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# TEST PLAN 180

## SENTRY – Model 860 Projectors & Model 867 Source Changer Type (B) Transport Package Tests

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|---|---|---|---|
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# TEST PLAN 180

# SENTRY - MODEL 860 PROJECTORS & MODEL 867 SOURCE CHANGER TYPE (B) TRANSPORT PACKAGE TESTS

Rev2

March 26, 2009

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# Test Plan No. 180

## Section 1 Introduction

This document outlines the test plan needed for the SENTRY (Model 860) Projector series and (Model 867) Source Changer to meet NRC requirements for Type B(U)-96 packages as described in the Code of Federal Regulations, 10 CFR Part 71, revised as of March 31, 1999. The test plan also covers the criteria stated in the IAEA Regulations for the Safe Transport of Radioactive Material, No. TS-R-1 1996 Edition (Revised).

This document describes the test package specifications, testing equipment, testing scenario, justifies the package orientations for the different test specimens and provides test worksheets to record key steps in the testing sequence.

### Roles and Responsibilities

The responsibilities of the groups identified in this plan are:

- **Engineering** executes the tests according to the test plan and summarizes the test results. Engineering also provides technical input to assist Regulatory Affairs and Quality Assurance as needed.
- **Regulatory Affairs** monitors the tests and reviews test reports for compliance with regulatory requirements.
- **Quality Assurance** oversees test execution and test report generation to assure compliance with the QSA Global Quality Assurance Program.
- **Engineering, Regulatory Affairs** and **Quality Assurance** are jointly responsible for assessing test and specimen conditions relative to 10 CFR 71 and IAEA TS-R-1 1996.

## Section 2 Transport Package Description

The SENTRY transport package is a family of packages, consisting of 2 different model numbers. Model 860 refers to the SENTRY projector series and Model 867 refers to the SENTRY source changer.

The Model 860 SENTRY Projector series is further broken down into 2 projectors types defined by their rated capacity for cobalt-60, the SENTRY 330 and SENTRY 110 projectors. Each projector type is available in either a standard or basic transport package configuration. The standard configuration will most likely be the most commonly used version of the transport package. The basic configuration is the same as the standard configuration but without the array of removable handling rib assemblies.

The Model 867 SENTRY source changer is rated at 330 curies of cobalt-60. Similar to the projectors, the source changer is available in both a standard and basic configuration.

Figure 2.1.is a schematic overview of the SENTRY transport package configuration tree.

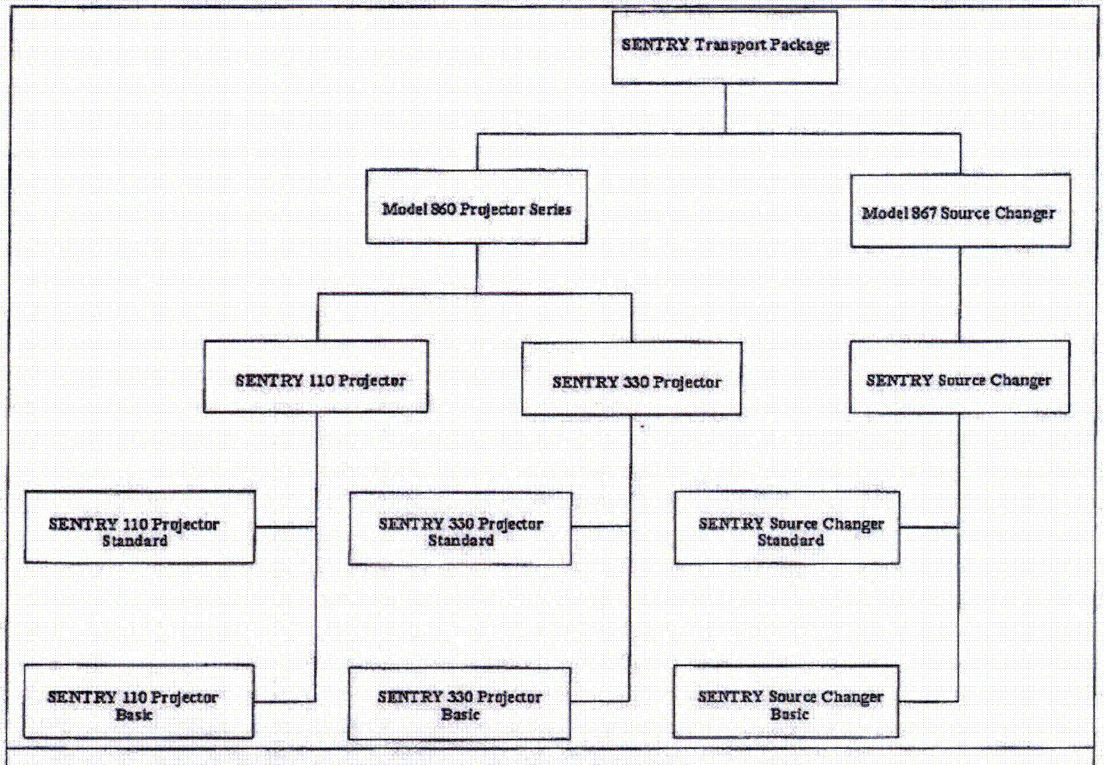



**Figure 2.1. SENTRY Transport Package Configuration Tree.**

Table 2.1 shows the specific differences between the SENTRY transport package configurations to be tested or evaluated in this test plan.

**Table 2.1. SENTRY Transport Package Configurations.**

| Configuration | Handling Ribs | Active Source Wire Assembly | Active Source Capsule | Max. Package Weight (Lbs.) | Refer to Figure | Source Capacity (Curies of Co60) |
|---|---|---|---|---|---|---|
| SENTRY 330 Projector – Standard | Yes | 42465-9 & 42465-10 | 60011 & 60012 | 780 | 2.2 | 330 |
| SENTRY 330 Projector – Basic | No | 42465-9 & 42465-10 | 60011 & 60012 | 700 | 2.3 | 330 |
| SENTRY 110 Projector – Standard | Yes | 42465-8 | 60011 | 580 | 2.2 | 110 |
| SENTRY 110 Projector – Basic | No | 42465-8 | 60011 | 500 | 2.3 | 110 |
| SENTRY Source Changer – Standard | Yes | 42465-8, 42465-9 & 42465-10 | 60011 & 60012 | 780 | 2.2 | 330 |
| SENTRY Source Changer - Basic | No | 42465-8, 42465-9 & 42465-10 | 60011 & 60012 | 700 | 2.3 | 330 |

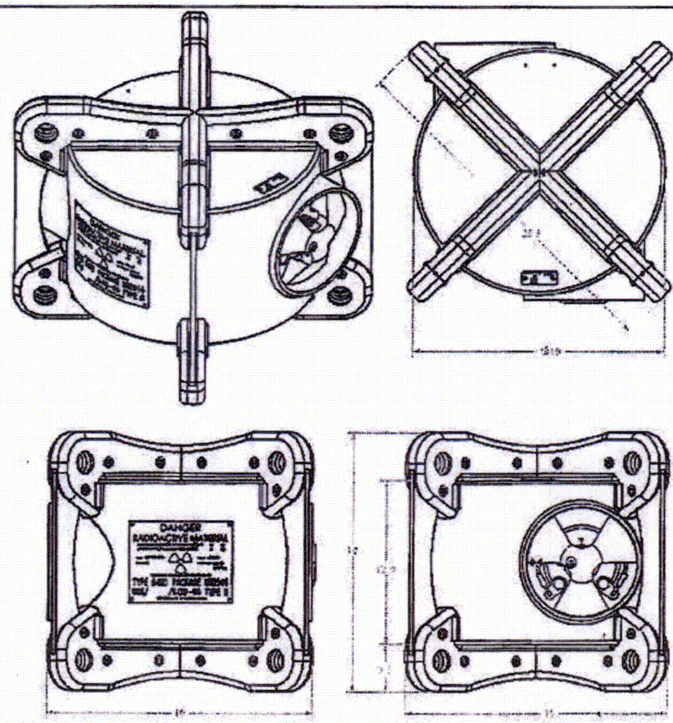


Figure 2.2. SENTRY Transport Package Projector & Changer – Standard Configuration.

