general dimensions are 19" (48 cm) wide x 19" (48 cm) tall x 19" (48 cm) deep.

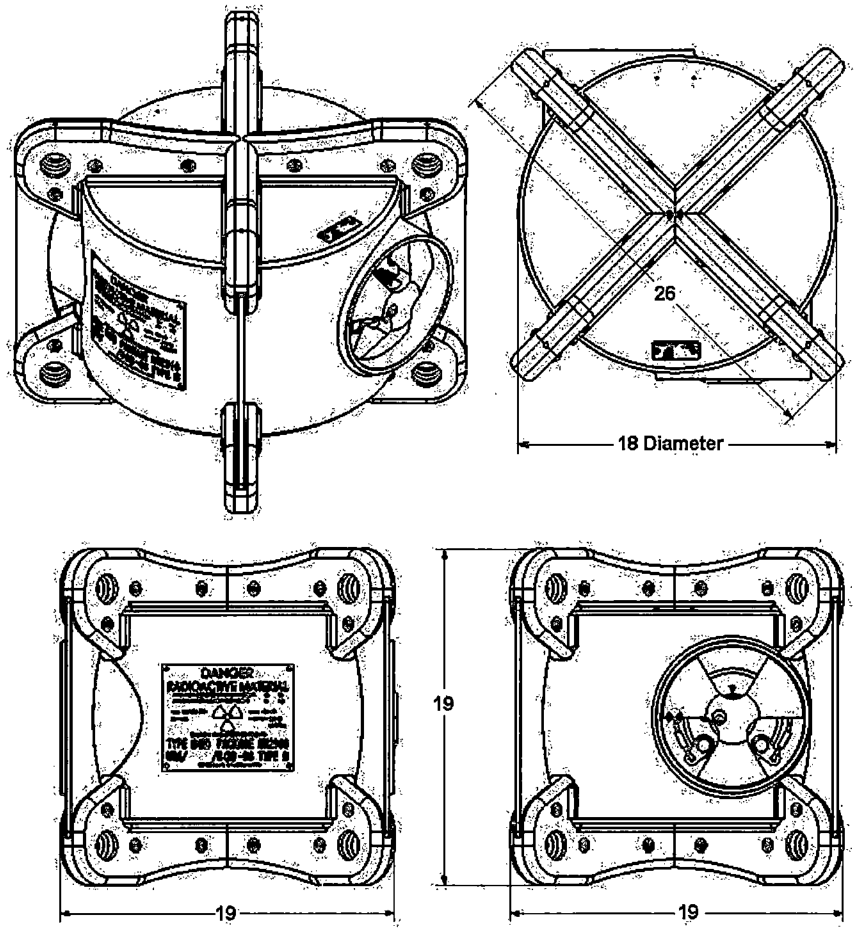


Figure 1.2a: Isometric View of Models Sentry 110, Sentry 330 and 867 Transport Packages – Standard Configurations

The external dimensions for all three Model packages in the basic configuration are the same. Their general dimensions in the basic configuration are 24" (61 cm) wide x 12" (30.5 cm) tall x 18" (46 cm) in diameter.

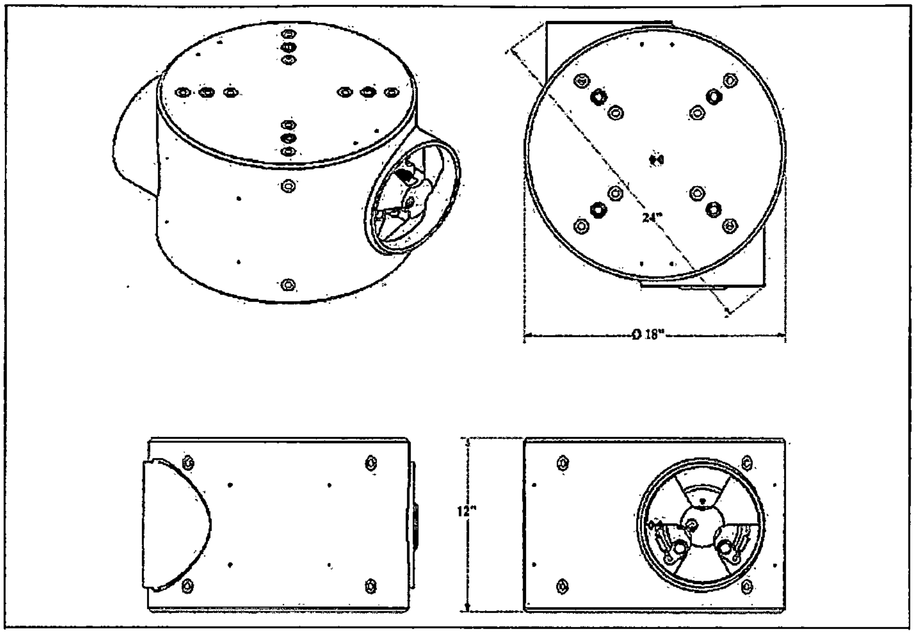


Figure 1.2b: Isometric View of Models Sentry 110, Sentry 330 and 867 Transport Packages – Basic Configurations

Additional details for these Packages are shown in Table 1.2a:

Table 1.2a: Model Sentry 110, Sentry 330 and 867 Package Information

Identification	Nuclide	Form[1]	Maximum Capacity	Maximum Content Weight[2]	Maximum DU Weight	Maximum Weight
Sentry 110 (Standard)	^{60}Co	Special Form Sources	110 Ci	0.09 lbs (40 grams)	320 lbs (145 kg)	605 lbs (274 kg)
Sentry 110 (Basic)	^{60}Co	Special Form Sources	110 Ci	0.09 lbs (40 grams)	320 lbs (145 kg)	525 lbs (238 kg)
Sentry 330 (Standard)	^{60}Co	Special Form Sources	330 Ci	0.09 lbs (40 grams)	485 lbs (220 kg)	780 lbs (354 kg)
Sentry 330 (Basic)	^{60}Co	Special Form Sources	330 Ci	0.09 lbs (40 grams)	485 lbs (220 kg)	700 lbs (318 kg)
867 (Standard)	^{60}Co	Special Form Sources	330 Ci	0.18 lbs (80 grams)	485 lbs (220 kg)	780 lbs (354 kg)
867 (Basic)	^{60}Co	Special Form Sources	330 Ci	0.18 lbs (80 grams)	485 lbs (220 kg)	700 lbs (318 kg)

[1]Special Form is defined in 10 CFR 71, 49 CFR 173, and IAEA TS-R-1.
[2]Maximum content weight includes the mass of the radioactive material and the source capsule handling wire assembly for a shipment containing the maximum number of source wire assemblies that can be transported per package design (e.g., 1 for the Models Sentry 110 and Sentry 330 and 2 for the Model 867 source changer).

1.2.1 Packaging

Figure 1.2c, with the following paragraphs describe the major components of the transport package including: the shield assembly, the welded body assembly, the rear plate lock assembly, the front plate assembly, the handling rib and link plate assemblies and the source assembly.

1.2.1.1 *Shield*

All transport package configurations include a depleted uranium shield which is completely encased and supported in a cylindrically shaped, stainless steel, welded body (see Figure 1.2c). The depleted uranium shield provides the primary radiation protection for the packages. The Model Sentry 110 and Model Sentry 330 have titanium source tubes which allow the source assembly to pass through the center of the shield. The Model Sentry 110 and Model Sentry 330 can contain only one source assembly during transport.

The Model 867 shield assembly has a partition or stop crimp installed at the center of the titanium source tube prior to casting which prevents the sources from exiting the opposite side of the container during loading into the fully stored position. A maximum of two (2) source assemblies can be loaded into the Model 867 for shipment, one in each side of the source tube of the container.

1.2.1.2 *Welded Body*

In all package constructions, the shield is located inside the welded body (shell) of the package by multiple means. The welded body includes two, tube shaped access ports which are integrally welded on opposite sides of the main body weldment. A set of two shield mounting bars are located at each end of the shield and are welded to the back plate of each access port tube. Lastly, heavy duty, titanium shield pins are passed through the shield and into the twin shield mounting bars. This construction provides two positive shield attachment points to the welded body of the package.

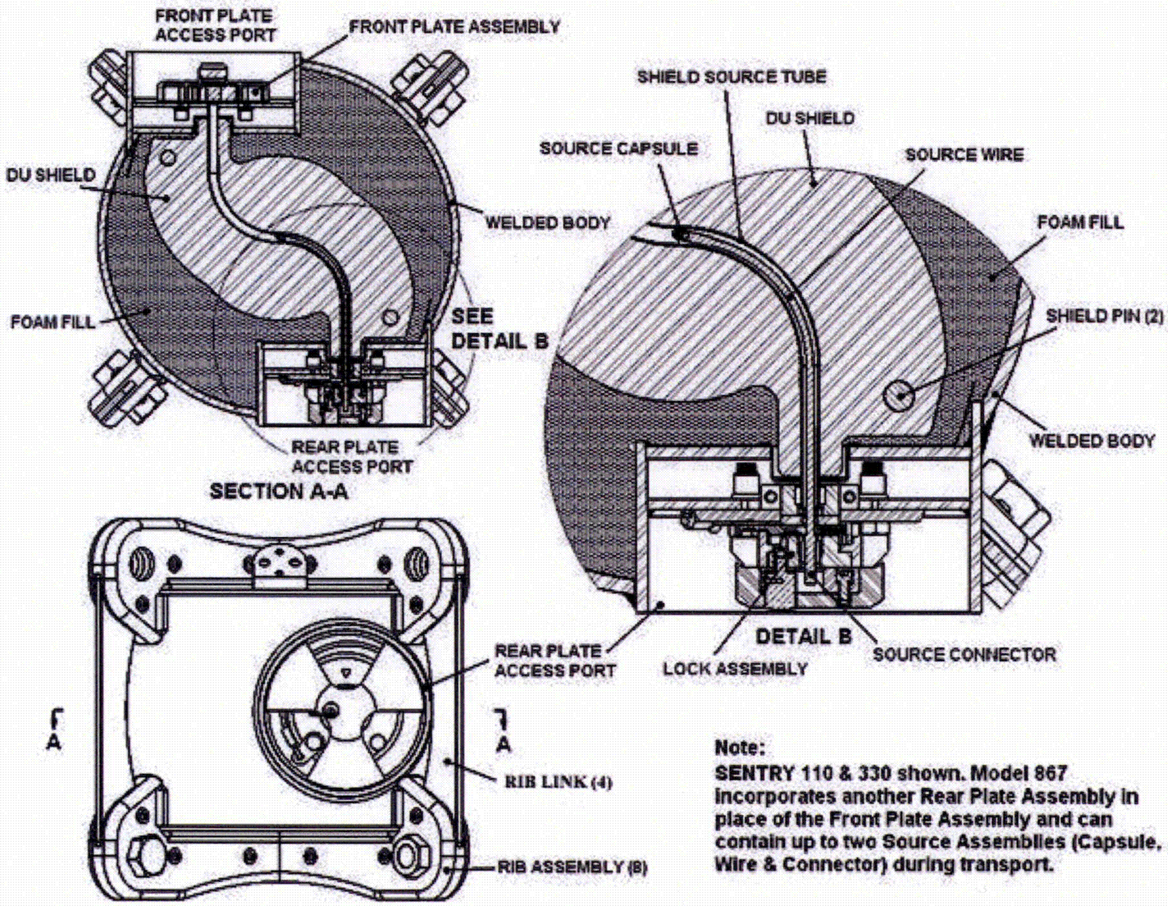


Figure 1.2c: Models Sentry 110, Sentry 330 and 867 Transport Packages – Common Components (Ribs and Link Assemblies are Optional)

The inner cavity of the welded body around the shield is filled with a closed cell polyurethane foam with a minimum density of 18 lb/ft^3. The foam prevents contamination to and from the depleted uranium shield. Copper separators are installed between all surfaces of the depleted uranium shield where it would otherwise come in contact with a stainless steel component to prevent any stainless steel-uranium interaction.

1.2.1.3 *Lock Assembly*

The Model Sentry 110 and Model Sentry 330 packages contain a single lock assembly. These packages do not allow the source assembly to exit the package through the lock assembly, but do secure the source in the shielded position for transport. The lock assembly for the Model Sentry 110 is identical to the lock assembly for the Model Sentry 330 except that the Model Sentry 330 uses a 0.19” (4.8 mm) thick spacer that is not used on the Model Sentry 110 package (see Figure1.2d).

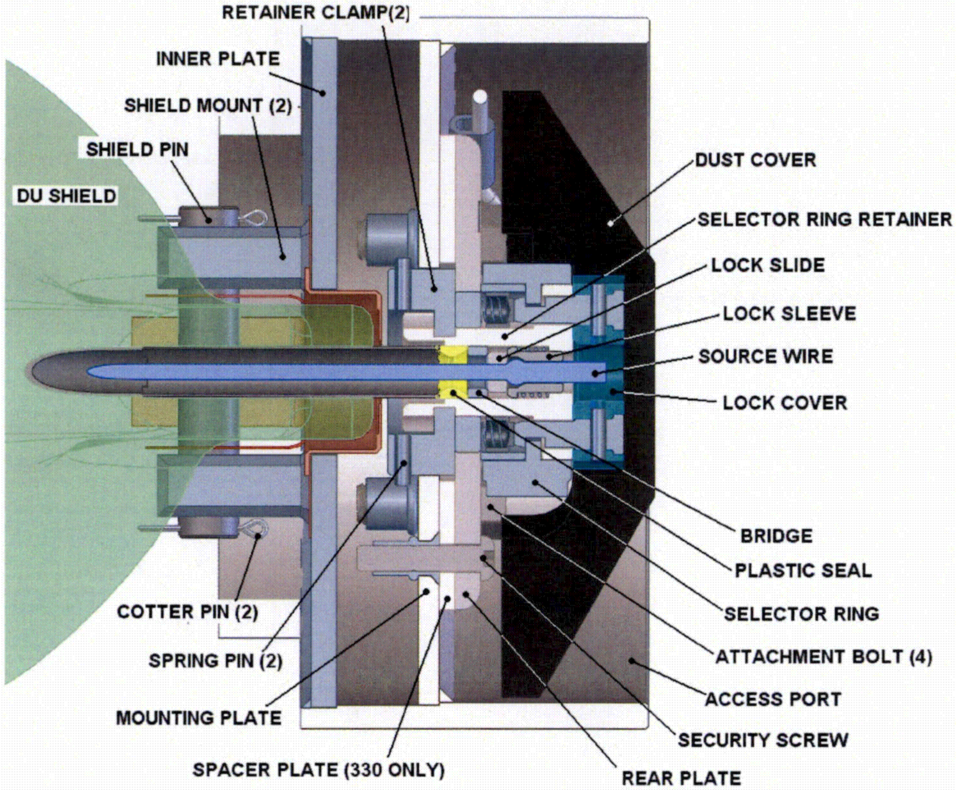


Figure 1.2d: Models Sentry 110 & Sentry 330 Lock Assembly Components

The Model 867 package contains two lock assemblies, one attached to each access port back plate. Source wire assemblies installed in the Model 867 enter and exit at the rear plate lock assembly, but cannot pass through the shield to the other rear plate access port. The source tube center partition blocks the path through the shield (see Figure 1.2e).