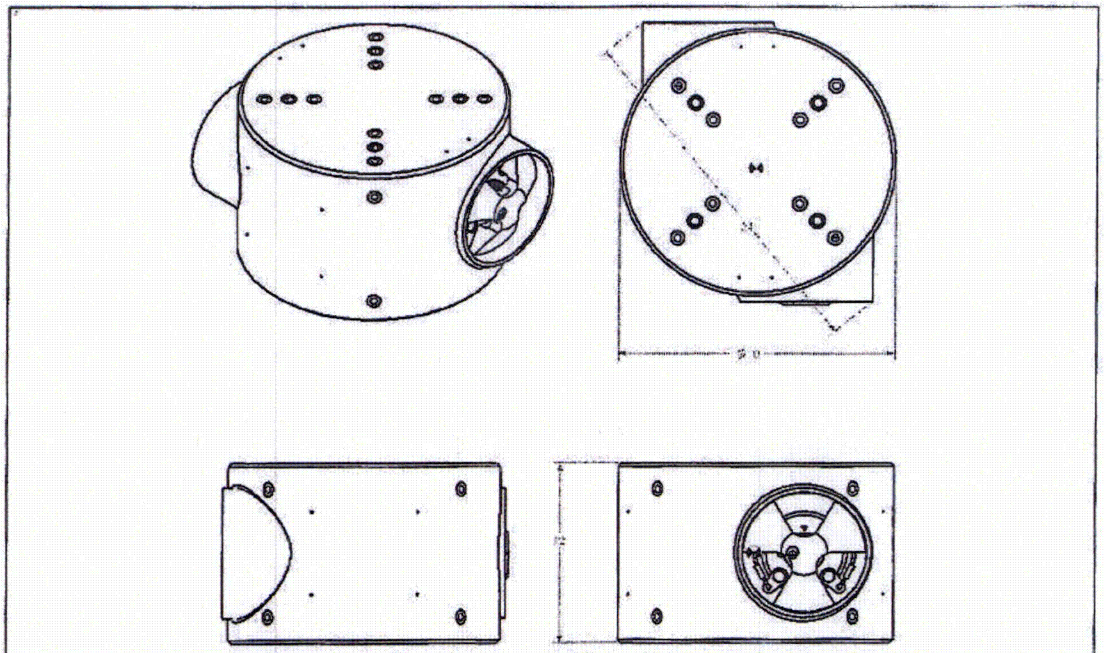


**Figure 2.3. SENTRY Transport Package Projector & Changer – Basic Configuration.**

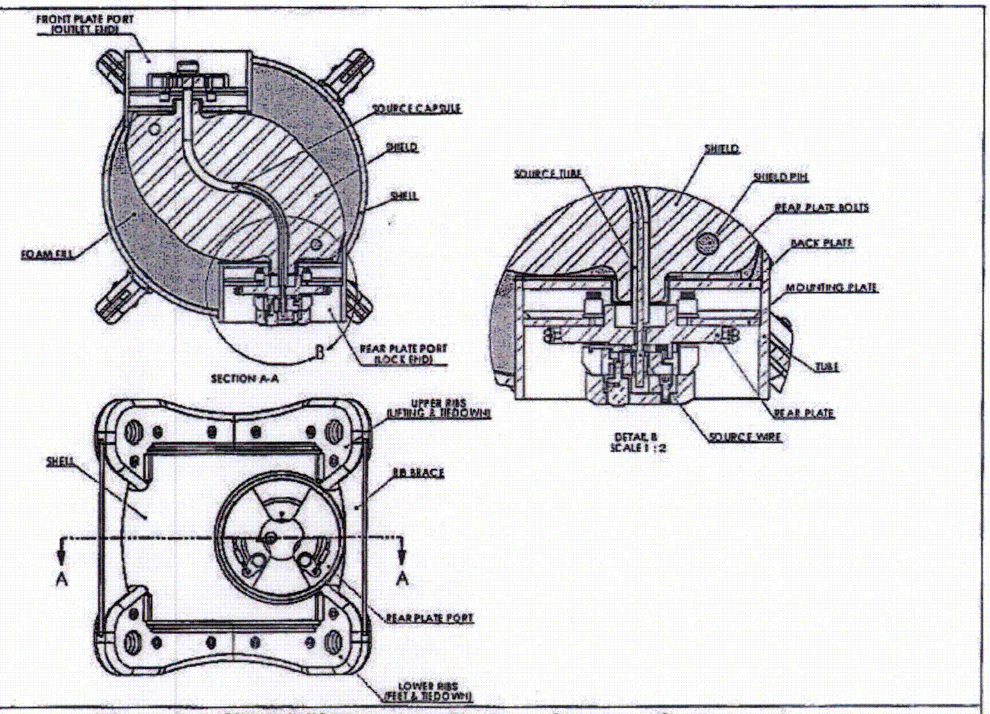



**Figure 2.4. SENTRY Transport Package Common Components**
**Optional Handling Ribs Shown**

All configurations include a depleted uranium shield completely encased and fully supported in a cylindrically shaped, stainless steel, welded body (See Figure 2.4). The welded body, also called the shell, includes two, tube shaped, access ports integrally welded on opposite sides of the main body. A twin set of shield mounting bars, one on each side of the shield, are welded to the back plate of each access port tube. Heavy duty, titanium, shield pins pass through the shield and into both shield mounting bars. This creates two positive shield attachment points to the welded body.

The shield source tube ends are also inserted into holes in each of the access port back plates. In addition to this, the shield is captured and centrally located between the top and bottom endplates. This combination of shield securing features provide for a robust shield support system within the welded body.

The inner cavity of the welded body, around the shield, is filled with polyurethane foam. The foam prevents contamination to and from the depleted uranium shield. Previous thermal tests have shown charred polyurethane foam will inhibit the flow of oxygen to the shield and prevent oxidation from occurring during a fire as long as the foam remains confined. This is shown on QSA Global test plan results number 70.

Previous tests have also shown the charred foam will not support the shield at temperatures at or above 800°C. Therefore, the SENTRY relies primarily on the shield support system inside the welded body to hold the shield in place during the thermal test where temperatures reach 800°C.

A titanium source tube, cast into the center of the shield, provides a conduit for the source wire assembly within the shield. The source tube of the SENTRY projector allows the source assembly to pass through the shield. However, the source tube of the SENTRY source changer has a stop to prevent the source assembly from passing through the center of the container. The source capsule is located close to the most shielded location at the center of the shield in all transport configurations.

The two opposing access ports provide a protected mounting space for both the rear-plate and front-plate assemblies. The front-plate assembly is used only on the projector configurations. The source changer configuration uses a rear-plate assembly in each access port.

In all configurations, the rear-plate assembly locks, secures, and locates the source wire assembly to an ideally shielded position within the package. A redundant fastening system attaches the rear-plate to the welded body. The primary attachment method of the fastening system is achieved by four, high strength, stainless steel, hex head bolts, BLT015, threaded into stainless steel rivet nuts assembled into the welded body. The rivet nuts facilitate repair in the event the threads are damaged in the future. An alternate configuration consists of using a threaded stainless steel ring with multiple tapped holes instead of using the rivet nuts. The ring can be rotated to use a different set of tapped holes in the event the initial set becomes damaged.

The secondary method of attachment is by a single stainless steel tamperproof button head screw. This screw reduces and limits unauthorized access to the source. The tertiary method of attachment is provided by two, stainless steel, retaining pins (projectors) or set screws (changer) assembled to the rear-plate. The pins or set screws enter the welded body through a horizontal slot in the mounting plate. The rear-plate is rotated 90 degrees to prevent the pins or set screws from passing back out through the mounting plate where no slot exists. This keeps the rear-plate from separating from the welded body in the event the primary and secondary attachment methods are compromised. The recessed location of the rear-plate mounting surface within the access port tube provides additional restraint preventing rotation and translation on the rear-plate. This effect requires only one screw or bolt to keep the source secured to the shield in the welded body.