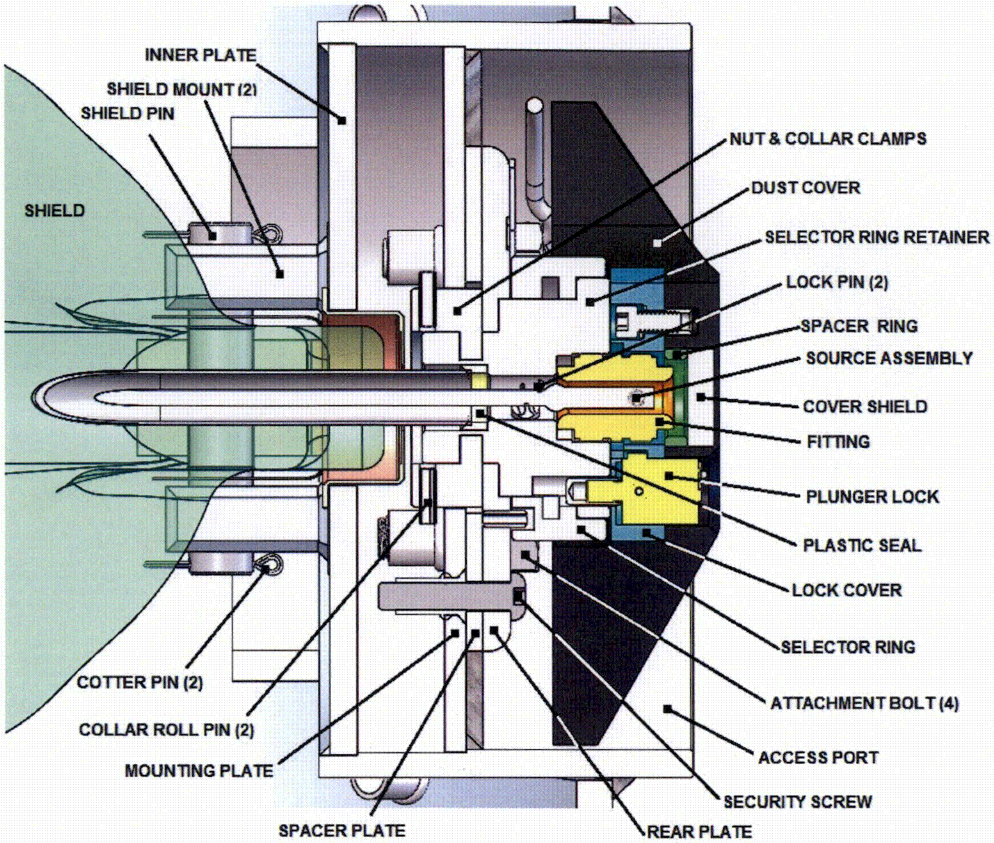


Figure 1.2e: Model 867 Lock Assembly Components

Each lock plate assembly is attached to the welded body with four (4) 1/2-13 UNC, 1½ inch long stainless steel hex head bolts (ASTM F593, Alloy Group 7, Grade 630 Condition AH) through either rivnuts or nut rings installed on the mounting plate.

All packages use a selector ring to change and indicate the safety state of the package. When the selector ring is rotated to the "LOCK" position, it securely holds the source wire assembly in place for transport. The Model Sentry 110 and Model Sentry 330 incorporate a lock slide in the lock mechanism to secure the source assembly in the package. The Model 867 lock assemblies use locking pins to hold the source assembly in the package. All lock assemblies incorporate a protective dust cover which secures over the end of the source assembly. The dust cover for the Model 867 package incorporates a cover shield. Once the dust cover is attached, a plunger lock is engaged which prevents rotation of the selector ring and further secures the source in the package during transport.

1.2.1.4 *Front Plate Assembly*

The Model Sentry 110 and Model Sentry 330 incorporate a front plate assembly. (The Model 867 does not include a front plate assembly since it uses two lock assemblies). On the Model Sentry 110 and Sentry 330, the front plate assembly can be opened to allow the source wire to exit the package when used for industrial radiography or when loading/unloading the package. The front plate assembly is attached to the welded body with four (4) 1/2-13, 1½ inch long stainless steel hex head bolts through rivnuts (or nut rings) assembled into the body mounting plate.

The front plate assembly consists of a shielded port mechanism contained within the front plate. The mechanism can only be opened with a guide tube connector fitting inserted into the opening and rotated. A knob covers the port and blocks access to the port disc. The port shield and knob both block access to the source assembly in the Model Sentry 110 and Model Sentry 330 version packages (see Figure 1.2f).

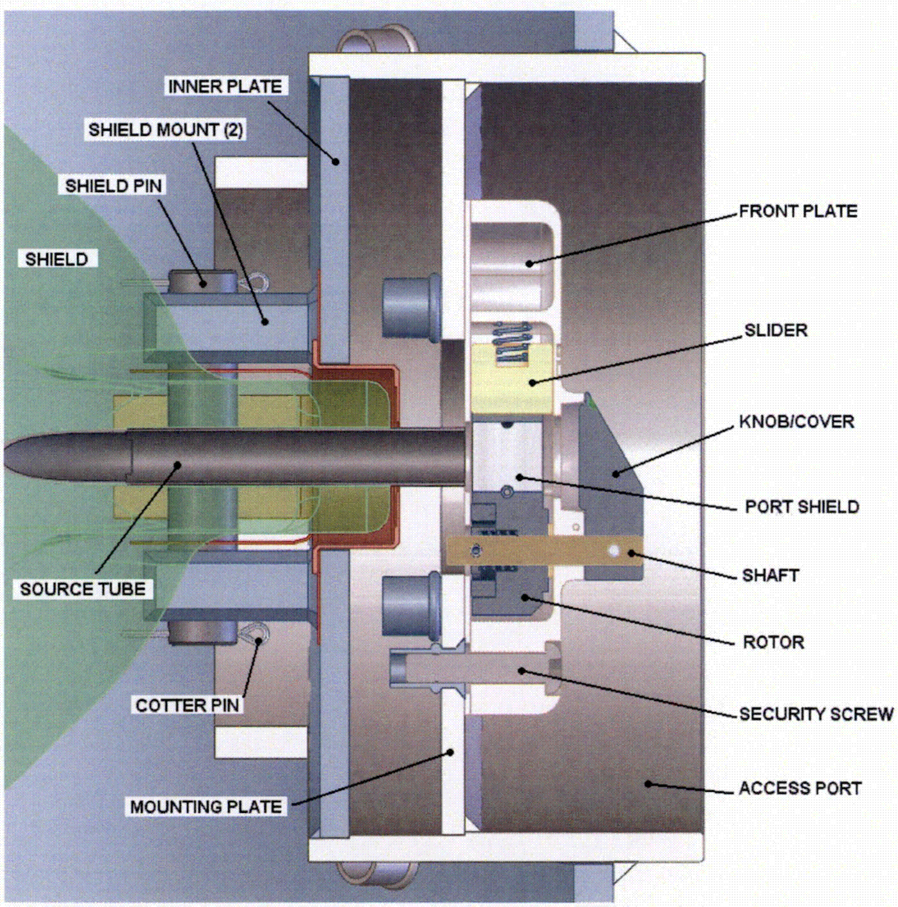


Figure 1.2f: Models Sentry 110 & Sentry 330 Front Plate Assembly Components

1.2.1.5 *Rib/Link Assemblies (Optional)*

The optional rib/link assemblies are bolted to the body weldment and also bolted/secured to each other. This assembly is intended to provide lifting attachments to aid package handling and securing during transport. The stainless steel rib sections include polyethylene or polyurethane plastic inserts.

Four rib assemblies are bolted to the top end of the package and another four rib assemblies are attached to the bottom. Three hex head bolts attach each rib assembly to the package, two bolts on the flat top or bottom surface and one bolt on the curved side surface.

Each link plate connects a set of upper and lower rib assemblies for load sharing capability when needed. Load pins, one at each end of the link plate, with fasteners secure the plates to the rib assemblies.

A heavy duty nut and bolt fits into the large hole of each link plate and rib assembly at the bottom of the package. These provide substantial load transfer capability from the upper to lower ribs.

The polyethylene (or polyurethane) plastic inserts fit into the center of each rib assembly to cover and protect the attachment bolts. Screws and washers are used to attach the inserts to the rib assemblies (see Appendix 1.3 drawings).

1.2.1.6 *Source Assemblies*

The Models Sentry 110, Sentry 330 and 867 Transport Packages are designed to transport special form capsules containing the isotopes listed in Table 1.2a. The source capsule, attached to a flexible steel wire, form the source wire assembly.

The Sentry 110 and Sentry 330 package designs can transport one source wire assembly. The Model 867 package design can transports up to two source wire assemblies.

All source wire assemblies consist of a special form source capsule crimped onto the end of a flexible steel wire. These source wire assemblies are secured in place in the package by the locking assemblies described in Section 1.2.1.3.

1.2.2 Contents

The Models Sentry 110, Sentry 330 and 867 Transport Packages are designed to transport special form capsules containing the isotopes listed in Table 1.2a.

The maximum decay heat for ^{60}Co in Table 1.2a is 5.5 Watts based on 330 Ci. The source assemblies are loaded into the transport package and secured according to the applicable procedure for the shield container (see Section 7).

The maximum weight of the contents for the shield containers is also listed in Table 1.2a. The content weight values are based on the weight of the full source wire assembly(ies) weights that can be transported in the package.

1.2.3 Special Requirements for Plutonium

Not applicable.. This package is not used for the transportation of plutonium.

1.2.4 Operational Features

This package does not involve complex containment systems for source securement. The sources for these packages are all special form, welded capsules. The capsules are attached to flexible handling wires and held in place by lock mechanisms after the source wire assemblies are inserted into the shield tube(s).

1.3 Appendix

Figure 1.3a shows a sketch representative of the Standard Configuration Model Sentry 110, Model Sentry 330 and Model 867 package as prepared for transport. Figure 1.3b. shows a sketch representative of the Basic Configuration Model Sentry 110, Model Sentry 330 and Model 867 package as prepared for transport. Additional drawings of these transport packages are enclosed in this appendix.

Figure 1.3a Sketch of Standard Transport Configuration

Model Sentry 330, Model Sentry 110 and Model 867
Transport Packages - Standard Configuration

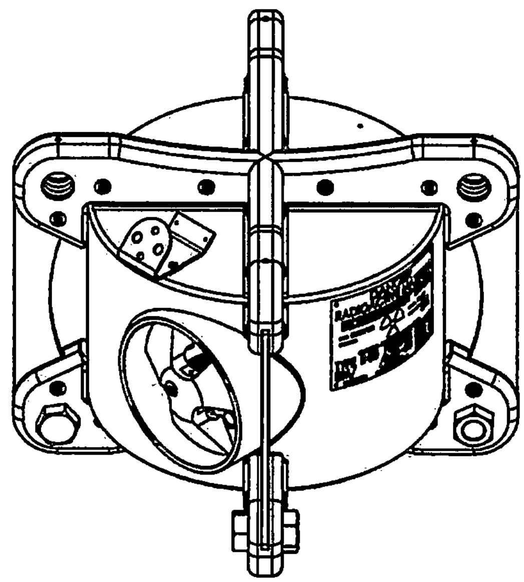
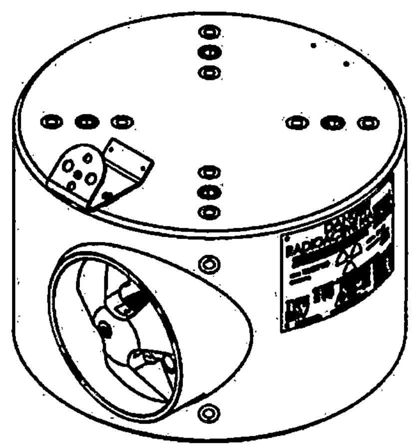


Figure 1.3b Sketch of Basic Transport Configuration

Model Sentry 330, Model Sentry 110 and Model 867
Transport Package - Basic Configuration



Security-Related Information Figure
Withheld Under 10 CFR 2.390

ERF #	APPROVALS	DATE
3285	J. Green	17 Jun 15
	[signature]	17 Jun 15
	[signature]	18 Jun 15

QSA GLOBAL
40 NORTH AVE, BURLINGTON, MA 01803

DESCRIPTIVE DRAWING

TITLE	SENTRY TRANSPORT PACKAGE		
SIZE A	DWG. NO. R86000		REV M
	SCALE: NONE	SHEET 1 OF 11	

Security-Related Information Figure
Withheld Under 10 CFR 2.390

QSA GLOBAL 40 NORTH AVE, BURLINGTON, MA 01803	DESCRIPTIVE DRAWING	
TITLE	SENTRY TRANSPORT PACKAGE	
SIZE A	DWG. NO. R86000 SCALE: NONE — SHEET 2 OF 11	REV M

Security-Related Information Figure
Withheld Under 10 CFR 2.390

QSA GLOBAL 40 NORTH AVE, BURLINGTON, MA 01803	DESCRIPTIVE DRAWING	
TITLE	SENTRY TRANSPORT PACKAGE	
SIZE A	DWG. NO. R86000 SCALE: NONE — SHEET 3 OF 11	REV M

Security-Related Information Figure
Withheld Under 10 CFR 2.390

QSA GLOBAL 40 NORTH AVE, BURLINGTON, MA 01803	DESCRIPTIVE DRAWING	
TITLE	SENTRY TRANSPORT PACKAGE	
SIZE A	DWG. NO. R86000 SCALE: NONE SHEET 4 OF 11	REV M

Security-Related Information Figure
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QSA GLOBAL 40 NORTH AVE, BURLINGTON, MA 01803	DESCRIPTIVE DRAWING	
TITLE	SENTRY TRANSPORT PACKAGE	
SIZE A	DWG. NO. R86000 SCALE: NONE — SHEET 5 OF 11	REV M

Security-Related Information Figure
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QSA GLOBAL 40 NORTH AVE, BURLINGTON, MA 01803	DESCRIPTIVE DRAWING	
TITLE	SENTRY TRANSPORT PACKAGE	
SIZE A	DWG. NO. R86000 SCALE: NONE · SHEET 6 OF 11	REV M

Security-Related Information Figure
Withheld Under 10 CFR 2.390

QSA GLOBAL 40 NORTH AVE, BURLINGTON, MA 01803	DESCRIPTIVE DRAWING	
TITLE	SENTRY TRANSPORT PACKAGE	
SIZE A	DWG. NO. R86000	REV M
	SCALE: NONE — SHEET 7 OF 11	

Security-Related Information Figure
Withheld Under 10 CFR 2.390

QSA GLOBAL 40 NORTH AVE, BURLINGTON, MA 01803		DESCRIPTIVE DRAWING
TITLE	SENTRY TRANSPORT PACKAGE	
SIZE A	DWG. NO. R86000	REV M
	SCALE: NONE	SHEET 8 OF 11

Security-Related Information Figure
Withheld Under 10 CFR 2.390

QSA GLOBAL 40 NORTH AVE, BURLINGTON, MA 01803	DESCRIPTIVE DRAWING	
TITLE	SENTRY TRANSPORT PACKAGE	
SIZE A	DWG. NO. R86000 SCALE: NONE SHEET 9 OF 11	REV M

Security-Related Information Figure
Withheld Under 10 CFR 2.390

QSA GLOBAL 40 NORTH AVE, BURLINGTON, MA 01803		DESCRIPTIVE DRAWING	
TITLE SENTRY TRANSPORT PACKAGE			
SIZE A	DWG. NO. R86000		REV M
	SCALE: NONE	SHEET 10 OF 11	

Security-Related Information Figure
Withheld Under 10 CFR 2.390

QSA GLOBAL 40 NORTH AVE, BURLINGTON, MA 01803	DESCRIPTIVE DRAWING	
TITLE	SENTRY TRANSPORT PACKAGE	
SIZE A	DWG. NO. R86000 SCALE: NONE · SHEET 11 OF 11	REV M

Section 2 - STRUCTURAL EVALUATION

This section identifies and describes the principal structural design of the packaging, components, and systems important to safety. In addition, this section describes how the package complies with the performance requirements of 10 CFR Part 71 and TS-R-1.

2.1 Description of Structural Design

2.1.1 Discussion

The Models Sentry 110, Sentry 330 and 867 Transport Packages are described in Section 1.2.

2.1.2 Design Criteria

The Models Sentry 110, Sentry 330 and 867 Transport Packages are designed to comply with the requirements for Type B(U) packaging as prescribed by 10 CFR 71 and IAEA No. TS-R-1 (ST-1, Revised) 1996 Edition (Revised). All design criteria are evaluated by a straightforward application of the appropriate section of 10 CFR 71 or IAEA No. TS-R-1 (ST-1, Revised) 1996 Edition (Revised).

In addition to the transport design criteria, the Model Sentry 110 and Sentry 330 transport packages are designed to meet the performance requirements for industrial radiography devices in ANSI N432-1980 and ISO 3999:2004(E).

2.1.3 Weight and Centers of Gravity

Table 1.2a includes the weight of each transport package described in this SAR in its specific configuration. The center of gravity is at the geometric center of the welded body for all the packages covered under this SAR.

2.1.4 Identification of Codes and Standards for Package Design

See Section 2.1.2 relating to design criteria of the package. Any applicable, specific codes or standards related to the finished assemblies for these transport packages are specified on the drawings contained in Section 1.3. All component 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 the standards referenced on the drawings in Section 1.3. All hardware meets the standards referenced on the drawings in Section 1.3. 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.

In general, the design was based on the Type A and Type B(U) container requirements of 49 CFR, 10 CFR 71 and IAEA regulations as identified in Section 1.1.

2.2 Materials

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 Models Sentry 110, Sentry 330 and 867 Transport Packages.

Table 2.2a: Mechanical Properties of Principal Transport Package Materials

Material	Form	Specification	Condition	Tensile Strength, minimum (KSI)	Yield Strength, minimum (KSI)	Elongation (% in 2 in) *(% in 4 D)
Stainless Steel 630 (17-4 PH)	Fastener	ASTM F593	AH	135	105	*16
Stainless Steel 630 (17-4 PH)	Bar	ASTM A564	H900	190	170	10
Stainless Steel 660	Fastener	ASTM A453	Class D	130	105	*15
Stainless Steel Any Group 1 Alloy	Fastener	ASTM F879	CW	80	40	25
Stainless Steel Any Group 1 Alloy	Fastener	ASTM F837	CW1	87	65	20
Stainless Steel 304/304L	Bar	ASTM A276 or A479	Annealed	70	25	30
Stainless Steel 304/304L	Plate	ASTM A240 or A666	Annealed	70	25	40
Stainless Steel 304/304L	Tube	ASTM A511	Annealed	75	30	35
Stainless Steel 303	Bar	Ref. #2, P.19	Annealed	85	35	50
Stainless Steel 316/316L	Fastener	Ref. #3	NA	Ref. #3	NA	NA
Stainless Steel 18-8	Fastener	Commercial Grade Item	NA	70	45	30
Stainless Steel CF16FA	Casting	ASTM A743	As Cast	70	30	25
Stainless Steel CF8	Casting	ASTM A743	As Cast	65	28	35
Titanium TI 6AL-4V	Bar	ASTM B348	Grade 5	130	120	*10
Titanium TI 3AL-2.5V	Tube	ASTM B338	Grade 9, Annealed	90	70	15
Tungsten	Bar	ASTM B777	Any Class	94	75	2
Depleted Uranium Minimum 99%	Casting	Ref.#1, P.822	As Cast	58	29	4
Brass Alloy 360	Bar	ASTM B16	H02	57	25	7
Copper Alloy 101 or 110	Sheet	ASTM B152	H02	37	NA	NA
Copper Alloy 110	Bar	ASTMB152	H02	43	NA	40
Silicon Bronze Alloy 655	Bar	ASTM B98	H04	65	38	20

Resource References:

1. **American Society for Metals, Metals Handbook Ninth Edition, Volume 2 Properties and Selections: Nonferrous Alloys and Pure Metals, 1979.**

2. **American Society for Metals, Metals Handbook Ninth Edition, Volume 3 Properties and Selections: Stainless Steels, Tool Materials and Special-Purpose Metals, 1980.**

3. National Aerospace Standard, NAS1330, Nut, Blind Rivet – Countersunk Head. Note: Two fasteners used – One per NAS1330N8E with 10,400 lb-min ultimate thread strength and one per NAS1300N5E with 6,870 lb-min ultimate thread strength. Both tested per ASTM F606.

2.2.2 Chemical, Galvanic or Other Reactions

Except for depleted uranium (DU) and titanium, the materials used in the construction of these packages, shown in Table 2.2a, are relatively close in terms of galvanic potential as shown on MIL-STD-889 Table II. Their close proximity on the galvanic table indicates the galvanic reaction between these materials will be negligible.

DU is located near the active (anodic) end of the table while titanium is located towards the passive (cathodic) end. Possible galvanic reaction between these two materials is expected but will not be significant for the following reasons:

- The large area and mass of DU (anodic) material relative to the titanium (cathodic) material reduces the current potential between the two materials.
- The polyurethane foam surrounding the DU material along with the elastomer seal around the shield source tube exit port prevents the potential for an electrolyte or other corrosive medium from contacting the DU and titanium interface.

A copper separator or barrier is used in between all DU and stainless steel interfaces to prevent the possibility of eutectic alloying during the fire test of the Hypothetical Accident Condition requirements defined in 10 CFR 71.73 (c) (4).

Lubricants, sealants, and other chemicals ingredients used in the SENTRY transport package are reviewed to ensure they do not contain halides (typically chloride) which could cause unexpected corrosion within the package under normal transport and hypothetical accident conditions.

With this construction 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

The materials listed in Table 2.2a have been used in transport packaging for decades without degradation of the package performance over time.

2.3 Fabrication and Examination

2.3.1 Fabrication

Package components are procured, manufactured and inspected for use under QSA Global, Inc. NRC approved QA Program Number 0040. All transport packages will be evaluated and documented for compliance to the drawings provided in Section 1.3 prior to initial use of the containers as a Models Sentry 110, Sentry 330 or 867 Transport Package.

2.3.2 Examination

Section 8 describes the acceptance testing and routine maintenance requirements for shield containers and package components used on these transport packages.

2.4 General Requirements for All Packages

2.4.1 Minimum Package Size

These transport packages exceeds the minimum size requirements since the smallest versions measure 12 inches (305 mm) tall, 24 inches (610 mm) wide, and 18 inches (457 mm) in diameter.

2.4.2 Tamper-Indicating Feature

These packages incorporates a seal wire attached to the locked protective cover over the front plate outlet port which, if broken during transport, serves as evidence of possible unauthorized access to the contents.

2.4.3 Positive Closure

These packages do not involve complex containment systems for source securement. The sources for these packages are all special form, welded capsules. The source wire assembly is held securely in the device by components of the lock assembly.

All packages use a security screw, in addition to the 4 hex head bolts, to attach and secure the lock assemblies to the package. A special, uncommon, drive bit is required to remove the security screw and gain access to the source assembly by removing the lock assembly plates.

A cover over the source wire connector prevents access to the source assembly until a keyed lock is actuated and the cover removed. This cover is in place during transport of the package.

2.5 Lifting and Tiedown Standards for All Packages

2.5.1 Lifting Devices

2.5.1.1 Basic Configuration (without rib/link assembly)

All packages in the basic configuration can be lifted by the use of properly rated chains or slings fitted through properly rated lifting eyebolts or hoist rings. The eyebolts or hoist rings must be threaded into any of the rivnuts located around the outside of the welded body of the package. Any one of the rivnuts can safely lift the heaviest package in the basic configuration without yielding as documented in Technical Report 171 (see Section 2.12).

2.5.1.2 Standard Configuration (with rib/link assembly)

All packages in the standard configuration can be lifted by the use of properly rated chains or slings fitted through the large hole in any one or all of the upper four rib assemblies. Any one or more of the rib assemblies can safely lift the heaviest package in the standard configuration without yielding as documented in Technical Report 171 (see Section 2.12).

2.5.2 Tie-Down Devices

2.5.2.1 Basic Configuration (without rib/link assembly)

The packages in the basic configuration have no tie down attachments. The package in this configuration can be blocked and braced according to standard transportation practices.

2.5.2.2 Standard Configuration (with rib/link assembly)

All packages in the standard configuration can be tied down by the use of properly rated chains or slings fitted through the large hole in any one or all of the upper four rib assemblies. The rib assemblies can safely tie down the heaviest package in the standard configuration without yielding as documented in Technical Report 172 (see Section 2.12).

2.6 Normal Conditions of Transport

2.6.1 Heat

The heat source for the Models Sentry 110, Sentry 330 and 867 Transport Packages is a maximum of 330 Curies of ^{60}Cobalt which generates 5.5 watts. Assuming the entire decay heat, 5.5 watts, is absorbed by the package, the maximum surface temperature caused by the effects of solar input and content decay is conservatively 127°C (261°F) at the top surface of the package (Section 3.4.1.1). This temperature is well below the maximum service temperature for the materials of components important to safety used in these transport packages. Therefore, these packages will not be adversely affected by a surface temperature of 127°C (261°F).

Table 2.6a: Radionuclide Decay Energy

Radionuclide	Package Activity (Ci)	MeV/Decay	Watts/Package
Cobalt-60	330	2.82	5.5

Resource references:

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

2.6.1.1 Summary of Pressures and Temperatures

Table 2.6b: Summary Temperatures Normal Transport

Temperature Condition	Model Sentry 110, Sentry 330 & 867	Comments
Insolation (38°C in full sun)	127°C (261°F)	Section 3.4.1.1.
Decay Heating (38°C in shade)	40°C (104°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 affect 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

If the top of the package reaches a maximum of 127°C due to solar heating (See Section 3.4.1.1) and its initial temperature was 38°C, then this temperature difference of 89°C would increase the diameter of the stainless steel top plate to a maximum of 0.029 inches based on the following:

$$E = D\alpha\Delta T$$

Where: D = Diameter of the outer weldment
α = Coefficient of Thermal expansion
ΔT = Temperature differential

Substituting we get: E = (18 in)(18E-6 in/in°C)(89°C) = 0.029 in

However, the side surface would also increase in diameter due to solar heating. Based on calculations in Section 3.4.1.1, the side surface would heat to a maximum of 90°C from its initial temperature of 38°C. This temperature difference would increase the diameter of the tube shaped side surface to a maximum of 0.017 inches

E = DαΔT = = (18 in)(18E-6 in/in°C)(52°C) = 0.017 in

If the maximum side surface temperature of the package at the access ports conducts without losses through to the internal titanium pins, then the temperature of the pins at the connection could be 90°C. In the worst case, the DU shield could still be at the initial temperature of 38°C for a 52°C temperature differential between the pin and shield.

The smallest sized pin mounting hole in the shield when at 38°C is 0.74 inches. The largest pin diameter at 38°C is 0.73 inches. At the initial temperature, a 0.01 inch minimum design clearance exists between the pin and hole.

If the diameter of the titanium pin were to expand due to the 52°C temperature change, it would grow by only 0.0004 inches (52°C x 11E-6 in/in °C x 0.73 in). This increase in diameter of the shield pin is less than the design clearance. The remaining gap between the pin and mating hole in the shield would not produce stress to the DU shield or pin.

Therefore the thermal expansion encountered during Normal Transport will be insignificant with respect to the manufacturing tolerances of the package.

2.6.1.3 Stress Calculations

The thermal stress in the package due to solar heat is caused by the relative expansion or strain between the warm top surface and relatively cool side surface. The strain caused by the differential thermal expansion is 0.012 inches (0.029 – 0.017) producing an internal stress of 19,333 psi: (29E+6 x (0.012/18 in)). This material stress is insignificant to the yield strength of the stainless steel body weldment.

2.6.1.4 Comparison with Allowable Stresses

All stresses calculated in Section 2.6.1 are about ½ the allowable yield strength of the materials of construction. Further, the Model Sentry 110, Sentry 330 and 867 packages were fully tested and passed under Normal Conditions of transport. It is therefore concluded that these packages will satisfy the performance requirements specified by the regulations.

2.6.2 Cold

The Models Sentry 110, Sentry 330 and 867 Transport Packages do not incorporate any materials that are susceptible to brittle fracture at low temperature. All materials used in these packages and important to safety will not be adversely affected by temperatures down to -40°C (-40°F), the minimum specified in the regulations. Thus, it is concluded that the Models Sentry 110, Sentry 330 and 867 Transport Packages will withstand the normal transport cold condition.

2.6.3 Reduced External Pressure

These transport packages are open to the atmosphere and contains no components which could create a differential pressure relative to atmospheric conditions or components within the package. Therefore, the reduced external pressure requirements of 3.5 psi in 10 CFR, 3.6 psi in 49 CFR and 8.7 psi (60 kPa) and 0.7 psi (5 kPa) in IAEA are met.

The authorized contents are special form source capsules that meet a minimum ISO 2919-2012 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 2 MN/m^2. Therefore, the reduced external pressure requirements of 3.5 psi in 10 CFR and 8.7 psi (60 kPa) in 49 CFR and IAEA will not adversely affect the package containment.

Reference: ISO 2919-2012, Radiation Protection – Sealed radioactive sources - General requirements and classification.

2.6.4 Increased External Pressure

These transport packages are open to the atmosphere and contain no components which could create a differential pressure relative to atmospheric conditions. Therefore, the increased external pressure requirements of 20 psi in 10 CFR 71 will not adversely affect the package containment.

Again, the authorized contents are special form source capsules that meet a minimum ISO 2919-2012 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 2 MN/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

The shields in these transport packages are attached to the welded body at both access ports by shield pins. A cotter pin at each of the shield pin retains the shield pin to the shield and access port. Cotter pins are routinely used in high vibration situations (i.e. wheel bearing nut retention) and will easily withstand vibration incident to transport. A similar construction has been used in the Model 880 devices (Reference Certificate of Compliance USA/9296/B(U)). The Model 880 devices have been used in transport for over 8 years without incident caused by vibration.

The lock assembly plate attachment bolts and screws are tightened to a prescribed torque at assembly to prevent unintentional release even after repeated use. It is therefore concluded these transport packages will withstand vibration normally incident to transport.

2.6.6 Water Spray

The Models Sentry 110, Sentry 330 and 867 transport packages are constructed of water-resistant materials throughout. Therefore, the water spray test would not reduce the shielding effectiveness or structural integrity of the package.

2.6.7 Free Drop

Five test specimens, serial numbers TP180A through TP180E were built to the basic transport configuration shown in Figure 1.2b for the Model Sentry 330 design. The differences between the Model 867 package and the Models Sentry 110 and Sentry 330 are that the Model 867 source tube has a stop in the middle of the s-tube and is equipped with two lock assemblies modified slightly from the design used on the Models Sentry 110 and Sentry 330 packages (see Section 1.2.1.3).

In 2015, an additional test specimen, serial number TP180J was built to the basic transport configuration shown in Figure 1.2b for the Model Sentry 867 design. This specimen was constructed and tested to evaluate a modification to the Model 867 dust cover assembly to include the addition of a tungsten cover shield. This modification increased the amount the dust cover assembly protruded beyond the 867 port tube and testing was performed to demonstrate compliance to the normal condition drop testing for this change.

The Standard package configuration (see Figure 1.2a), for all package designs, is the heaviest configuration. The array of handling rib assemblies of the Standard configuration increases the weight for each Basic package design by approximately 80 lb. Since, the handling ribs provide protection and substantial impact energy absorption in certain free drop orientations, the worst case package construction for normal condition testing was determined to be test specimens manufactured to the Model Sentry 330 (or Model 867) Basic design, but adjusted for the worst case package transport weight.

The drop height for each specimen was adjusted higher than the 1.2 meters to produce the equivalent impact energy as a specimen built to the maximum package weight of 780 pounds. This adjustment compensated for any weight differential between the test specimens and the maximum package weight for the tested configuration requested under this submission.

Test Plan 180, Section 3.3 (see Section 2.12) includes a detailed discussion and evaluation of the drop test height adjustment made to compensate for test unit specimens that weighed less than the maximum weight requested under this submission.

The fracture toughness (strength and ductility) of the structural material in these transport packages will not change significantly within the temperature range of -40°C to +38°C (-40°F to +100°F). Within this temperature range, the depleted uranium shield will exhibit only slightly less ductility than the other structural materials. Since the depleted uranium shield is retained in the package by internal support structures and the body weldment, this slight variation in ductility will have no significant impact on the results of the package performance during the normal transport testing.