There are three rear-plate assembly designs used in the SENTRY transport package. All three designs use the same basic rear-plate assembly concept but the projector and source changer configurations differ in the way the source wire assembly is locked to the package.

Except for the SENTRY 110 projector rear-plate being 0.31 inches thinner than the SENTRY 330 rear-plate, both projector configurations use the same rear-plate assembly. The difference in rear-plate thickness is to allow for the difference in length of the dedicated source wire assemblies used in each projector.

All SENTRY configurations 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 selector ring retainer allows the selector ring to rotate and keeps it attached to the rear-plate assembly. The selector ring retainer also provides the housing for the critical spring-loaded locking components and is attached to the rear-plate by 4 stainless steel socket head cap screws.

The projector configurations use the round ball feature of the connector to capture the source wire assembly between two spring-loaded locking components, the sleeve and lock slide, of the rear-plate assembly to secure the source wire assembly to the package.

The source changer configuration uses two spring-loaded fork shaped locking pins to hold the helical wrap feature of the Teleflex wire or cable to secure the source wire assembly to the package. The source changer cannot use the same source wire securing mechanism as the projectors because of two reasons.

1. The source changer accommodates two different length source wire assemblies.
2. The source changer requires the source to enter and exit from the same rear-plate assembly.

A sealed, special form, stainless steel, source capsule contains the radioactive contents of the package. The source capsule and a stainless steel connector are independently swaged to each end of a flexible stainless steel wire or cable to form the source wire assembly.

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

The front-plate assembly of the projector does not hold the source assembly but instead blocks access into or out of the source tube cavity from the end opposite the rear-plate access port.

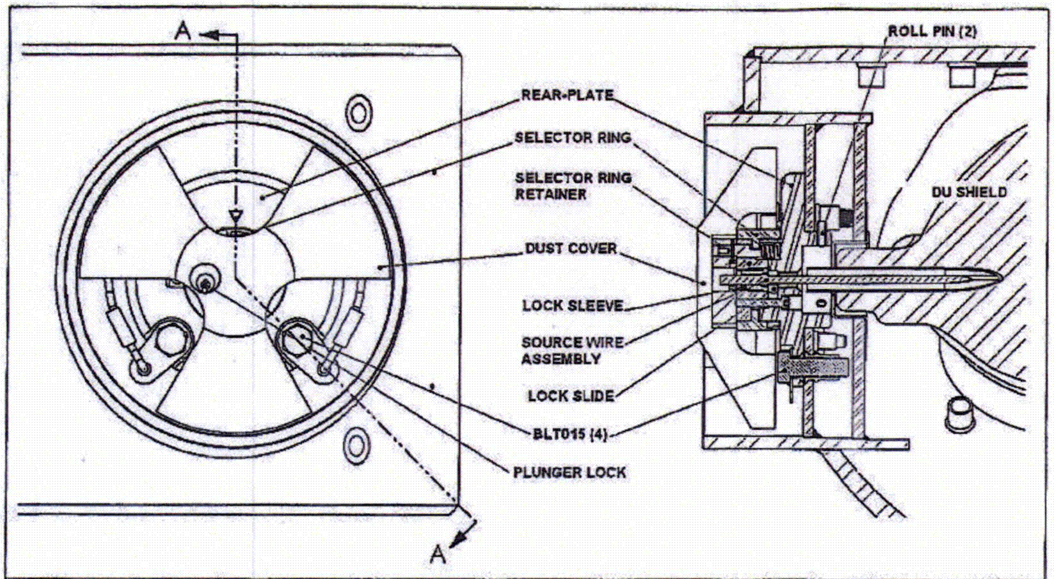



**Figure 2.5. SENTRY Projector(s) Rear-plate Assembly with source wire secured**

Figure 2.5 shows the rear-plate assembly end of the projector version of the SENTRY transport package. The SENTRY 110 rear-plate is thinner than the SENTRY 330 rear-plate by 0.31 inches to account for the difference in source wire lengths. Except for the shield and the rear-plate thickness, all other components are identical in both projectors.

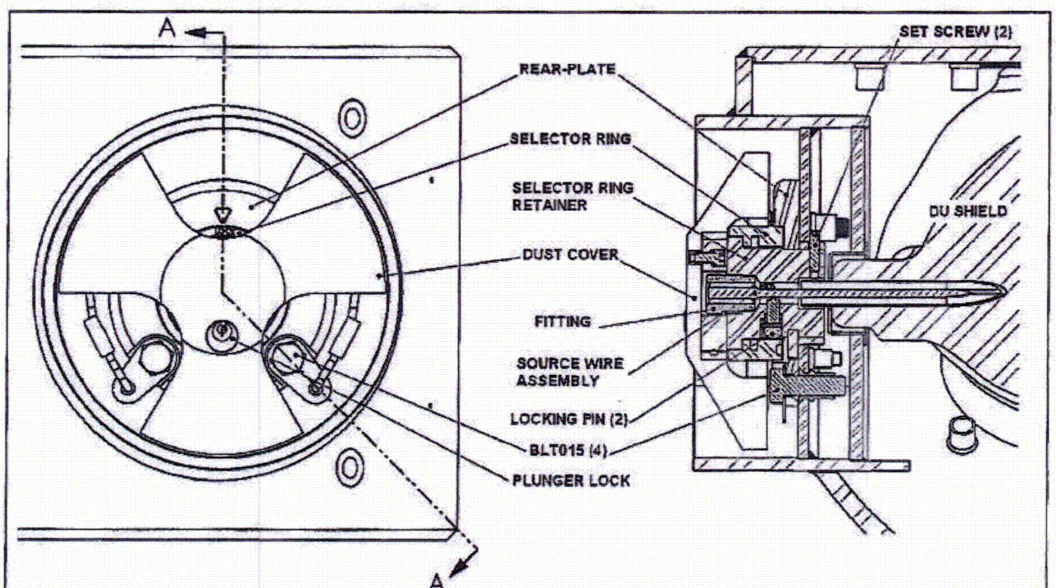



**Figure 2.6. SENTRY Source Changer Rear-plate Assembly with source wire secured**

Figure 2.6 shows the rear-plate assembly end of the source changer version of the SENTRY transport package. The source changer rear-plate is essentially the same thickness as the SENTRY 330 projector rear-plate. Many of the source changer rear-plate components differ from the projector version, but the rear-plate fastening system is identical.