Test Plan Report 79 (see Section 2.12) shows the compressive impact strength of the polyurethane foam changes very little between -40°C to +38°C (-40°F to +100°F). The foam is aided in limiting the shield movement during the impact of the drop test by the titanium pins and the welded structure. These items aid in keeping the shield secure and in place during a drop impact. Testing at ambient temperature was performed to demonstrate compliance with the normal transport condition drop testing since the -40°C to +38°C (-40°F to +100°F) temperature range will not have any significant detrimental impact on the results of the drop tests performed.

Based on design similarities, the Models Sentry 110 and 867 packages will be expected to perform as well if not better than the Model Sentry 330 test units evaluated under this section. The only significant difference between the Model 867 and Model Sentry 330 lock plate assemblies was tested by test specimen TP180J under Test Plan 213. All other testing performed with the Sentry 330 package specimens will not significantly impact the Model 867's ability to meet the normal condition drop test conditions and the Model 867 package performance can be bounded by the testing of the Model 867 unit under Test Plan 213 and the additional Model Sentry 330 test results and evaluations.

2.6.7.1 Rear Plate Port Drop Orientation – Square Hit

Test specimen TP180A was subjected to the 1.2 meter (4 foot) free drop in accordance with Test Plan 180 (Section 2.12). The rear plate port orientation of the 1.2 meter (4 foot) free drop was selected because of its potential to cause a shift in the shield position with possible damage to the source wire. In addition, it was possible that this drop orientation could cause a failure/break in the rear plate attachment bolts which could impact the source security in the package. The orientation for this drop test is shown in Figure 2.6a.

The test specimen was dropped at an ambient temperature of +11°C (+51°F). Photographs of the drop orientation are provided in Test Plan 180 Report #1 (Section 2.12).

The black plastic dust cover compressed slightly into the port tube and the welded port tube was slightly bent in towards the dust cover. One of the dust cover attachment pins sheared. No damage was found on the rear plate attachment bolts. The source assembly remained secured in the package and the source location within the package remained unchanged after the test.

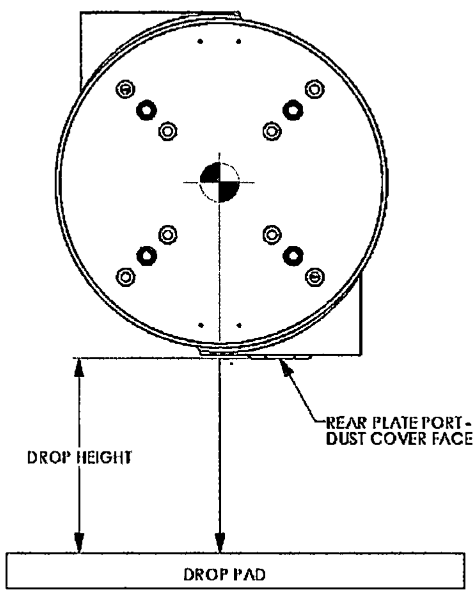

Figure 2.6a – 1.2 m (4 ft) Drop Orientation TP180A

Since the source location remained unchanged, it was assumed there was no change in the radiation dose rates after the 1.2 m (4 ft) drop test. This was later confirmed for this test specimen (TP180A) after performance of the 30 ft drop test under Test Plan 180 Report #2 (Section 2.12). The maximum radiation measurements at the surface and at one meter from the surface of test specimen TP180A were within the regulatory limits of 200 mR/hr and 10 mR/hr respectively for this test specimen after performance of the 30 ft drop test.

2.6.7.2 Rear Plate Port Drop Orientation – Edge Hit

Test specimen TP180B was subjected to the 1.2 meter (4 foot) free drop in accordance with Test Plan 180 (Section 2.12). This rear plate port orientation of the 1.2 meter (4 foot) free drop was selected in an attempt to bend the rear plate port edge enough to break the rear plate attachment bolts or other important lock components. The orientation for this drop test is shown in Figure 2.6b.

The test specimen was dropped at an ambient temperature of +11°C (+51°F). Photographs of the drop orientation are provided in Test Plan 180 Report #1 (Section 2.12).

The welded port tube bent in towards the dust cover by about 1 inch (2.54 cm). No damage was found on the source wire or the rear plate attachment bolts. The source location within the package changed slightly, however, a post test radiation profile showed that the external radiation dose rates remained within the regulatory limits of 200 mR/hr and 10 mR/hr respectively.

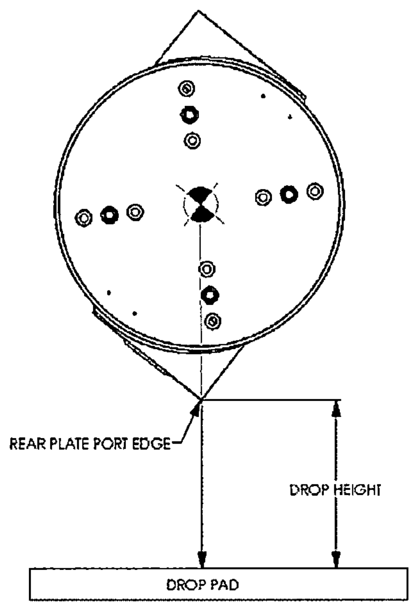

Figure 2.6b – 1.2 m (4 ft) Drop Orientation TP180B

2.6.7.3 Shell Side Drop Orientation – Weld Seam Hit

Test specimen TP180C was subjected to the 1.2 meter (4 foot) free drop in accordance with Test Plan 180 (Section 2.12). This side shell weld seam drop orientation was selected in an attempt to fracture the shell seam weld and/or shift the shield away from the source. The orientation for this drop test is shown in Figure 2.6c.

The test specimen was dropped at an ambient temperature of +11°C (+52°F). Photographs of the drop orientation are provided in Test Plan 180 Report #1 (Section 2.12).

The longitudinal seam of the welded body showed minor deformation. No weld seam break occurred. No damage was found on the source wire or the rear plate attachment bolts. The source location within the package remained unchanged.

Since the source location remained unchanged, it was assumed there was no change in the radiation dose rates after the 1.2 m (4 ft) drop test. This was later confirmed for this test specimen (TP180C) after performance of the 30 ft drop test under Test Plan 180 Report #2 (Section 2.12). The maximum radiation measurements at the surface and at one meter from the surface of test specimen TP180C were within the regulatory limits of 200 mR/hr and 10 mR/hr respectively for this test specimen after performance of the 30 ft drop test.

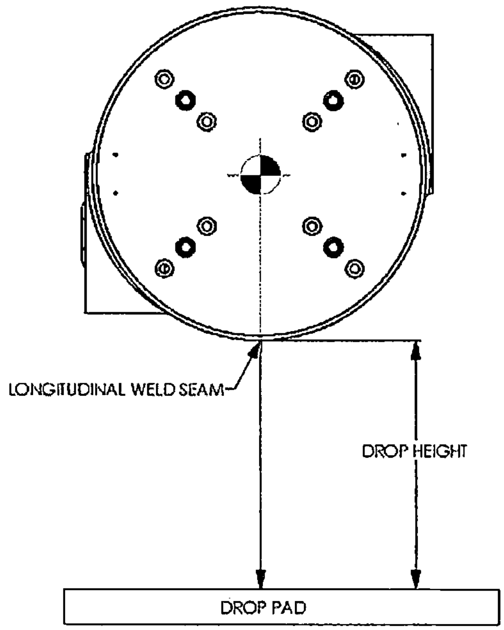

Figure 2.6c – 1.2 m (4 ft) Drop Orientation TP180C

2.6.7.4 Shell Edge Drop Orientation – Seam Hit

Test specimen TP180D was subjected to the 1.2 meter (4 foot) free drop in accordance with Test Plan 180 (Section 2.12). This orientation was selected in an attempt to fracture the shell longitudinally and/or fracture the edge welds. The orientation for this drop test is shown in Figure 2.6d.

The test specimen was dropped at an ambient temperature of +11°C (+51°F). Photographs of the drop orientation are provided in Test Plan 180 Report #1 (Section 2.12).

The end seam of the welded body was slightly deformed. There was no break in the weld seam. No damage was found on the source wire or the rear plate attachment bolts. There was no change in the source location within the package.

Based on the source location, the minimal damage produced to the test unit and a comparison of the pre and post radiation profiles of other test units with significantly more damage, it was determined that a post radiation profile of TP180D was not necessary. The condition of test unit TP180D after the 1.2 m (4 ft) drop test and the fact that the source location remained unchanged after the drop test is sufficient to demonstrate that the external radiation dose rates remained within the regulatory limits of 200 mR/hr and 10 mR/hr respectively.

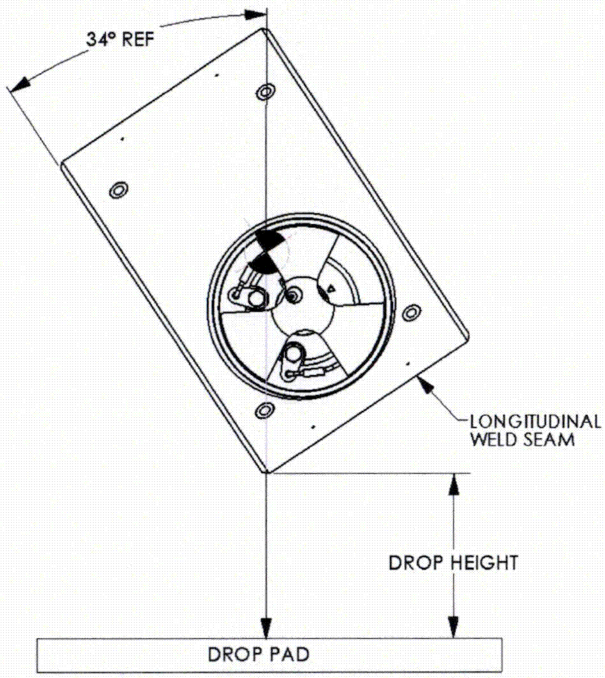

Figure 2.6d – 1.2 m (4 ft) Drop Orientation TP180D

2.6.7.5 Welded Body Drop Orientation – Top Surface Hit

Test specimen TP180E was subjected to the 1.2 meter (4 foot) free drop in accordance with Test Plan 180 (Section 2.12). This top body surface drop orientation of the 1.2 meter (4 foot) free drop was selected in an attempt to fracture the shield and/or shift the shield away from the source. The orientation for this drop test is shown in Figure 2.6e.

The test specimen was dropped at an ambient temperature of +11°C (+51°F). Photographs of the drop orientation are provided in Test Plan 180 Report #1 (Section 2.12).

The pins holding the lock cover sheared and allowed the black plastic dust cover to fall away from the rear plate assembly when the unit was moved. Examination of the rear plate lock assembly after the test revealed a slight twisting of the screws holding the selector ring retainer

to the assembly. No other damage was found on the welded body, source wire or rear plate attachment screws. The source location within the package changed slightly, however, a post test radiation profile showed that the external radiation dose rates remained within the regulatory limits of 200 mR/hr and 10 mR/hr respectively.

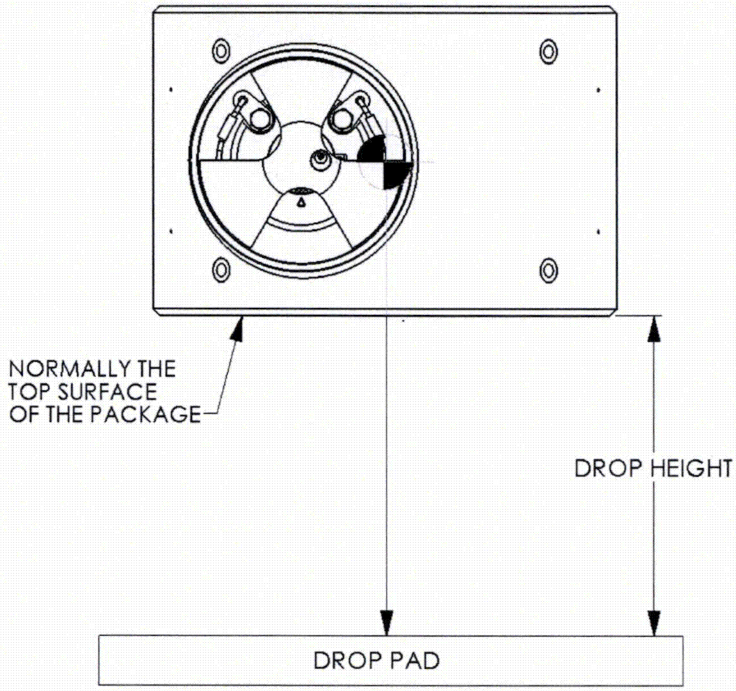

Figure 2.6e – 1.2 m (4 ft) Drop Orientation TP180E

2.6.7.6 Rear Plate, Dust Cover Modification, 867 Port Drop Orientation – Square Hit

Test specimen TP180J was subjected to the 1.2 meter (4 foot) free drop in accordance with Test Plan 213 (Section 2.12). The rear plate port orientation of the 1.2 meter (4 foot) free drop was selected based on earlier testing of the Sentry 330 and to attempt to cause damage, failure or malfunction to the source securing features of the rear plate assembly on the Model 867 package with the modified dust cover assembly. The modification to the dust cover incorporates a tungsten shield disc which causes the dust cover assembly to extend further beyond the port assembly than the previously tested Sentry 330 units.

Impact in this orientation could possibly cause a significant change in the source location which could alter the radiation measurements to unacceptable levels after testing. The protruding plastic cover may absorb more impact energy than the previous drop test specimens from Test Plan Report 180, but the protrusion will also transfer an instantaneous shock wave into other important rear plate components before the cover deforms enough to receive support from the outer rim of the welded stainless steel port tube enough to protect the bulk of the rear plate assembly.

The plastic cover was expected to deform considerably upon impact, pushing the shield disc into the package ultimately pressing into the threaded adaptor transferring the impact load into the selector ring retainer and possibly compromising the source locking pins. If the locking pins no longer capture the source assembly and a retaining cap is no longer present after the fire test then the source could move from the fully shielded position in the package. The orientation for this drop test is shown in Figure 2.6f.

The test specimen was dropped at an ambient temperature of +20°C (+68°F). Photographs of the drop orientation are provided in Test Plan 213 Report (Section 2.12).

The black plastic dust cover compressed into the port tube and the welded port tube on the opposite side of the package was slightly bent in towards the dust cover. No damage was found on the rear plate attachment bolts or the dust cover attachment pins. The source assembly remained secured in the package and the source location within the package remained unchanged after the test.

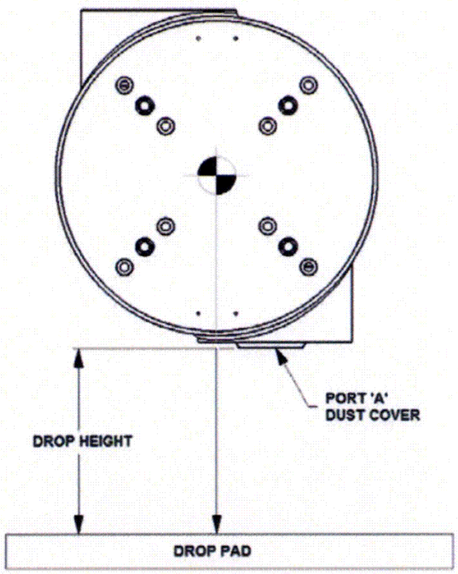

Figure 2.6f – 1.2 m (4 ft) Drop Orientation TP180J

Radiation measurements taken after this test showed no substantial increase in dose rates with no increase above 20% after testing with radiation profile results remaining within the regulatory limits of 200 mR/hr and 10 mR/hr at the surface and 1 meter from the package respectively.

2.6.7.7 Normal Transport Drop Test Results Summary Evaluation

Although all Test Plan 180 test specimens maintained source integrity and the radiation dose rates after drop testing remained within regulatory limits, the test results from TP180E raised concerns as to how the tested design would perform under the more damaging hypothetical accident condition drop tests.