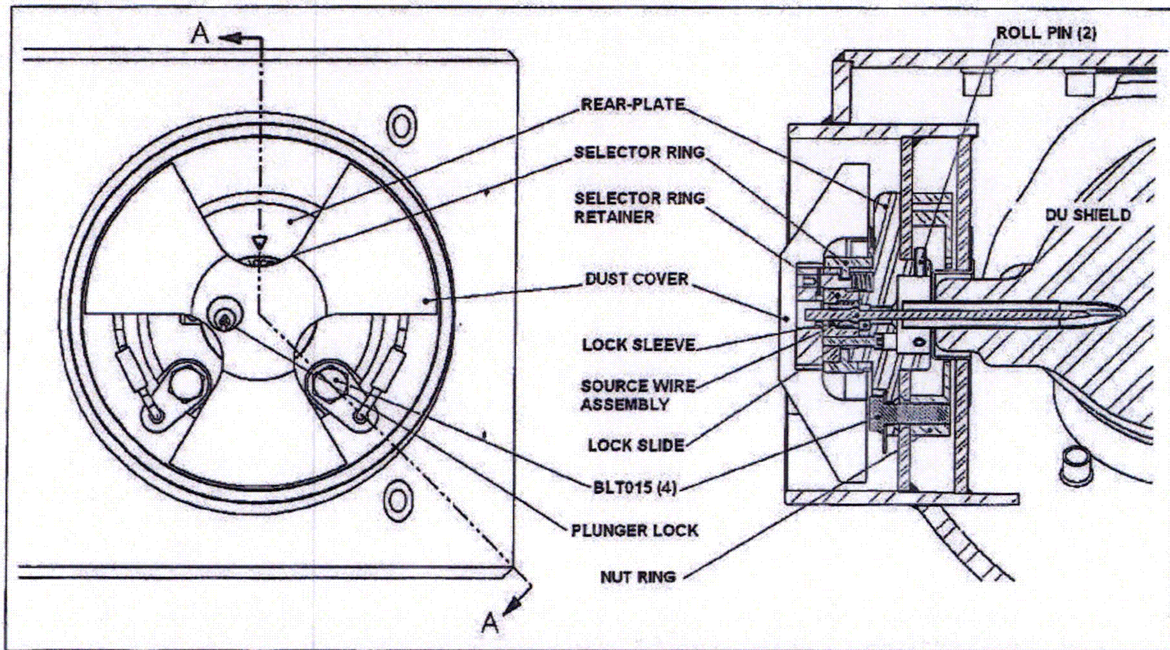



**Figure 2.7. SENTRY Projector(s) Alternate Rear-plate Assembly with source wire secured**

Figure 2.7 shows an alternate configuration for the rear-plate assembly end on both the projector and source changer versions of the SENTRY transport package. This alternate configuration replaces the rivet nuts with a nut ring. The rivet nuts or, in this case, the nut ring is an integral part of the rear-plate fastening system.

# Section 3 Regulatory Compliance

The main purpose of this test plan is to demonstrate that the SENTRY projector/transport package complies with the Type B(U)-96 transport package test requirements of 10 CFR 71 and IAEA TS-R-1 1996.

The sequence of testing shall follow the order given in section 8.1. All test specimens are first subjected to the required normal conditions of transport tests followed by the hypothetical accident condition tests of 10 CFR Part 71.73. This represents the worst case testing sequence for the SENTRY transport package.

## 3.1 Normal Transport Condition Tests

The **water spray preconditioning** (10 CFR 71.71 (c) (6)) of the package will not be performed as the SENTRY projector/transport package is constructed of waterproof materials throughout. Water spray would not degrade the structural integrity of the SENTRY transport package.

The **compression test** (10 CFR 71.71 (c) (9)) will either be conducted by stacking the required weight onto the package or evaluated by using a finite element analysis (FEA) model. If the test is conducted, then it will follow this test plan. Otherwise, the FEA model evaluation will be documented in a technical report.

The SENTRY transport package shall be subjected to the **penetration test** of 10 CFR 71.71 (c) (10) and then the **1.2 meter free drop test** per 10 CFR 71.71 (c) (7).

## 3.2 Hypothetical Accident Condition Tests

The **crush test** (10 CFR 71.73 (c) (2)) will not be performed because the capsules containing the radioactive material and attached to the source wire assemblies are qualified as Special-Form radioactive material.

The SENTRY transport package shall be subjected to the **9 meter free drop test** (10 CFR 71.73 (c) (1), and then the **puncture test** (10 CFR 71.73 (c) (3).

The **thermal test** (10 CFR 71.73 (c) (4)) will most likely be assessed and not performed. The assessment will be based on the examination of the damage to the test specimen after the puncture test. Experience from thermal testing the Model 660 & Model 680 transport packages has shown the shield will oxidize and diminish its ability to protect only when the adjacent foam fill is allowed to combust and then fall away from the shield. Charred foam seems to provide enough thermal insulation to prevent the shield from oxidizing as long as the charred foam remains in place. Any damage producing an unintentional opening in the shell or welded body would need to be assessed to determine whether the transport package would pass or fail the thermal test.

The **immersion test** (10 CFR 71.73 (c) (6)) will not be performed. Only the source capsule (containment vessel) is sealed and able to pressurize as a result of 50 feet of water depth. The source capsule is designed and tested to withstand external pressures over 22-lbf/in$^2$.

### *3.3 Free Drop Height Adjustment*

All free drop test heights specified in 10 CFR Part 71 shall be adjusted higher to allow for SENTRY transport packages built heavier than the test specimen but less than the maximum package weight to comply with 10 CFR Part 71. The actual test specimens will likely weigh less than the maximum weight specified on their respective top level assembly drawings. Table 3.1 compares the test specimen against the maximum transport package weight for each SENTRY transport package configuration.

The actual weight of the SENTRY transport package is directly affected by the following:

1. Minor thickness variations in component materials.
2. Slight polyurethane foam fill density changes as the pre-filled foam ages (self life).
3. Extra shield material layers accumulating on the shield casting as the mold cavity wears.

**Table 3.1. SENTRY Transport Package Weight Comparison.**

| SENTRY Package Configuration | Estimated Test Specimen Weight (Lbs) | Maximum Transport Package Weight (Lbs) | Potential Weight Difference (Lbs) |
|---|---|---|---|
| SENTRY 330 Projector – Standard & SENTRY Source Changer – Standard | 734 | 780 | 46 |
| SENTRY 330 Projector – Basic & SENTRY Source Changer – Basic | 653 | 700 | 47 |
| SENTRY 110 Projector – Standard | 556 | 580 | 24 |
| SENTRY 110 Projector – Basic | 475 | 500 | 25 |

The impact energy is equal to the total potential energy just before the package is dropped. The potential energy (PE) is simply equal to the weight (W) of the package multiplied by the height (H) of the drop.

$$PE = W \times H$$

In the potential energy equation, the weight (W) is directly proportional to the height (H). A lighter test specimen can be dropped from a higher drop height in order to produce equivalent impact (potential) energy for a heavier test specimen dropped at a lower height. The following example calculates the adjusted 30-foot free drop height for the SENTRY 330 Projector – Standard configuration.

Drop #1: Maximum package weight = 780 Lbs. and free drop height requirement = 30 feet.

$$PE\ (1) = 780 \times 30 = 23400 \text{ Lbs-Ft}$$

Drop #2: Actual test specimen weight = 734 Lbs. and adjusted free drop height = Unknown feet.

$$PE\ (2) = PE\ (1) = 23400 \text{ Lbs-Ft} = 734 \text{ Lbs} \times H \text{ feet}$$

$$H = 31.9 \text{ feet} = 31 \text{ feet } 11 \text{ inches}$$

The actual adjusted drop heights will be determined once the test specimens are weighed and just before the 30 foot, 4 foot and 1 meter puncture drop test. The adjusted heights will provide impact energy equal to or greater than the maximum transport package weight if dropped at the 10 CFR Part 71 specified drop heights (30 feet free drop, 4 feet free drop, and 1 meter puncture).

# Section 4 Discussion on System Failure Modes of Interest

The testing in this plan will attempt to cause failure or malfunction to critical SENTRY transport package components and/or systems needed to protect against elevated dose levels during normal transport and after a hypothetical accident as described in 10CFR part 71. The most critical components are the shield, the rear plate assembly, and the relative position between them. The failure modes of interest are as follows:

**Table 4.1. SENTRY Transport Package Failure Modes.**

| # | Failure Mode | Possible Cause | Target Components |
|---|---|---|---|
| 1A | Failure of the depleted uranium (DU) shield to provide sufficient shielding. | An impact from the drop or penetration tests could fracture the shield material. | ▪ DU Shield |
| 1B | | A fracture of the shells welded cylindrical body from the drop and/or penetration tests could produce an opening large enough to allow the foam to burn away during the fire test. The shield could oxidize in the fire test without sufficient foam. | ▪ Welded Body<br>▪ DU Shield<br>▪ Foam Fill |
| 2 | Failure of the shield retaining structure to hold the shield in place relative to the source assembly. | Abrupt changes in motion and damage from the drop and penetration tests could shift the shield away from the source. | ▪ Welded Body<br>▪ DU Shield<br>▪ Source Assembly |
| 3 | Failure or malfunction of the rear plate assembly to keep the source assembly in a sufficiently shielded location. | Abrupt changes in motion and damage from the drop and penetration tests could shift the source away from the shield. | ▪ Welded Body<br>▪ DU Shield<br>▪ Rear Plate<br>▪ Source Assembly |
| 4 | Failure of the rear plate attachment hardware to retain the rear plate to the package. | Abrupt changes in motion and damage from the drop and penetration tests could remove the source from the shield. | ▪ Rear Plate<br>▪ Rear Plate Bolts |

## 4.1 *Pass Criteria*

Upon conclusion of any test, the test specimen shall be considered passing the test if it does not show signs of loss or dispersal of radioactive or simulated radioactive contents and show no substantial reduction in the effectiveness of the packaging. To pass, the test specimen must also not show an increase in external surface radiation levels above 200-mR/hr after any normal transport test and above 1-R/hr at 1 meter (40 inches) from the packages external surface after the hypothetical accident condition tests.

# Section 5 Assessment of Package Conformance

## 5.1 *Normal Conditions of Transport (71.43 (f))*

There should be no loss or dispersal of radioactive contents, no significant increase in external surface radiation levels and no substantial reduction in the effectiveness of the packaging.

IAEA TS-R-1 1996 paragraph 646 stipulates the same criteria except that it also requires that the loss of shielding integrity should not result in more than a 20% increase in the radiation level at any external surface of the package.

## 5.2 *Hypothetical Accident Conditions (71.51 (a)(2))*

There should be no escape of radioactive materials greater than $A_2$ in one week and no external dose rate greater than 1 R/hr at 1m from the external surface with the maximum radioactive contents which the package is designed to carry.

## 5.3 *Transport Package Contents*

The SENTRY transport package is designed to carry a special form cobalt-60 source capsule. Containment of the radioactive source is tested at manufacture. The source capsule design has been certified in accordance with the performance requirements for special form as specified in 10 CFR Part 71 and IAEA TS-R-1 1996.

This test plan therefore does not discuss/specify tests associated with the containment of the radioactive source. The purpose of the tests is to demonstrate that the source remains shielded within the limits specified by the regulations.

Since source integrity has been demonstrated through special form testing, a simulated source will be used during testing of the package. The radiation levels after testing will be measured by replacing the simulated source with an active source. The post-test measurements will be compared with pre-test measurements to verify the source has not shifted within the shield.

# Section 6 Construction and Condition of Test Specimens

The SENTRY transport package test specimens shall be constructed in accordance with QSA Global engineering drawings and Quality Assurance Program. The drawings and quality program accurately represent the intended design along with methods for manufacturing and verifying the finished product.

Figure 6.1 Shows the SENTRY transport package – test specimen configuration tree.

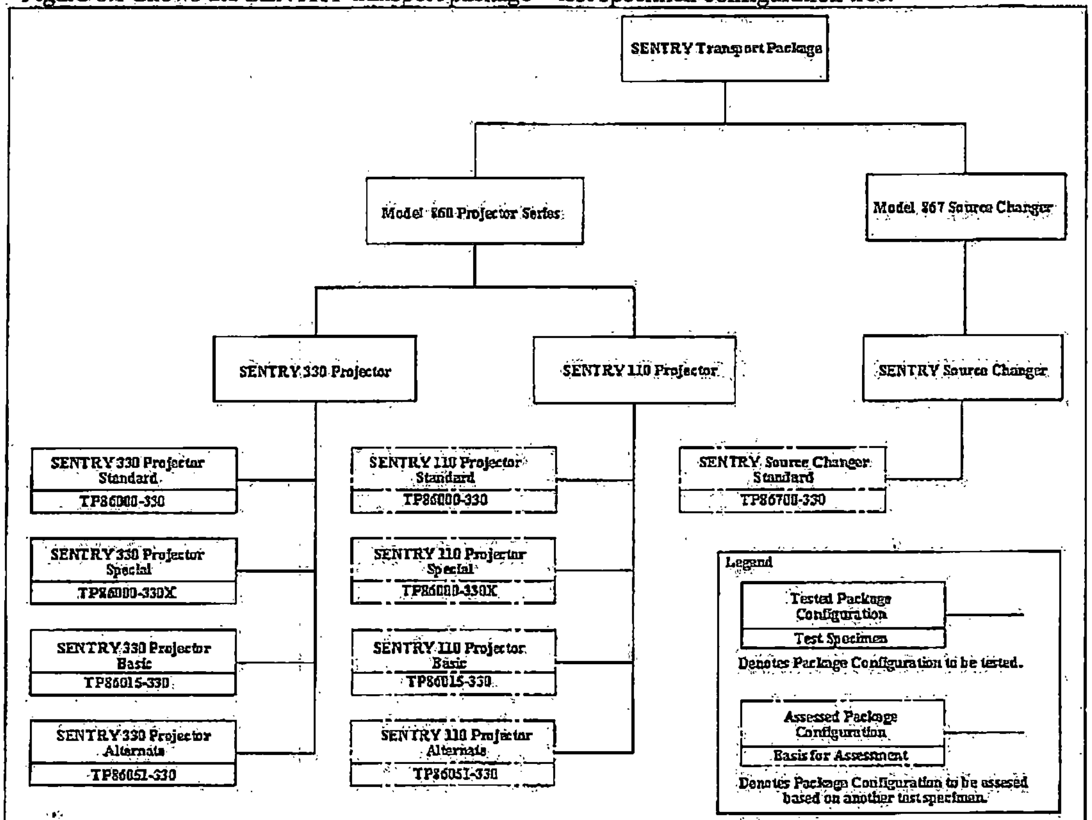



Figure 6.1. SENTRY Test Specimen Configuration Tree.

Table 6.1 shows the test specimen build documentation and identification.

**Table 6.1. Test Specimen Manufacturing Documentation and Identification**

| Test Specimen Configuration | Drawing Number | TMI | Serial Number(s) |
|---|---|---|---|
| SENTRY 330 Projector – Standard | TP86000-330 | 190 | TP180F |
| SENTRY 330 Projector – Special | TP86000-330X | 199 | TP180G |
| SENTRY 330 Projector – Basic | TP86015-330 | 189 | TP180A, TP180B, TP180C, TP180D, TP180E |
| SENTRY 330 Projector – Alternate (Nut Ring) | TP86051-330 | 228 | TP180H |
| SENTRY Source Changer – Standard | TP86700-330 | 192 | TP180J |

## 6.1 Test Specimen Justification

The **SENTRY 330 Projector – Standard** configuration is the heaviest package of all the SENTRY transport packages. The array of handling rib assemblies of this configuration makes it heavier than the Basic configuration by about 80 pounds. However, the handling ribs will provide protection and substantial impact energy absorption in certain free drop orientations when they are present. A conservative worst case free drop condition would be to drop the "non-ribbed" Basic configuration at a higher drop height to account for the 80 pound weight difference.

Based on the above reasoning, the **SENTRY 330 Projector – Basic** configuration shall be tested extensively and used as the basis for assessing compliance to the free drop testing requirements of 10 CFR Part 71 and IAEA TS-R-1 1996 for all the other SENTRY transport packages. Some of the other package configurations may be tested as described in this test plan or if the post testing assessment determines the need to do so.

The structure of the **SENTRY 110 Projector** is identical to the SENTRY 330 Projector, except for the thickness of the rear plate and shield mid section (center). The cross sectional area around where the shield attaches to the structure is nearly identical for both the SENTRY 330 & 110 packages. Therefore, the heavier SENTRY 330 configuration would be testing a higher stress, worst case, condition. Drop testing the SENTRY 110 Projector will not be performed. However, if there is sufficient damage to the rear plate assembly, access port and/or mounting surface of the SENTRY 330 after it has been drop tested, then the damage effect to the SENTRY 110 rear plate will be assessed and testing of the SENTRY 110 could be performed at a later date if deemed necessary.