The test results for TP180E caused the roll pins of the lock cover to shear away, this allowed the dust cover to fall away from the package. The lock cover is a sub component of the plastic trefoil shaped dust cover and is intended to provide protection to the source connector of the source wire assembly. Without the lock cover in place, a hit in the axial direction of the connector could drive the connector through the slot of the lock slide or cause the lock slide to fail which could adversely impact the source location in the package.

Since the hypothetical accident condition testing includes a 1 meter (3.3 ft) puncture drop after a 9 m (30 ft) drop test in this orientation, it was decided to modify the lock cover design to increase its robustness and assure satisfactory performance during the hypothetical accident condition transport testing. To address this issue, the test units used in the normal condition transport testing were modified as follows:

- The roll pins used to secure the lock cover assembly pins were increased in size and shape from 0.16 cm (0.062 inch) diameter pins to a heavy duty 0.48 cm (0.188 inch) diameter pin.

- The lock cover assembly pins were changed from a 0.71 cm (0.28 inch) diameter headless pin, to a 0.97 cm (0.38 inch) diameter headed pin. The head prevents the pins from detaching from the rear plate in the event the roll pins were to fail. (See Figure 2.6g).

Security-Related Information Figure Withheld Under 10 CFR 2.390

Original Lock Cover Design **Current Lock Cover Design**

Figure 2.6g – Lock Cover Design Modification
(Pin Changes are Highlighted)

In addition, the 4 screws used to secure the selector ring retainer in the lock assembly were found to be slightly twisted after the 1.2 m (4 ft) drop test on TP180E. It was also important to ensure the selector ring retaining mechanism remained intact and attached to the rear plate after the hypothetical accident condition transport testing. If the 4 screws attaching the selector ring retainer were to fail, the selector ring retainer would fall away from the package leaving the source unsecured. Therefore, it was decided to also redesign the selector ring retainer securing mechanism to ensure it remains intact and attached to the rear plate after the hypothetical accident condition drop testing.

To improve package performance, the test units used in the normal condition transport testing were also modified to make the following changes:

- The selector ring retainer was lengthened so that it was now able to pass through and extend beyond the back side of the rear plate assembly.
- The selector ring retainer was clamped in place on the back side of the rear plate in such a way that it cannot become detached unless the rear plate assembly mounting hardware is removed (see Figure 2.6h).

Security-Related Information Figure Withheld Under 10 CFR 2.390

Figure 2.6h – Lock Assembly Retention Design Modification
Old Design on Left. Modified Design on Right.
(Component Changes are Highlighted)

Test units, modified as described in this section, were tested under the Hypothetical Accident Condition 30 ft (9 m) drop test in the worst case orientations (see Section 2.7.1). Based on the results of the more damaging 30 ft drop testing and the test results from Test Plan 213 Report for the modified Model 867 dust cover assembly, it is concluded that the Model Sentry 110, Sentry 330 and 867 packages with all these modifications will meet the normal condition drop test requirements for transport as specified under 10 CFR 71.71(c)(7).

2.6.8 Corner Drop

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 or Stacking

The Models Sentry 110, Sentry 330 and 867 packages can be considered to be vertically oriented, cylindrical tubes that are capped at both ends. The basic configuration of the package measures 46 cm (18 inches) in diameter by 30.5 cm (12 inches) high. The cylindrical tube and end caps are 1 cm (3/8 inch) thick type 304 or 304L stainless steel. The minimum yield strength for this material is 30,000 psi.

Assuming a maximum package weight of 354 kg (780 lbs), the calculated compressive load would be 5 times this value or 1,769 kg (3,900 lbs). The vertically projected area of the package equals 1,645 cm^2 (255 in^2). This value, multiplied by 13 kPa (2 lb/in^2) produces a compression load of 231 kg (510 lbs) which is significantly less than the calculated compressive load equal to 5 times the maximum package weight. Therefore, compliance with the compression test requirements will be bounded by the load analysis for 5 times the maximum package weight.

During transport, the compressive load would be uniformly applied onto the top end cap, compressing the tube in the longitudinal direction. The maximum compressive stress for the test is calculated by dividing the tube's cross sectional area, 120 cm^2 (20 in^2), into the applied load. This results in a compressive stress on the tube's cross section of 195 psi.

A safety factor can be calculated by dividing the minimum yield strength of the tube material (30,000 psi) by the maximum resulting compressive stress (195 psi). This produces a safety factor of 154 which indicates that the package can support a load of 1,769 kg (3,900 lbs) for the test time of 24 hours with no structural loss.

The slenderness ratio of a 30.5 cm (12 inch) long by 46 cm (18 inch) diameter hollow cylinder establishes the package as a short column. For a short column, the strength limit of the tube material is the determining factor for assessing failure. In this case, it is demonstrated that buckling failure will not be a concern for these packages.

Based on this assessment, it is concluded that the Models Sentry 110, Sentry 330 and 867 will be able to withstand, without damage to the package integrity, the worst case compressive load as specified under 10 CFR 71.71(c)(9).

2.6.10 Penetration

Since the dust cover assemblies on the Models Sentry 110, Sentry 330 and 867 packages are identical, only 1 penetration test was performed to demonstrate compliance to this test requirement. Test specimen TP180A was subjected to a penetration test, in accordance with Test Plan 180 (see Section 2.12).

The penetration test targeted the dust cover area of the transport package. The dust cover protects the rear plate lock features from a direct hit from a penetration bar. The only damage option would be to attempt to penetrate the cover and/or the integral plunger lock.

The TP180A test specimen was tested at an ambient temperature of +18.9°C (+66.1°F) since the materials used in the dust cover and lock assemblies are not adversely affected by temperatures between -40°C to +38°C (-40°F to +100°F).

Photographs of the testing are provided in Test Plan 180 Report #1 (Section 2.12). The penetration bar impacted on the brass plunger lock of the black trefoil dust cover. Inspection following the test indicated that the bar hit as intended on the specimen, and produced a small dent on the plastic dust cover. The impact damaged the plunger lock such that the key could not be inserted into the lock after the test, however, the source remained secure in the shielded position and there was no loss of structural integrity or reduction of shielding efficiency as a result of the impact.

Based on this testing, it is concluded that the Models Sentry 110, Sentry 330 and 867 will be able to withstand, without damage to the package integrity, the penetration test specified under 10 CFR 71.71(c)(10).

2.7 Hypothetical Accident Conditions

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.

Four test specimens, serial numbers TP180A through TP180C and TP180E were built to the Basic transport configuration shown in Figure 1.2b for the Model Sentry 330 design. Two test specimens, serial numbers TP180D and TP180G, were built to the Standard Model Sentry 330 design, except that the plastic inserts were omitted from the test specimens (see Figure 2.7a). The lock cover and lock plate assemblies for all test units were modified as described under Section 2.6.7.6. These redesigns were intended to improve the overall package performance and were prompted by the test results from the normal transport drop testing.

An additional test specimen, TP180J, was assembled to the Model 867 package configuration with the modified dust cover assembly design incorporating a tungsten shield insert. This test specimen was tested under Test Plan 213 (see Section 2.12).

The TP180D and TP180G test specimen configuration was a special configuration that would not normally be used in transport, however this standard configuration without the plastic inserts present represented the worst case impact damage to the body weldment for any of the Standard package configurations. This test specimen configuration demonstrated the optional nature of the plastic inserts since the Standard configuration will still maintain transport container compliance even in the case where the plastic inserts may be damaged or missing from the package.

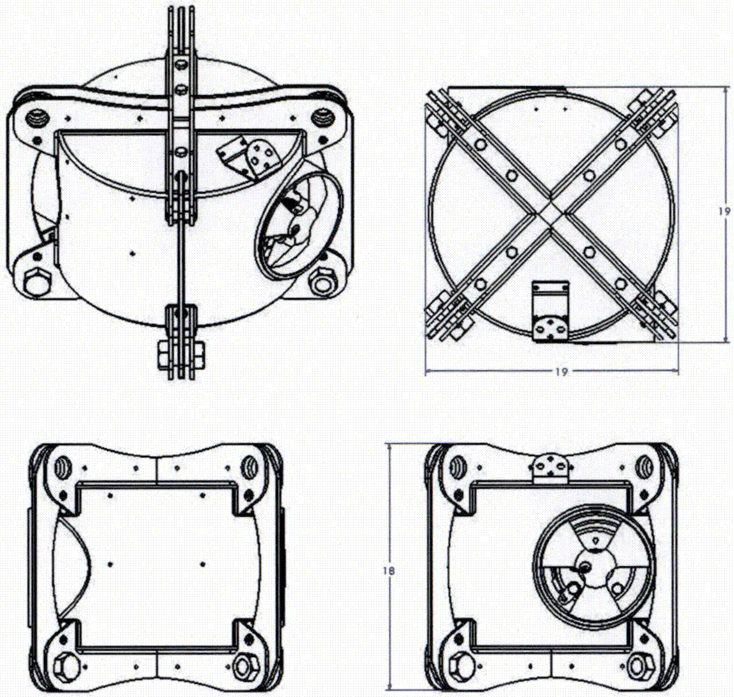

Figure 2.7a – Transport Package Special Configuration – Test Specimen TP180D & TP180G

The statements under Section 2.6.7 (Free Drop test for Normal Transport) regarding package similarities, drop orientations, weight adjustments and test specimen temperature prior to testing are also applicable for the Hypothetical accident drop testing performed for these packages.

Based on design similarities, the Models Sentry 110 and 867 packages will be expected to perform as well if not better than the Model Sentry 330 test units evaluated under this section. The only significant difference between the Model 867 and Model Sentry 330 lock plate assemblies was tested by test specimen TP180J under Test Plan 213. All other testing performed with the Sentry 330 package specimens will not significantly impact the Model 867's ability to meet the Hypothetical accident condition drop test conditions and the Model 867 package performance can be bounded by the testing of the Model 867 unit under Test Plan 213 and the additional Model Sentry 330 test results and evaluations.

The test sequence as specified in 10 CFR 71.73 was determined to be the order which would result in the maximum damage to the package, considering the subsequent application of the fire test. The damaged induced by the 9 m (30 ft) drop impact will make the package vulnerable to containment related damage during the puncture test.

Performing the puncture test before the 9 m (30 ft) drop test will produce minimal damage to the unit and have less potential to adversely affect source containment than performing the puncture test after inducing damage in the 9 m (30 ft) drop test.

The package is only vulnerable to shielding degradation during the thermal test if the body weldment is breached in either the 9 m (30 ft) drop test or 1 m (1.2 ft) puncture tests. Therefore these tests must be performed first to determine if the package will be potentially vulnerable to shield degradation during the thermal test conditions. Based on this assessment, the test sequence listed in 10 CFR 71.73 will produce the worst case potential damage to the containment system.

2.7.1 Free Drop

2.7.1.1 End Drop

a. Flat Body Top Drop Orientation – TP180E & TP180G

Test specimen TP180E was subjected to the 9 m (30 foot) free drop in accordance with Test Plan 180 (Section 2.12). This drop orientation was selected because of its potential to fracture the shield material, cause a shift in the shield position with possible damage to and/or movement of the source wire from the shielded position. The orientation for this drop test is shown in Figure 2.7b.

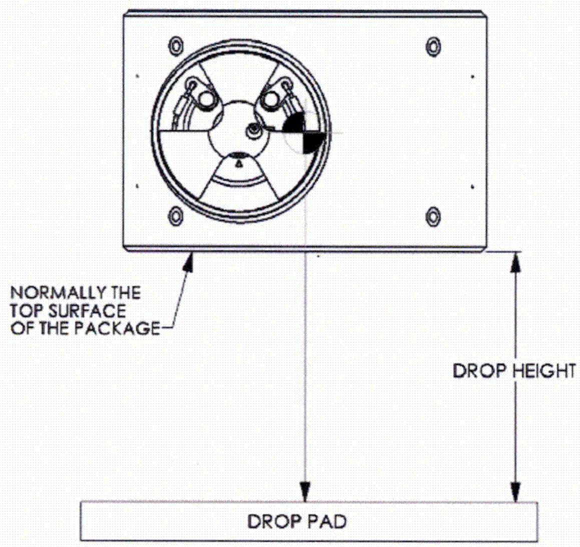

Figure 2.7b – 9 m (30 ft) Drop Orientation TP180E & Second Drop Orientation TP180G

The test specimen was dropped at an ambient temperature of +9°C (+48°F) prior to the drop test. Photographs of the drop orientation are provided in Test Plan 180 Report #2 (Section 2.12).

The impact in the drop appeared as expected during the test, but a review of the drop test video showed the test specimen tilted slightly just before impact, hitting the corner of the package before rotating onto the flat endplate. The impact caused a dent to the corner of the package which was further confirmation of the initial impact location. After the test, the source location moved about 0.16 cm (1/16 inch) towards the front plate end of the

package. The impact of test unit TP180E did not achieve the intended impact orientation, but is more representative of a slap-down, oblique impact than the intended top surface drop.

Due to the deformation caused by the impact of test unit TP180E, it was determined that a second drop of this test unit for the 9 m (30 ft) top surface drop was not advisable as the deformation could interfere with the intended impact.

A decision was made to perform this drop orientation on another test specimen, TP180G. This test specimen, TP180G, was previously dropped in another orientation from 9 m (30ft), but appeared to be in excellent condition and acceptable for a second drop in the top end drop orientation. Before TP180G was dropped the second time, the handling ribs were removed from the specimen to convert it to the basic configuration. (Note: This drop test orientation became the second drop test performed on test unit TP180G.) Test specimen TP180G was dropped as intended, hitting squarely on the flat top surface of the welded body end plate

Post test inspections for test unit TP180E was performed after performance of the 1 m (3.3 ft) puncture test (see Section 2.7.2). The 9 m (30 ft) drop test, which was essentially an oblique, slap down drop orientation, did not create an opening in the package exterior. Radiation profile measurements taken after the puncture testing showed no appreciable elevation in dose levels compared to measurements taken before testing. The slight measurement difference is attributed to a minor shift in the shield relative to the exterior of the package and variation in the accuracy of the measuring equipment (±10%).

b. Flat Body Bottom Drop Orientation – TP180G

Test specimen TP180G was subjected twice to the 9 m (30 foot) free drop in accordance with Test Plan 180 (Section 2.12). The first drop test performed for TP180G was made with the handling ribs attached and was for the bottom surface drop orientation (see Figure 2.7c). This drop orientation was selected to demonstrate that that plastic inserts in the handling ribs were optional and to demonstrate that the handling ribs of the Standard configuration will be less damaging to the package than the Basic configurations tested.

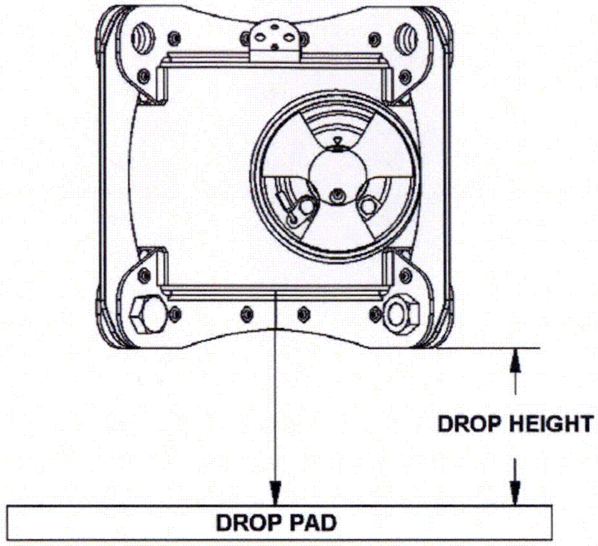

Figure 2.7c – 9 m (30 ft) 1st Drop Orientation TP180G

The test specimen was dropped at an ambient temperature of +9°C (+48°F) prior to the drop test. Photographs of the drop orientation are provided in Test Plan 180 Report #2 (Section 2.12)

The test unit rotated slightly during the drop causing two of the ribs to hit first on impact then immediately impacting the rest of the bottom rib surfaces of the package. The impact broke one load pin and four of the bolts used to assemble the ribs. Some of the ribs were bent and cracked. The bottom ribs were slightly compressed into the bottom endplate of the package causing local deformations and shallow cuts. After the test, the source location moved about 0.15 cm (0.06 inch) towards the rear plate end of the package.