The **SENTRY 330 Projector – Special** configuration is identical to the SENTRY 330 Projector – Standard configuration except it is built without the plastic inserts of the handling rib assemblies. The idea here is to demonstrate compliance in the event the inserts are severely damaged or removed by rough handling and use.

The **SENTRY 330 Projector – Alternate** configuration is identical to the SENTRY 330 Projector – Standard configuration except the alternate configuration has a nut ring in place of the rivet nuts to attach the rear plate assembly. The need for drop testing the SENTRY 330 Projector – Alternate configuration would be considered only if there were sufficient damage to the SENTRY 330 Projector rear plate assembly, access port and mounting surface.

The structure of the **SENTRY Source Changer** is identical to the SENTRY 330 Projector. There are some differences in the components of the rear plate assemblies. Although the rear plate mounting system is the same for both packages. The need to drop test the SENTRY Source Changer would be considered only if there were sufficient damage to the SENTRY 330 Projector rear plate assembly, access port and mounting surface.

## 6.2 Structural Materials of Test Specimen

The structural materials of all the SENTRY transport packages are made of type 300 series stainless steel and titanium. The shielding materials are depleted uranium and tungsten. Fasteners needed to retain and secure important safety components are made of type 17-4 PH and type 300 series stainless steel. Type 300 series stainless steels are defined as the austenitic group of stainless steel materials identified under the Unified Numbering System (UNS) S3xxxx, where "xxxx "denotes the sub class of the material in the numbering system. The non-safety related components are made from brass, copper, plastic, and rubber.

### 6.3 Temperature Conditions

The fracture toughness (strength and ductility) of the SENTRY transport package structural materials will not change significantly within the temperature range of minus 40°F to plus 100°F. Within this temperature range, the DU shield will exhibit only slightly less ductility than the other structural materials.

Test plan/report 79 shows compressive impact strength of the polyurethane foam changes very little between minus 40°F to plus 100°F. The foam is not the only feature limiting the shields movement during the impact of the drop test. The shield relies heavily on the titanium pins and the welded structure to help keep it secure and in place. Therefore, all test specimens will be dropped at ambient temperature since the temperature within the minus 40°F to plus 100°F temperature range is not expected to change the results of any of the tests.

### 6.4 Pressure Conditions

Except for the source capsule, the transport package is open to the atmosphere and therefore in equilibrium with the outside pressure of the package. The internal operating pressure of the containment system, namely the source capsule, has been tested to withstand the pressure range of 3.5 PSI absolute to 20 PSI absolute. The tests will therefore be performed at atmospheric pressure.

### 6.5 Vibration Conditions

Vibration normally occurring in transport will be addressed under test plan 178, ISO/ANSI performance testing, and is not expected to adversely affect the structural aspects of the transport package. The rear plate assembly fastening system however could possibly be affected by transport vibration. These fasteners are preloaded or stretched within the materials proportional limit by a specified torque applied during assembly. The assembly preload is designed to withstand dynamic forces and vibration normal to transport. The vibration test of test plan 178 will verify the performance of the fastening system when subjected to vibration normally occurring in transport.

# Section 7 Material and Equipment List

The equipment list worksheets in Section 9 identify the equipment required, with additional space to list other necessary equipment and measuring instruments needed to perform the tests. Additional materials and equipment used to facilitate the tests will be listed as needed.

# Section 8 Test Procedure

All test specimens must follow the planned sequence presented below. Any change to the planned drop orientations shall require a documented justification and description for the new orientation.

## *8.1 Test Sequence*

1. Test specimen preparation and inspection.
2. Compression test or analysis (10 CFR 71.71 (c) (9))
3. Penetration test (10 CFR 71.71 (c) (10))
4. 1.2m (Four-foot) free drop test (10 CFR 71.71(c) (7))
5. Optional test inspection (radiation profile)
6. 9m (30-foot) free drop test (10 CFR 71.73(c) (1))
7. Puncture test (10 CFR 71.73(c) (3))
8. Test inspection.
9. Thermal assessment (10 CFR 71.73(c) (4)).
10. Final test inspection and/or assessment.
11. Test specimen storage.

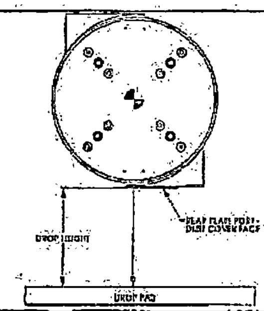
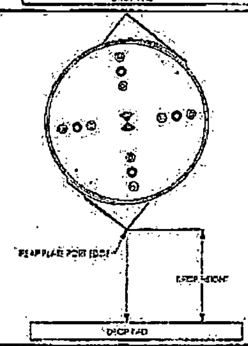
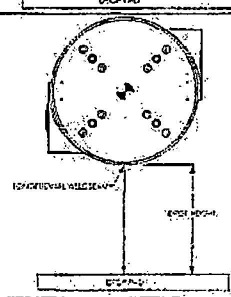
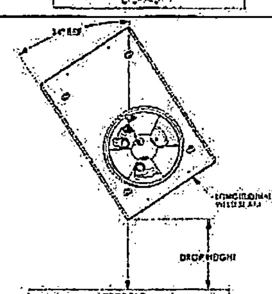
## *8.2 Test Specimen Preparation and Inspection*

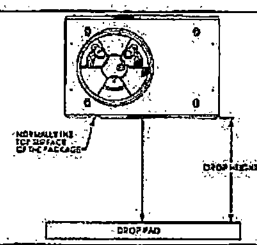
1. Manufacture the SENTRY test specimen per table 6.1.
2. Inspect the test specimens to ensure that:
   - All fabrication and inspection records are documented in accordance with the QSA Global Quality Assurance Program.
   - The test specimens comply with the requirements of the drawing.
3. Perform and record the radiation profile in accordance with QSA Global Work Instruction WI-Q-1806.
4. Engineering, Regulatory Affairs and Quality Assurance will jointly verify that the test specimens comply with the drawings and the QSA Global Quality Assurance Program.
5. Prepare the test specimens for transport.

### 8.3 Drop Test Orientation Overview

This section provides an overall look at the test specimen orientations for each test.

**Table 8.3 Free Drop Test Orientation Overview**

| Drop Orientation # | Test Specimen Serial Number | Impact Point | Diagram | Failure Mode(s) |
|---|---|---|---|---|
| 1 | **SENTRY 330 Projector – Basic Configuration**<br>Serial Number: **TP180A** | Hit square on the rear plate port. |  | Failure modes #2 & #3: attempt to shift shield enough to damage source wire and/or #4: break rear plate attachment bolts. |
| 2 | **SENTRY 330 Projector – Basic Configuration**<br>Serial Number: **TP180B** | Hit the edge of the rear plate port. |  | Failure mode #4 & #3: attempt to bend port enough to break rear plate attachment bolts or other important lock parts. |
| 3 | **SENTRY 330 Projector – Basic Configuration**<br>Serial Number: **TP180C** | Hit on the side of the shell directly on the seam weld. |  | Failure mode **#1B**: attempt to fracture shell seam weld and/or **#2**: shift shield away from source. |
| 4 | **SENTRY 330 Projector – Basic Configuration**<br>Serial Number: **TP180D** | Hit on the edge of the shell directly on the seam weld. |  | Failure Mode **#1B**. Attempt to fracture shell longitudinal and edge welds. |

| | | | | |
|---|---|---|---|---|
| 5 | **SENTRY 330 Projector – Basic Configuration**<br><br>Serial Number: **TP180E** | Hit square on the top surface of the welded body. |  | Failure mode **#1A**: attempt to fracture the shield and/or **#2 & #3**: shift shield away from source. |
| 6 | **SENTRY 330 Projector – Standard Configuration**<br><br>Serial Number: **TP180F** | Evaluate after drop orientation #1 thru #5 | Based on worst case damage from drop orientations #1 thru #5. | TBD |
| 7 | **SENTRY 330 Projector – Special Configuration**<br><br>Serial Number: **TP180G** | Evaluate after drop orientation #1 thru #5 | Based on worst case damage from drop orientations #1 thru #5. | TBD |
| 8 | **SENTRY Source Changer**<br><br>Serial Number: **TP180J** | Evaluate after drop orientation #1 thru #5 | Based on worst case damage from drop orientations #1 thru #5. | TBD |
| 9 | **SENTRY 330 Projector – Basic Alternate Configuration**<br><br>Serial Number: **TP180H** | Evaluate after drop orientation #1 thru #5 | Based on worst case damage from drop orientations #1 thru #5. | TBD |

## 8.4 Compression Test or Analysis

The compression test is a normal condition of transport test. The package is subjected for 24 hours to a compressive load applied uniformly to the top and bottom of the package in the position in which the package would normally be transported. The compressive load must be equivalent to either 5 times the weight of the package or 2 $lbf/in^2$ times the vertically projected surface area of the package, whichever is greater.

The maximum package weight is 780 lbs per table 3.1. Five times the maximum package weight is equal to 3900 lbs. The total vertically projected surface area of the package is 255 $in^2$. This area times 2 $lbf/in^2$ is equal to 510 lbs. Therefore, 3900 lbs will be applied to the package for the compression test.

### 8.4.1 Compression Test Set-up

To set up a package for the compression test:

1. Place the test specimen in its normal transport orientation.
2. Gradually and uniformly apply the 3900 lbs load to the top surface of the test specimen.
3. Set and start the timer for 24 hours.
4. Measure and record the ambient temperature.
5. Photograph the set-up.
6. After 24 hours, remove the applied 3900 lbs load.
7. Record the damage to the package and take a photographic record.

### 8.4.2 Compression Test Assessment

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

- Review the test execution to ensure that the test was performed in accordance with 10 CFR 71, IAEA TS-R-1 1996, and this test plan.
- Make a preliminary evaluation of the specimens relative to the requirements of 10 CFR 71 and IAEA TS-R-1 1996.
- Assess the damage to each specimen to decide whether testing of that specimen is to continue.

## 8.5 Penetration Test

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

The 3/8 inch thick stainless steel welded body of the SENTRY transport package will easily withstand and probably just dent slightly from the impact of the 13 lbs steel cylinder (penetration bar) dropped from 40 inches. The most vulnerable exposed surface of the package is the plunger lock of the rear plate dust cover. Therefore, the plunger lock will be the target for this test.

### 8.5.1 Penetration Test Set-up

To set up a package for the penetration test:

1. Orient the specimen so the plunger lock of the rear plate dust cover faces up towards the dropping direction of the penetration bar.
2. Raise the penetration bar
3. Measure and record the ambient temperature.
4. Photograph the set-up.
5. Drop the penetration bar.
6. Record the damage to the package and take a photographic record.

### 8.5.2 Penetration Test Assessment

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

- Review the test execution to ensure that the test was performed in accordance with 10 CFR 71, IAEA TS-R-1 1996, and this test plan.
- Make a preliminary evaluation of the specimens relative to the requirements of 10 CFR 71 and IAEA TS-R-1 1996.
- Assess the damage to each specimen to decide whether testing of that specimen is to continue.

## 8.6 1.2m & 9m Free Drop Tests

The 1.2 meter free drop test is a normal conditions of transport test. This test is meant to induce normal transport damage as a precondition the test specimen for the hypothetical accident sequence.

The 9 meter free drop test is the hypothetical accident conditions test. This test is meant to demonstrate compliance to the hypothetical accident sequence.

Unless determined otherwise, the 9 meter drop orientation will be identical to the 1.2 meter orientation for all five differently oriented test specimens.

The 1.2 meter (4 foot) and 9 meter (30 foot) drop heights are minimum heights. The actual or adjusted free drop heights shall be recorded on the test data sheet.

### 8.6.1 1.2m & 9m Free Drop Test Set-up

To set up a package for the specified drop test:

1. Place each specimen on the drop surface and position it according to the specimen-specific orientation.
2. Raise the package so that the impact target is at the specified height above the drop surface. Ensure the center of gravity is over the impact point
3. Measure and record the ambient temperature.
4. Photograph the set-up.
5. Start the video recorder.
6. Drop the package.
7. Stop the video recorder.
8. Record the damage to the package and take a photographic record.

### 8.6.2 Specimen TP180A 1.2m & 9m Free Drop Test Orientation

Figure 8.6.2 shows the package orientation for Specimen TP180A. This drop orientation attempts to induce failure modes #2 & #2 (Table 4.1.), shift the shield enough to break the source wire and/or failure mode #4, remove the rear-plate attachment bolts, BLT015. The impact surface is on the extended face of the dust cover and rim of the rear-plate access port.

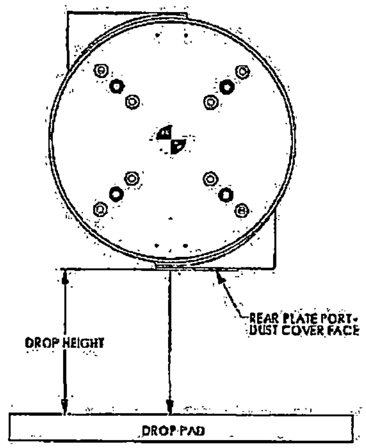



**Figure 8.6.2: Specimen TP180A Free Drop Orientation**

### *8.6.3 Specimen TP180B 1.2m & 9m Free Drop Test Orientation*

Figure 8.6.3 shows the package orientation for Specimen TP180B. The drop orientation attempts to induce failure mode #3 & #4, damage the rear-plate access port to bend the rear-plate and remove the rear-plate attachment bolts, BLT015 or other important lock parts. The impact point is the edge of the rear-plate access port.

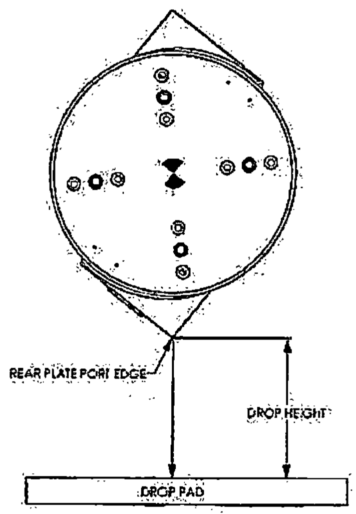



**Figure 8.6.3: Specimen TP180B Free Drop Orientation**

### *8.6.4 Specimen TP180C 1.2m & 9m Free Drop Test Orientation*

Figure 8.6.4 shows the package orientation for Specimen TP180C. The drop orientation attempts to induce failure mode #1B, fracture the shells seam weld and/or #2, shift the shield away from the source. The impact point is on the side of the shell directly on the seam weld.

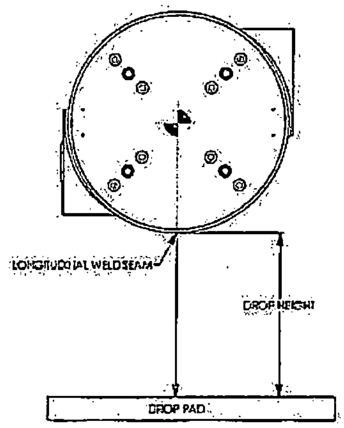



**Figure 8.6.4: Specimen TP180C Free Drop Orientation**

### 8.6.5 Specimen TP180D 1.2m & 9m Free Drop Test Orientation

Figure 8.6.5 shows the package orientation for Specimen TP180D. The drop orientation attempts to induce failure mode #1B, fracture the shell longitudinal and edge welds. The impact point is on the edge of the shell directly on the seam weld.