The second 9 m (30 ft) drop for TP180G was performed after removal of the rib assemblies. This drop orientation was the top surface flat body hit initially attempted on test unit TP180E (see Figure 2.7b). The test specimen was dropped at an ambient temperature of +19°C (+66°F). Photographs of the drop orientation are provided in Test Plan 180 Report #2 (Section 2.12)

This impact hit squarely on the top endplate surface causing no obvious external damage to the body weldment. The impact did cause the brass shaft of the front plate outlet port knob to fracture. The fracture caused the knob to be completely removed from the package.

Without the front knob in place, the front plate rotor is allowed to turn freely and could align the port shield into the unshielded position under worst case conditions. This movement of the port shield will increase radiation dose levels locally on the surface of the package and slightly at 1 meter from the surface of the package due to scatter radiation from the source tube.

Post test inspections for test unit TP180G was performed after performance of the 9 m (30 ft) drop tests. The first 9 m (30 ft) drop test was a flat bottom drop on the handling rib assembly to demonstrate the impact limitation effect of the handling ribs as well as the optional nature of the plastic inserts used in the handling ribs as these components are not necessary to ensure package compliance or integrity during transport. The second 9 m (30 ft) drop test was a flat drop on the top surface of the package after removal of the handling rib assembly.

Radiation profile measurements taken after the 9 m (30 ft) drop testing showed an increase in radiation dose at the surface and one meter from the surface of the package due to the loss of the port shield in the front plate assembly. The increased radiation dose rates were less than 550 mR/hr at the surface of the package and less than 2.5 mR/hr at one meter from the surface of the package. These radiation levels are well within the maximum allowable limit of 1 R/hr at 1 meter from the package surface required under the regulations.

2.7.1.2 Side Drop

a. Rear Plate (Lock Assembly Side) Port Drop Orientation – Square Hit

Test specimen TP180A was subjected twice to the 9 m (30 foot) free drop in accordance with Test Plan 180 (Section 2.12). The rear plate port orientation of the 9 m (30 foot) free drop was selected because of its potential to cause a shift in the shield position with possible damage to the source wire. In addition, it was possible that this drop orientation could cause a failure/break in the rear plate attachment bolts which could impact the source security in the package. The orientation for this drop test is shown in Figure 2.7c.

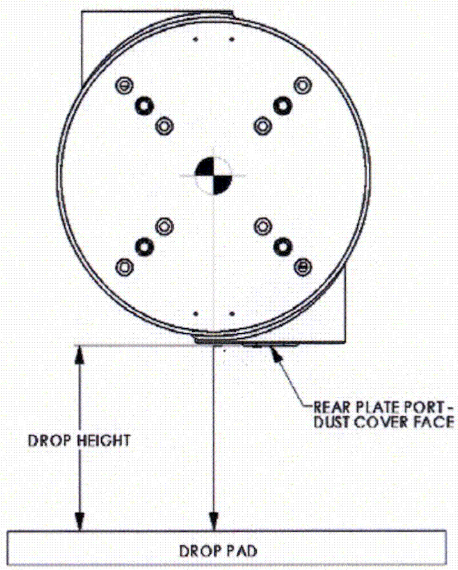

Figure 2.7c – 9 m (30 ft) Drop Orientation TP180A

The test specimen was dropped at an ambient temperature of +53°F. Photographs of the drop orientation are provided in Test Plan 180 Report #2 (Section 2.12). The impact in the first drop did not appear to hit directly on the face of the dust cover protecting the rear plate, however, this impact did cause the corner of the package and edge of the rear plate access port to slightly deform into the package.

The second 9 m (30 ft) drop hit the dust cover as planned. This impact caused additional deformation to the access port, produced a fracture through the dust cover and compressed the plunger lock into the rear plate assembly. The source assembly remained secured in the package and the source location within the package remained unchanged after the test.

Post test inspections for this unit were performed after performance of the 1 m (3.3 ft) puncture test (see Section 2.7.2). The 9 m (30 ft) drop tests did not create an opening in the package exterior. Radiation profile measurements taken after the puncture test showed no appreciable elevation in dose levels compared to measurements taken before testing. The slight measurement difference is attributed to a minor shift in the shield relative to the exterior of the package and variation in the accuracy of the measuring equipment (±10%).

b. Body Weldment Side Drop Orientation – Package Weld Seam Hit

Test specimen TP180C was subjected twice to the 9 m (30 foot) free drop in accordance with Test Plan 180 (Section 2.12). The intended drop orientation was a side impact on the weld seam. This orientation was selected because of its potential to fracture the shell seam weld and/or shift the shield away from the source. The orientation for this drop test is shown in Figure 2.7d.

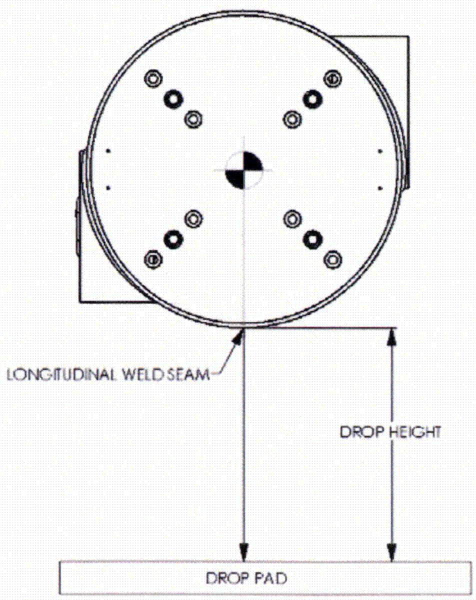

Figure 2.7d – 9 m (30 ft) Drop Orientation TP180C – Side Weld Seam Hit

The test specimen was dropped at an ambient temperature of +8°C (+47°F). Photographs of the drop orientation are provided in Test Plan 180 Report #2 (Section 2.12). The test unit rotated slightly during the drop and impacted on the corner weld at the weld seam intersection with the longitudinal weld of the package. This impact location was originally intended as the impact location for test specimen TP180D which is an oblique package impact (see Figure 2.7g). Results of this test unit drop will be concluded in Section 2.7.1.4 since the drop orientation for the first drop of TP180C meets the impact orientation originally intended for TP180D.

A second 9 m (30 ft) drop test was performed for TP180C. The second drop hit squarely on the longitudinal weld seam of the package side as planned (see Figure 2.7d). This impact caused the curved surface of the body to flatten along the full length of the longitudinal weld seam, but no break or breach of the body weldment occurred. The source assembly remained secured in the package and the source location within the package remained unchanged after the test.

Post test inspections for this unit were performed after performance of the 1 m (3.3 ft) puncture test (see Section 2.7.2). The 9 m (30 ft) drop tests did not create an opening in the package exterior. Radiation profile measurements taken after the puncture test showed no appreciable elevation in dose levels compared to measurements taken before testing. The slight measurement difference is attributed to a minor shift in the shield relative to the exterior of the package and variation in the accuracy of the measuring equipment (±10%).

c. Rear Plate (Lock Assembly Side) Port Drop Orientation – Square Hit

Test specimen TP180D was subjected to the 9 m (30 foot) free drop in accordance with Test Plan 195 (Section 2.12). The rear plate port orientation of the 9 m (30 foot) free drop was selected because of its potential to cause a shift in the shield position with possible damage to the source wire. In addition, it was possible that this drop orientation could cause a failure/break in the rear plate attachment bolts which could affect the source security in the package. The orientation for this drop test is shown in Figure 2.7e.

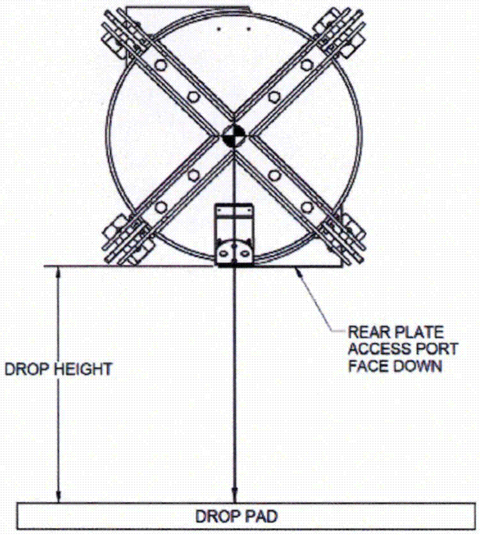

Figure 2.7e – 9 m (30 ft) Drop Orientation TP180D – Lock Port Side Hit

The test specimen was dropped at an ambient temperature of +90°F. Photographs of the drop orientation are provided in Report - Test Plan 195 (Section 2.12). The impact hit directly on the face of the dust cover protecting the rear plate and protruding handling rib assemblies.

The 9 m (30 ft) drop hit the dust cover as planned. This impact caused slight deformation to the access port and deformed the handling rib assemblies at the rear plate access port side of the package. The source assembly remained secured in the package and the source location within the package remained unchanged after the test.

Post test inspections on this specimen were performed after the 1 m (3.3 ft) puncture test (see Section 2.12). The 9 m (30 ft) drop tests and puncture drop did not create an opening in the welded body. Radiation profile measurements taken after the puncture test showed no appreciable elevation in dose levels compared to measurements taken before testing. The slight measurement difference is attributed to a minor shift in the shield relative to the exterior of the package and variation in the accuracy of the measuring equipment (±10%).

f. *867 Rear Plate (Lock Assembly Side) Port Drop Orientation – Square Hit*

Test specimen TP180J was subjected twice to the 9 m (30 foot) free drop in accordance with Test Plan 213 (Section 2.12). The rear plate port orientation of the 9 meter (30 foot) free drop was selected based on earlier testing of the Sentry 330 and to attempt to cause damage, failure or malfunction to the source securing features of the rear plate assembly on the Model 867 package with the modified dust cover assembly. The modification to the dust cover incorporates a tungsten shield disc which causes the dust cover assembly to extend further beyond the port assembly than the previously tested Sentry 330 units. The orientation for this drop test is shown in Figure 2.7f.

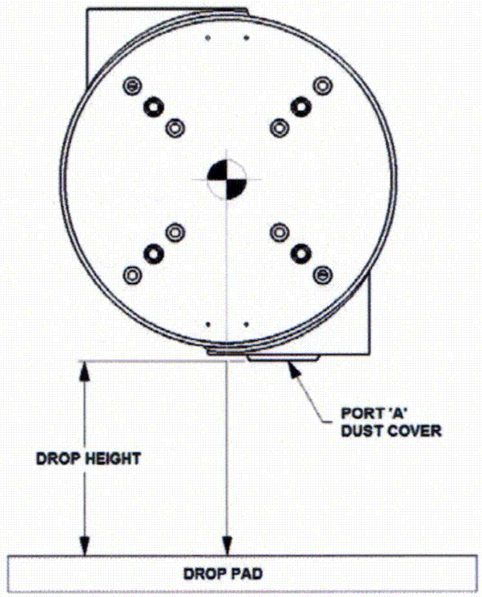

Figure 2.7f – 9 m (30 ft) Drop Orientation TP180J

The test specimen was dropped at an ambient temperature of +31°C (+88°F). Photographs of the drop orientation are provided in Test Plan 213 Report (Section 2.12). The test specimen rotated slightly during descent in the first drop and the impact did not appear to hit directly on the face of the dust cover as intended. This impact deformed the body weldment edge seam inward about 2 inches causing an 8 inch wide flat with a 2 inch high outward bulge on the top surface of the body weldment. The seam weld remained sealed and intact.

A second 9 m (30 ft) drop was attempted to hit the dust cover as planned. The test specimen again rotated during descent and appeared to hit the roughly the same edge surface as in the first impact. This impact caused additional deformation to the edge seam, increasing it about 1 inch outward but the seam weld remained sealed and intact. From witness marks on the drop test pad, the second impact was determined to be a glancing blow to the dust cover before hitting the edge seam again.

Post test inspections for this unit were performed after performance of the 1 m (3.3 ft) puncture test (see Section 2.7.2). The 9 m (30 ft) drop tests did not create an opening in the package exterior. Radiation profile measurements taken after the puncture test showed no appreciable elevation in dose levels compared to measurements taken before testing. The slight measurement difference is attributed to a minor shift in the shield relative to the exterior of the package and variation in the accuracy of the measuring equipment (±10%).

2.7.1.3 Corner Drop

Corner Package Drop Orientation – Port Tube Hit

Test specimen TP180B was subjected to the 9 m (30 foot) free drop in accordance with Test Plan 180 (Section 2.12). This drop orientation was selected because of its potential to deform the port enough to break the rear plate attachment bolts or other important lock components. The orientation for this drop test is shown in Figure 2.7g.

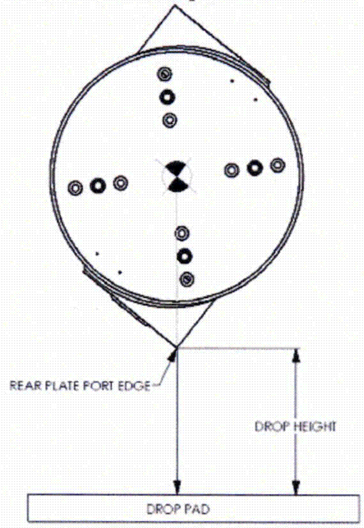

Figure 2.7g – 9 m (30 ft) First Drop Orientation TP180B – Corner Package Port Tube Hit

The test specimen was dropped at an ambient temperature of +8°C (+47°F). Photographs of the drop orientation are provided in Test Plan 180 Report #2 (Section 2.12). The test unit impacted directly on the protruding edge of the rear plate access port tube as planned.

This impact caused the access port tube to flatten into the access port, compressing the dust cover against the rear plate assembly. The source assembly remained secured in the package but the source location moved about 0.06 cm (1/16 inch) towards the rear plate end of the package.

Post test inspections for this unit were performed after performance of the 1 m (3.3 ft) puncture test (see Section 2.7.2). The 9 m (30 ft) drop test did not create an opening in the package exterior. Radiation profile measurements taken after the puncture test showed no appreciable elevation in dose levels compared to measurements taken before testing. The slight measurement difference is attributed to a minor shift in the shield relative to the exterior of the package and variation in the accuracy of the measuring equipment (±10%).

2.7.1.4 Oblique Drops

Slap Down Drop Orientation – Weld Seam Hit

During the first 9 m (30 ft) drop of test specimen TP180C, the package rotated slightly and initial impact for this test unit met the impact conditions intended for TP180D. The corner body drop on the package weld seam orientation was selected because of its potential to fracture the shell longitudinal and end plate welds upon the initial and secondary slap down impacts. The orientation for this drop test is shown in Figure 2.7h.

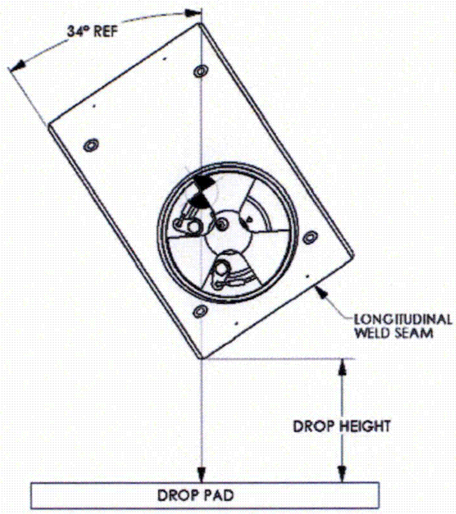

Figure 2.7h – 9 m (30 ft) First Drop Orientation TP180C – Corner Package Weld Seam Hit

The test specimen was dropped at an ambient temperature of +8°C (+47°F). Photographs of the drop orientation are provided in Test Plan 180 Report #2 (Section 2.12). The test unit impacted on the corner weld at the weld seam intersection with the longitudinal weld of the package.

This impact caused localized deformation and flattening to the circular corner of the package. The source assembly remained secured in the package but the source location moved about 0.08 cm (1/32 inch) towards the rear plate end of the package.

Post test inspections for this unit were performed after performance of the 1 m (3.3 ft) puncture test (see Section 2.7.2). The 9 m (30 ft) drop tests did not create an opening in the package exterior. Radiation profile measurements taken after the puncture test showed no appreciable elevation in dose levels compared to measurements taken before testing. The slight measurement difference is attributed to a minor shift in the shield relative to the exterior of the package and variation in the accuracy of the measuring equipment (±10%).

2.7.1.5 Summary of Results

As demonstrated in Test Plan 180 Report #2, Test Plan 213 Report and described and assessed in sections 2.7.1.1 through 2.7.1.4, the Models Sentry 110, Sentry 330 and 867 in both the Basic and Standard package constructions (including the standard construction without the optional plastic rib assembly inserts) satisfies the hypothetical accident condition 9 m (30 ft) drop test requirements of 10 CFR 71.73(c)(1). Testing of the test specimens continued as described in Section 2.7.3 of this SAR for the Puncture test requirements of 10 CFR 71.73(c)(3).

2.7.2 Crush

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

2.7.3 Puncture

Justification for all test unit puncture orientations are included in Test Plan 180, Test Plan 180 Addendum, Test Plan 180 Report #2 and Test Plan 213 (see Appendix 2.12). The orientations were determined following the 9 meter drop tests and were selected based on an assessment as to which orientation would impart the most damage to each specimen and results of the normal condition of transport drop testing.

2.7.3.1 Puncture test of TP180A and TP180B

This test specimens were dropped 1.1 m (3.6 ft) onto the fractured dust cover of the rear plate assembly at an angle as shown in Figure 2.7i. This drop orientation was selected because of its potential to pry off the lock plate or its attachment hex bolts from the package causing the source to be removed from its shield.

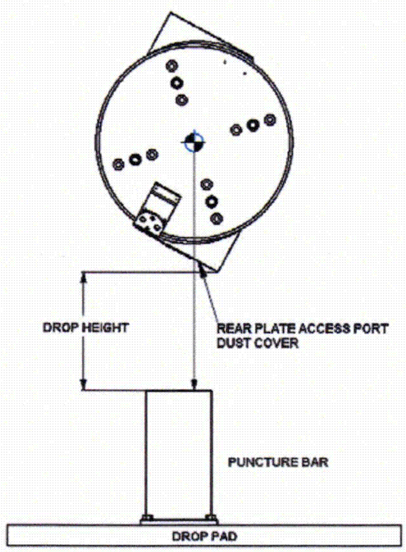

Figure 2.7i – 1 m Drop Orientation TP180A and TP180B

The test specimen TP180A was dropped at an ambient temperature of +6°C (+42°F) prior to the 1.1 m (3.6 ft) puncture test. Photographs of the drop orientation and resultant damage are provided in Test Plan 180 Report #2 (Section 2.12). The test specimen was dropped onto the puncture bar causing the dust cover to tear off about 1/3 of the cover and caused additional cracking to the portion of the dust cover that remained on the package.

All the rear plate hardware remained intact after the drop. The source assembly remained secured in the package and the source location within the package moved 0.32 cm (1/8 inch) towards the front plate end of the package due to a shift in the shield location towards the rear plate side of the package.

The puncture test did not create an opening in the package exterior. Radiation profile measurements taken after the puncture test showed no appreciable elevation in dose levels compared to measurements taken before testing. The slight measurement difference is attributed to a minor shift in the shield relative to the exterior of the package and variation in the accuracy of the measuring equipment (±10%).

The test specimen TP180B was dropped at an ambient temperature of +7°C (+44°F) prior to the 1.1 m (3.6 ft) puncture test. Photographs of the drop orientation and resultant damage are provided in Test Plan 180 Report #2 (Section 2.12). The test specimen was dropped onto the puncture bar causing no visible additional damage to the unit.

Post test disassembly and inspection revealed the plastic dust cover to be wedged in place by the bent over port flange and the lock cover pins were sheared off. Inspection of the lock plate revealed the plate and securing bolts remained intact, but the lock assembly could not be unlocked to release the source wire assembly normally.

The puncture test did not create an opening in the package exterior. Radiation profile measurements taken after the puncture test showed no appreciable elevation in dose levels compared to measurements taken before testing. The slight measurement difference is attributed to a minor shift in the shield relative to the exterior of the package and variation in the accuracy of the measuring equipment (±10%).

2.7.3.2 Puncture test of TP180C

This test specimen was dropped 1.1 m (3.6 ft) onto the corner and longitudinal weld seams as shown in Figure 2.7j. This drop orientation was selected in an attempt to break open the welded shell body and expose the foam fill.

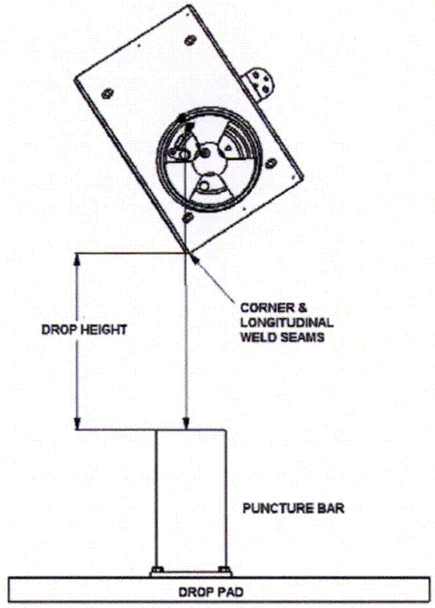

Figure 2.7j – 1 m Drop Orientation TP180C

The test specimen TP180C was dropped at an ambient temperature of +7°C (+44°F) prior to the 1.1 m (3.6 ft) puncture test. Photographs of the drop orientation and resultant damage are provided in Test Plan 180 Report #2 (Section 2.12).

After the drop, the test specimen inspection revealed only superficial contact marks at the corner. No weld seam breach was created. Post test disassembly and inspection confirmed all lock plate hardware remained intact, and the lock functioned normally.

During the post test examination, a shift in the shield within the package of approximately 0.3 inches towards the longitudinal weld seam was noticed. The shift resulted in fracturing the tip of the source tube at the rear access port end. The source assembly remained secured in the package with no movement of the source location within the package.

Radiation profile measurements taken after the puncture test showed no appreciable elevation in dose levels compared to measurements taken before testing. The slight measurement difference is attributed to a minor shift in the shield relative to the exterior of the package and variation in the accuracy of the measuring equipment (±10%).

2.7.3.3 Puncture test of TP180E

This test specimen was dropped 1.1 m (3.6 ft) onto the lock plate of the package. This drop orientation was selected because of its potential to push the source connector through the lock slide causing the source to be removed from its shielded position. The orientation for this drop test is shown in Figure 2.7k.

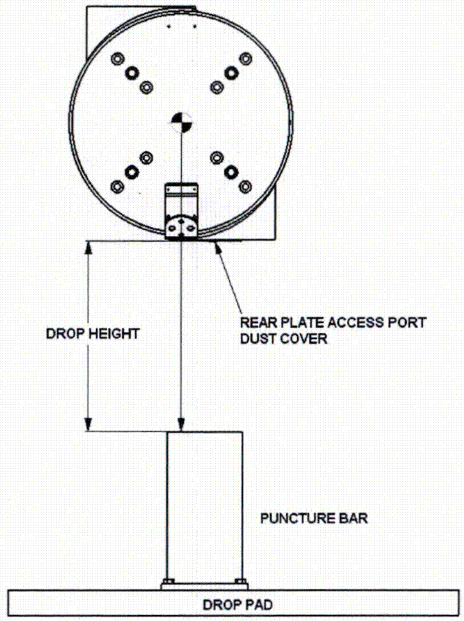

Figure 2.7k – 1 m Drop Orientation TP180E

The test specimen was dropped at an ambient temperature of +9°C (+48°F) prior to the 1.1 m (3.6 ft) puncture test. Photographs of the drop orientation and resultant damage are provided in Test Plan 180 Report #2 (Section 2.12).

This puncture test was performed twice from 3.6 feet in the same orientation since the test unit appeared to miss the target. The second drop test impacted as intended. Resultant damage caused some deformation to the lock plate port and only a superficial contact scratch to the dust cover. No failure was found after the puncture tests.

The source assembly remained secured in the package with a movement of approximately 0.16 cm (1/16 inch). All lock plate hardware remained intact. Radiation profile measurements taken after the puncture test showed no appreciable elevation in dose levels compared to measurements taken before testing. The slight measurement difference is attributed to a minor shift in the shield relative to the exterior of the package and variation in the accuracy of the measuring equipment (±10%).

2.7.3.4 Puncture test of TP180J

This test specimen was dropped 1.1 m (3.6 ft) onto the dust cover of a Model 867 package. This drop orientation was selected because of its potential to induce failure in the source securing mechanism of the rear plate assembly. The impact surface is the protruding face of the dust cover assembly extending beyond the rim of the rear plate access port. The orientation for this drop test is shown in Figure 2.7l.

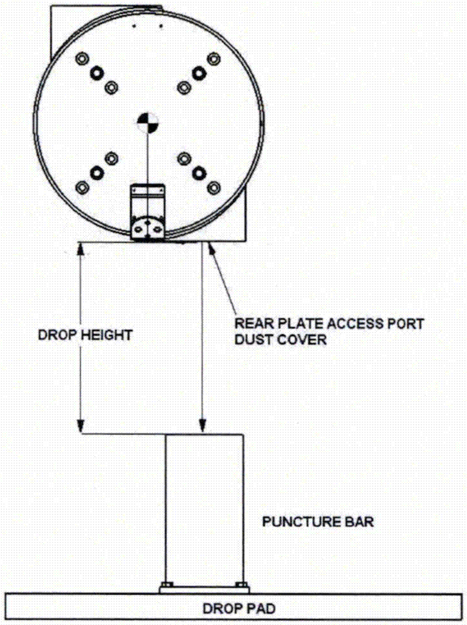

Figure 2.71 – 1 m Drop Orientation TP180J

The test specimen was dropped at an ambient temperature of +31°C (+88°F) prior to the 1.1 m (3.6 ft) puncture test. Photographs of the drop orientation and resultant damage are provided in Test Plan 213 Report (Section 2.12).

The test specimen impacted as intended hitting squarely on the top surface of the rigidly mounted puncture billet. The port tube rim did not appear to contact the billet upon impact, leaving the entire impact being fully applied to the dust cover assembly. Resultant damage caused compression of the dust cover assembly into the port but no significant damage. A portion of the dust cover had to be cut to allow removal of the assembly from the specimen. Further examination revealed the spacer ring in the cover had crushed axially but remained retained in the cover along with the cover shield. The brass lock was damaged preventing key insertion. The brass lock was drilled out to allow removal of the cover. The lock cover was completely intact and remained in place, the rear plate assembly remained securely attached to the unit and the source assembly remained in its fully shielded position within the package.

Radiation profile measurements were taken after the puncture test without the benefit of the dust cover assembly with the cover shield since the cover would melt or burn away in the thermal test. Radiation measurements taken after testing resulted in no appreciable elevation in dose levels compared to measurements taken before testing. The slight measurement difference is attributed to a minor shift in the shield relative to the exterior of the package and variation in the accuracy of the measuring equipment (±10%).

2.7.3.5 Puncture test of TP180G

No puncture test was performed on this test unit. The majority of the damage induced during the 9 m (30 ft) drops was superficial in nature and was less severe than was seen on other test units that did undergo subsequent puncture testing (e.g., lower potential to breach the body weldment than was seen on TP180C and less potential to damage or move the radioactive source than was seen on TP180A, TP180B and TP180E).

The loss of the front plate knob increased the radiation dose rates from the package (see Section 2.7.1.1b) but the increase was well within acceptable regulatory limits. Any further damage to the front plate assembly would not change the radiation dose levels on or around the package since the rotor shield has already been removed from the package during the 30 ft drop tests. Therefore, performance of the puncture test for TP180G was unnecessary since unit compliance is bounded by the 9 m (30 ft) drop results and damage induced on the other test units from Test Plan 180 Report #2.

2.7.3.6 Summary of Results

As demonstrated in Test Plan 180 Report #2 and Test Plan 213 Report and described and assessed in sections 2.7.3.1 through 2.7.1.5, the Models Sentry 110, Sentry 330 and 867 in both the Basic and Standard package constructions (including the standard construction without the optional plastic rib assembly inserts) satisfies the hypothetical accident condition 1 m (40 in) drop test requirements of 10 CFR 71.73(c)(3).

2.7.4 Thermal

The thermal test was not performed. Compliance for this requirement is assessed in this Section. The assessment demonstrates that the thermal test would not be sufficient to weaken the package and cause its failure under the final profile criteria.

Review of the condition of the test specimens after the drop tests suggests the fire test would have no effect on the resulting radiation measurements if the thermal test was performed. This is justified based on the condition of the test specimens after the drop tests and the properties of the materials used to secure and shield the source within the specimens.

Because no damage occurred during the Hypothetical Accident Conditions of Transport Tests that could result in oxidation of the depleted uranium shield, thermal testing was not performed on any of the test specimens. Specifically, the lock assemblies remained secured and there were no openings in the transport package welded body that could result in oxidation of the depleted uranium shield.

2.7.4.1 Summary of Pressures and Temperatures

Table 2.7a: Summary Table of Temperatures

Surface Temperature Condition	Model Sentry 110, Sentry 330 and 867 Packages
Fire Test During	800°C (1,472°F)
Post-Fire (Maximum Temperature)	800°C (1,472°F)

These containers are vented to atmosphere. As such, no pressure will build up in the units 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
Sentry 110	0	0 psig
Sentry 330	0	0 psig
867	0	0 psig

2.7.4.2 Differential Thermal Expansion

Differential thermal expansion of the outer stainless steel shell circumference during the fire test is approximated by considering the extreme temperature differential of -40°C to +800° C (-40°F to +1,472° F):

$$E = \pi D \alpha \Delta T$$

Where: D = Diameter of the outer shell (18 in)
α = Coefficient of thermal expansion
ΔT = Temperature differential (from -40°F to 1,472°F)

Substituting we get: $E = \pi$ (18 in)(9.9μin/in°F)(1,512°F) = 0.85 in

An expansion of 0.85 inches to the circumference changes the diameter of the outer shell from 18 to 18.27 inches. This change does not create thermal stress in the structure since it can be considered unrestrained.

2.7.4.3 Stress Calculations

The exterior and support structure of the SENTRY transport package in all configurations is not restrained, is open to atmospheric pressure, and is constructed on the same stainless steel material. For these reasons, no thermal stress exists in the exterior or support structure of the package when subjected to thermal differentials caused by the hypothetical accident condition fire test.

The design clearance between mating components of different materials is sufficient enough to prevent a press fit stress condition caused by a temperature change of 800°C (1,472°F).

2.7.4.4 Comparision of Allowable Stresses

Since there are no thermal stresses in the package structure, there is no need to compare the calculated thermal stresses with the materials allowable stress.

2.7.4.5 Additional Thermal Analysis

The condition of all test specimens after being subjected to the 9 m (30 foot) free drop and 1 m (40 inch) puncture tests indicate the transport packages are capable of withstanding the thermal test without the loss of source security or shielding effectiveness. The small tungsten shield disk present in the Model 867 dust cover assembly has been demonstrated, by radiation profiles after testing on specimen TP180J with the shield disk omitted, to have no impact on the package compliance to the dose rate requirements after testing. Further, the damage inflicted on every test specimen showed no unintentional opening in the welded body to allow charred foam to fall away from the package and allow circulating air around the shield to cause depleted uranium oxidation during a thermal test. Since there are small fastener holes and fit clearance gaps around the welded body, there will be no build-up of gas pressure caused by the decomposition of the polyurethane foam at elevated temperatures.

The circulation of air or oxygen through the package has been shown empirically to be the primary contributing factor in the oxidation of depleted uranium shields during thermal testing (see Section 2.12). Further analysis against shield degradation due to oxidation is contained in Section 2.7.4.5(a).

Without the possibility of gross shield oxidation, and subsequent shield degradation, failure under the thermal test conditions would be limited to a mechanical degradation of the packages' shield support structure. The shield support structure for these transport packages is comprised of components constructed of welded 304/304L stainless steel.

The internal shield support structure for all test specimens was intact and completely functional. The shield is completely captured within the welded body at the top and bottom ends, as well as the welded access ports. All source assemblies remained secure in the shielded position after all testing.

The lock assemblies remained intact, attached to the package and continued to secure the source assembly in the shielded position within the package. The source securing components of the lock assemblies consists of the attachment plate, lock slide and sleeve (or lock pins for the Model 867), selector ring, selector ring retainer, four ½-13 bolts and one 5/16-18 screw.

(a) Oxidation of Depleted Uranium (DU) Shielding

Significant oxidation of the depleted uranium does not occur if there is insufficient flow of oxygen available to the shield. Two major contributing factors to limiting this oxidation are the oxygen inhibitive nature of charred polyurethane foam and the packages' ability to contain the foam once charred. This has been demonstrated by thermal testing conducted by QSA Global Inc. in support of previous Type B package submissions described in the following paragraphs.

Under Test Plan Report 72-S2 (Section 2.12), in support of Certificate of Compliance number USA/9035/B(U) for the Model 680-OP Series, camera s/n B198 was subjected to thermal testing. Before testing, the unit was intact and essentially undamaged with no gaps between mating surfaces. After the 30 foot and puncture drop tests, ¾ inch long by 1/16 inch wide gaps were present on both sides of the unit at the side plate/shell interface. Thermocouple readings showed temperatures of up to 1,000°C on the unit and over 900°C within the depleted uranium shield. The foam was completely pyrolized but was contained within the unit. No oxidation of the shield occurred and the unit passed final profile at 0.33 R/hr at one meter.

Under Test Plan 80 Report (Section 2.12), in support of Certificate of Compliance number USA/9269/B(U) for the Model 650L, test specimen TP80(B) was subjected to thermal testing. The drop tests (30 foot and puncture) caused the outer shell to split completely open and the inner shell to crack, creating a 3 inch long by ½ inch wide gap. Subsequent thermal testing caused pyrolization of all the foam and vaporization in the area of the gap. Some minor oxidation of the shield was also noted. Thermocouples recorded temperatures in the shield of over 900°C and close to 1,000°C at the shell. Although the shield oxidized slightly in the area of the gap, the unit passed final profile at 0.028 R/hr at one meter.

As demonstrated in previous thermal testing, minor air gaps in the containment surrounding the shield are insufficient to allow significant oxidation of the depleted uranium shield during the thermal test. The Models Sentry 330 transport package test specimens had no breach of the shield containment and would therefore prevent oxygen ingress to the shield and any resulting deterioration of the depleted uranium shield during the thermal test.

(b) Material Properties at Elevated Temperatures

The melting temperature for all materials of the internal support structure, lock assembly and source assembly are above the thermal test temperature of 800°C. The thermal expansion for the internal support structure materials is less than the design clearance allowed for assembly. Further, the stainless steel and titanium components of the internal support structure, lock assembly and source assembly retain about 30% and 60% of their room temperature strength at 800°C.

The worst case load condition for the thermal test is for the internal structure to support the static weight of the shield in suspension. The dynamic impact nature of the drop tests can subject the structure to a force over 100 times the static weight of the shield. This means the strength of the materials used in the structure would need to decrease by two orders of magnitude or to about 1% of their strength at room temperature. The 30-minute thermal test is not long enough for significant creep deformation to occur in the structure.

(1) Tear Out of the Shield Support Pin

If the package is suspended with the shield supported by only one welded access port shield mount pin, then the strength of the 304 stainless steel shield mounts at 800 °C would provide sufficient support to maintain the shield secured to the structure.

Tear out Area = 0.75 in (pin diameter) times 0.74 in (mount thickness) times 2 (number of mounts) = 1.11 in^2

Maximum Shield Weight (SENTRY 330) = 485 lbs.

Therefore: 485 lbs. / 1.11 in^2 = 437 psi

The strength of 304 stainless steel at 800 °C = ~13,000 psi

(Reference: ASM Stainless Steels, J.R. Davis ed.,1994, p. 508)

This gives a factor of safety of approximately 30 against yielding.

(2) Depleted Uranium(DU) Cracking around the Titanium Pin

Examining the mating parts; the size of the titanium shield pin is 0.73 inches in diameter and the size of the DU shield hole and 304 stainless steel shield mount containing the pin are both 0.75 inches in diameter.

The coefficient of linear thermal expansion for the materials of the parts identified above are as follows:

- 304 Stainless Steel: 10 μ in/in °F (18 μ in/in °C) (Reference: ASM Specialty Handbook Stainless Steels, ed. J.R.Davis, 1994 p. 10.)
- Ti-6Al-4V Titanium: 6 μ in/in °F (11 μ in/in °C) (Reference: ASM Material Properties Handbook Titanium Alloys, ed. Rodney Boyer, Gerhard Welsch, E.W. Collings, 1994, p. 516).
- Depleted Uranium: 8 μ in/in °F (14 μ in/in °C) (Reference: ASM Metals Handbook Desk Edition, ed. Howard E. Boyer, Timothy L. Gall, 1985, p. 1.48)

Based on the part tolerances, there is a minimum of 0.008 inches radial design clearance between the titanium shield pin and the 304 stainless steel shield mount hole. There is a minimum of 0.005 inches radial design clearance between the titanium shield pin and the DU shield hole.

At 800°C the maximum thermal expansion of the shield pin, shield mount hole, and DU shield hole in the radial direction are 0.003, 0.005, and 0.004 inches, respectively. Since the maximum difference between anyone of these is 0.002 inches, there will be no thermal stress applied to these parts during the fire test.

(3) De-Attachment of the Lock Assembly

Consider any test specimen suspended with the lock plate assembly facing downward. In this orientation the weight of the lock plate assembly is held in place by the four 17-4 PH stainless steel hex bolts and the one stainless steel security screw.

The weight of the rear plate assembly is less than 10 pounds. If only one hex bolt remains in place after the free drop and puncture tests, then the stress in the one bolt would be.

$S = F/A = 10 \text{ lbs} / 0.1419 \text{ in}^2 = 71$ pounds per square inch (psi)

A = Bolt Stress Area: 0.1419 in^2 (1/2-13 thread)
F = Maximum Weight of Lock Plate with Cover: 10 lbs.

The allowable stress for the bolt material at 800°C is approximately 40,000 psi (Reference: AK Steel Product Data Sheet 17-4 PH Stainless Steel, P. 8, Table 6 - extrapolated).

Therefore, the calculated factor of safety for one bolt holding the lock plate in place is about 563. This ensures the lock plate will remain attached at 800°C for one hour.

(c) Conclusions

The test specimens were subjected to the 9 m drop and 1 m puncture tests in accordance with Test Plan 180, Test Plan 195 & Test Plan 213(Section 2.12).

The test specimens demonstrated these transport packages, in all described configurations, satisfy the test requirements of 10 CFR 71 for hypothetical accident drop test conditions. The versions of this transport package with the handling rib assemblies attached do not adversely affect the results of these tests. This conclusion is drawn from the drop test results and thermal analysis as supported by the test data, test inspection data and damage assessments.

Based on the previous empirical data and analyses, we conclude that oxidation of the shield will not occur, the structural integrity of the package will remain intact and the containment of the source will not be affected. As such, these transport packages comply with the requirements of this section.

2.7.5 Immersion - Fissile Material

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

2.7.6 Immersion - All Packages

The Models Sentry 110, Sentry 330 and 867 Transport Packages are open to the atmosphere and contain 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 these packages is a special form source, which minimally meets the ANSI N43.6 and ISO 2919 requirements for Class 3 pressure testing. Therefore the Models Sentry 110, Sentry 330 and 867 could withstand the immersion test criteria since the Class 3 pressure test requirements are 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)

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

2.7.8 Summary of Damage

As demonstrated in Test Plan 180 Reports #1 and #2, Test Plan 195 Report and Test Plan 213 Report, and as described and assessed in sections 2.6 through 2.7, the Models Sentry 110, Sentry 330 and 867 in both the Basic and Standard package constructions (including the standard construction without the optional plastic rib assembly inserts) satisfies the hypothetical accident condition test requirements of 10 CFR 71.73(c).

Table 2.7c summarizes the results of the Normal Conditions of Transport and Hypothetical Accident testing performed on the worst case constructions for these transport packages. Compliance for all untested package configurations is based on assessments on the tested configurations.

Table 2.7c: Summary of Test Unit Results

Unit, Configuration & Test Plan	Test Description	Results
Assessed Test Plan 180	Compression test (Analysis)	Analysis shows no damage expected
TP180A (Basic – Sentry 330) Test Plan 180	1 m penetration bar onto lock dust cover	Small Dent in plastic cover and brass lock
	1.2 m drop onto dust cover	Dented port tube & fractured dust cover pin
	Testing After Lock Modifications (See Section 2.6.7.6 of this SAR)	
	9 m drop #1 onto dust cover (miss)	Increased dent in port tube
	9 m drop #2 onto dust cover	Increased dent in port tube & fractured plastic dust cover
	1 m puncture onto dust cover	About 1/3 of plastic cover removed
	Post-Drop Inspection	Broken dust cover lock
TP180B (Basic – Sentry 330) Test Plan 180	1.2 m drop onto welded body lock port	Bent port tube towards dust cover
	Testing After Lock Modifications (See Section 2.6.7.6 of this SAR)	
	9 m drop onto welded body lock port	Port tube crushed onto dust cover
	1 m puncture onto dust cover	Superficial dent on plastic dust cover
	Post-Drop Inspection	Sheared dust cover pins, slight bend to lock plate
TP180C (Basic – Sentry 330) Test Plan 180	1.2 m drop onto welded body long weld seam	Dent on edge and longitudinal body weld seam
	Testing After Lock Modifications (See Section 2.6.7.6 of this SAR)	
	9 m drop #1 onto welded body edge weld seam (miss)	Dent on edge body weld seam
	9 m drop #2 onto welded body long weld seam	Longitudinal weld seam flattened into body
	1 m puncture onto welded body edge weld seam	Superficial dent in body edge weld seam
	Post-Drop Inspection	Source tube at lock plate port cracked and easily removed by hand, but no impact on source security
TP180D (Basic – Sentry 330) Test Plan 180	1.2 m drop onto welded body edge weld seam	Superficial dent in edge weld seam of welded body
TP180E (Basic – Sentry 330) Test Plan 180	1.2 m drop onto welded body top end surface	Dust cover pins sheared off - allowing cover to be easily removed.
	Testing After Lock Modifications (See Section 2.6.7.6 of this SAR)	
	9 m drop onto welded body top end surface	Minor bulge in cylinder on impact end of welded body
	1 m puncture #1 onto dust cover (miss)	Dent to rear plate port tube
	1 m puncture #2 onto dust cover	Superficial dent on plastic dust cover
	Post-Drop Inspection	Source tube appears to be oval shaped

Unit, Configuration & Test Plan	Test Description	Results
TP180G (Standard – Sentry 330 minus plastic rib inserts) Test Plan 180	Testing After Lock Modifications (See Section 2.6.7.6 of this SAR)	
	9 m drop #1 onto bottom handling rib assemblies	Bent and fractured handling ribs and rib attachment bolts. Shallow indentations into welded body bottom plate.
TP180G (Basic – Sentry 330) Test Plan 180	Testing After Lock Modifications (See Section 2.6.7.6 of this SAR)	
	9 m drop #2 onto welded body top end surface	Front plate knob shaft fractured – removing knob.
	Post-Drop Inspection	No other signs of damage found
TP180D (Standard – Sentry 330 minus plastic rib inserts) Test Plan 195	Testing After Lock Modifications (See Section 2.6.7.6 of this SAR) and Drop Heights Increased to Adjust for Maximum Package Weight of 780 lbs	
	9 m drop onto welded body lock port and handling ribs assemblies	Minor dent to lock plate port tube. Handling ribs bent with two fractured bolts and one fractured load pin.
	1 m puncture onto dust cover	Dust cover shifted about ½ inch
	Post-Drop Inspection	Source connector and dust cover pins sheared off. Dust cover easily removed. Source remained locked and secure.
TP180J (Basic 867 w/Tungsten shield disk in dust cover) Test Plan 213	1.2 m drop onto dust cover	Port bent slightly. Impact marks on dust cover, port rim and edge of body weldment.
	9 m drop #1 onto dust cover (partial hit)	Top edge seam of body weldment flattened inward about 2 inches creating an 8 inch wide flat. Top bulged ~2 inches.
	9 m drop #2 onto dust cover (partial hit)	Increased top edge seam damage by about 1 inch in all directions.
	1 m puncture onto dust cover	Dust cover assembly crushed inwards. Brass plunger lock scuffed.
	Post-Drop Inspection	Brass plunger lock inoperable requiring drill out for removal. Some internal damage to dust cover assembly components but lock cover assembly and source assembly intact and undamaged.

Based on the condition of the test units after the drop testing, and as assessed in Section 3.5 both the Basic and Standard package constructions (including the standard construction without the optional plastic rib assembly inserts) satisfies the hypothetical accident condition thermal test requirements of 10 CFR 71.73(c)(4).

2.8 Accident Conditions for Air Transport of Plutonium or Packages with Large Quantities of Radioactivity

Not applicable. This package is not used for transport of plutonium or normal form radioactive material. This package is also not used for transport of special form material in quantities ≥ 3,000 A_1.

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

The Model Sentry transport packages are designed for use with a special form source capsule Models 60011, 60012, or X2163 attached to a flexible source assembly (reference typical Models A424-14, A424-13, A424-15, A424-18 or 943). The source capsules are approved under a U.S. Department of Transportation special form certifications USA/0377/S-96 and USA/0603/S-96. A copy of the current USDOT certificates, including the current approved capsule drawings, are included in Section 2.12.7 and 2.12.13. Details of encapsulation as well as chemical and physical form of the radioactive material will comply with specifications approved under U.S. Department of Transportation special form certifications.

Details of typical flexible source assemblies can be found under USA SS&D registration MA-1059-S-105-S and CNSC device registrations R-061-1996-4-2016, R-061-2032-4-2016, R-061-1794, R-061-1828, R-061-2054 or R-061-2098.

2.11 Fuel Rods

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

2.12 Appendix

2.12.1 Test Plan 180 Revision 2 dated 7 April 2009

2.12.2 Test Plan 180 Addendum dated 25 February 2010

2.12.3 Test Plan 180 Report #1 dated 14 January 2010

2.12.4 Test Plan 180 Report #2 dated 7 April 2010

2.12.5 Test Plan Report 72-S2 (680-OP) dated 15 February 1999 (minus Appendices A through C)

2.12.6 Test Plan Report 80 dated June 1999 (Minus Manufacturing Records)

2.12.7 USDOT Special Form Certificate USA/0377/S-96 Rev 8

2.12.8 Test Plan 79 Report dated 22 October 1998

2.12.9 Technical Report 171 Sentry Transport Package Lifting Analysis dated 30 Jun 2010

2.12.10 Technical Report 172 Sentry Transport Package Tie-Down Analysis dated 21 Jul 2010

2.12.11 Test Plan 195 dated 30 June 2010

2.12.12 Test Plan Report 195 dated 21 July 2010

2.12.13 USDOT Special Form Certificate USA/0603/S-96 Rev 3

2.12.14 Test Plan 213 Report Rev 0 dated 6 May 2015

2.12.15 Test Plan 213 Report Rev 0 dated 17 Jun 2015

2.12.1 Test Plan 180 Revision 2 dated 7 April 2009