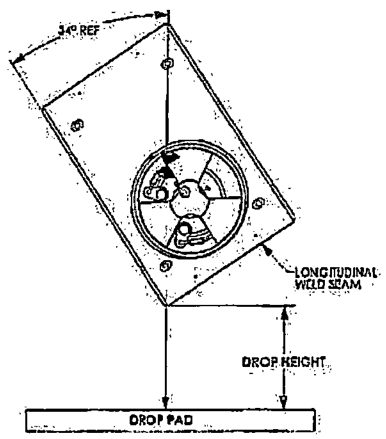



**Figure 8.6.5: Specimen TP180D Free Drop Orientation**

### 8.6.6 Specimen TP180E 1.2m & 9m Free Drop Test Orientation

Figure 8.6.6 shows the package orientation for Specimen TP180E. The drop orientation attempts to induce failure mode #3, shift the shield away from the source and/or #1A, fracture shield to cause a reduction in shielding. The impact point is square on the top surface of the package.

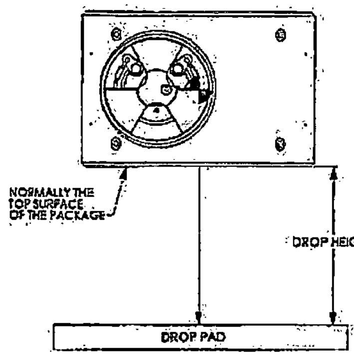



**Figure 8.6.6: Specimen TP180E Free Drop Orientation**

### 8.6.7 1.2m & 9m Free Drop Test Assessment

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

- Review the test execution to ensure that each test was performed in accordance with 10 CFR 71, IAEA TS-R-1 1996, and this test plan.
- Make a preliminary evaluation of the specimens relative to the requirements of 10 CFR 71 and IAEA TS-R-1 1996.
- Assess the damage to each specimen to decide whether testing of that specimen is to continue.
- Assess the damage on each specimen at the rear-plate attachment area to determine whether testing the thinner rear-plate of the SENTRY 110 Projector – Basic configuration needs to performed.
- Evaluate the condition of each specimen after the 1.2m free drop test to determine what changes, if any, are necessary in package orientation in the 30-foot drop test to achieve maximum damage.
- Evaluate the condition of each specimen after the 9m free drop test to determine what changes, if any, are necessary in package orientation in the puncture test to achieve maximum damage.

## 8.7 Puncture Tests

The package is dropped from a height of at least 1m (40") onto the puncture billet. This test uses the 12" high puncture billet. The billet meets the minimum height (8") required in 10 CFR 71.73(c) (3). The specimen has no projections or overhanging members longer than 12" which could act as impact absorbers, allowing the billet to cause the maximum damage to the specimen. The billet is to be bolted to the drop surface used in the drop tests.

The justification for each puncture orientation is the same as the orientation for the 30-foot drop test. If the orientation needs to be changed, the new orientation must be documented and approved with a justification describing how it would be a worst condition than the planned orientation.

### 8.7.1 Puncture Test Set-up

**NOTE:** *Because each test is designed to add to damage inflicted on a specific component or assembly in the preceding test, it is important that each specimen maintain its identity throughout the battery of tests and that the set-up instructions specific to the specimen are strictly followed.*

To set up a package for the puncture test:

1. Measure and record the weight of the test specimen.
2. Measure and record the ambient temperature.
3. Position the test package according to the specimen-specific orientations of figure 8.6.2 through 8.6.6 or to an orientation otherwise justified and approved prior to the test.
4. Raise the package so that the impact target is <u>at least</u> 1m (40") between the impact point on the package and the top of the puncture billet.
5. Photograph the set-up.
6. Start the video recorder.
7. Drop the package.
8. Stop the video recorder.
9. Record the damage to the package and take a photographic record.

### 8.7.2 Puncture Test Assessment

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

- Review the test execution to ensure that the tests were performed in accordance with 10 CFR 71, IAEA TS-R-1 1996, and this test plan.
- Make a preliminary evaluation of each specimen relative to the requirements of 10 CFR 71 and IAEA TS-R-1 1996.
- Justify and identify the orientation to subject the SENTRY 330 Projector - Standard, SENTRY 330 Projector - Special, SENTRY 330 Projector - Alternate, and SENTRY Source Changer configurations.

### 8.8 SENTRY 330 Projector - Standard Configuration Test Sequence

Repeat the 4-foot, 30-foot, and puncture drop test sequence on the SENTRY 330 Projector – Standard configuration test specimen per the orientation selected in section 8.7.2. Document and justify the selected orientation.

### 8.9 SENTRY 330 Projector- Special Configuration Test Sequence

Repeat the 4-foot, 30-foot, and puncture drop test sequence on the SENTRY 330 Projector – Special configuration test specimen per the orientation selected in section 8.7.2. Document and justify the selected orientation.

### 8.10 SENTRY Source Changer Configuration Test Sequence

Assess the damage to the SENTRY 330 Projector – Standard configuration and determine whether testing is required for the SENTRY Source Changer configuration. If testing is required, then repeat the 4-foot, 30-foot, and puncture drop test sequence on the SENTRY Changer test specimen per the orientation selected in section 8.7.2 or another worst case orientation. Document and justify the selected orientation.

### 8.11 SENTRY 330 Projector – Alternate Configuration Test Sequence

Assess the damage to the SENTRY 330 Projector – Basic configuration and determine whether testing is required for the SENTRY 330 Projector - Alternate configuration. If testing is required, then repeat the 4-foot, 30-foot, and puncture drop test sequence on the SENTRY 330 Projector – Basic Alternate test specimen per the orientation selected from section 8.7.2 or another worst case orientation. Document and justify the selected orientation.

### 8.12 Test Inspection

Perform the test inspection after the puncture tests.

1. Measure and record the damage to each of the test specimens.
2. Measure and record the package for signs of any permanent strain.
3. Remove and assess the condition of the simulated source.
4. Reassemble the packages using a representative active source, making sure that the source position and the package configuration are the same as they were immediately after the puncture test.
5. Measure and record a radiation profile of each test specimen in accordance with QSA Global Work Instruction WI-Q-1806.
6. Assess the significance of any change in radiation at the surface and at one meter from the packages.
7. Determine whether it is necessary to radiograph the test specimens for inspection of hidden component damage or failure.
8. Record any damage or failure found in radiograph of the test specimens, if performed.

## 8.13 Thermal Test Assessment

Each test specimen shall be assessed to determine whether the test specimen will pass the thermal test.

The assessment will be based on the examination of the damage to the test specimen after the puncture test. Experience from thermal testing the Model 660 & Model 680 transport packages has shown the shield will oxidize and diminish its ability to protect only when the adjacent foam fill is allowed to combust and then fall away from the shield. Charred foam seems to provide enough thermal insulation to prevent the shield from oxidizing as long as the charred foam remains in place. Any damage producing an unintentional opening in the shell or welded body would need to be assessed to determine whether the transport package would pass or fail the thermal test.

**Engineering, Regulatory Affairs, and Quality Assurance** team members will make a final assessment of each test specimen and jointly determine whether the specimens meet the requirements of 10 CFR 71 and IAEA TS-R-1 1996.

## 8.14 Test Specimen Storage

Place the test specimens in an appropriate container and store the container in the "low level" waste room. Written management approval is needed to dispose of any test specimen of this test plan. If the specimens are disposed of, then include a copy of the signed disposal approval in the SENTRY design history file.

## Section 9 Worksheets

Use the following worksheets for executing the tests of section 8. Each test shall have three worksheets; an equipment list, a procedure checklist, and a data sheet. Record the information onto copies of these worksheets for each test performed.

Attach a copy of the relevant inspection report or calibration certificate after the range and accuracy of the equipment has been verified.

## Test Specimen & Equipment List

| Test Specimen & Equipment Documentation | | | | | |
|---|---|---|---|---|---|
| **Test Specimen** | | | | | |
| **Configuration** | **Drawing Number** | **Serial Number** | **Attach IIR** | **Attach NCR** | **Attach Route Cards** |
| | | | | | |
| | | | | | |
| | | | | | |
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| Tools & Equipment | | |
|---|---|---|
| **Tool Description** | **Enter the Model and Serial Number Mark NA when not used.** | **Attach Inspection Report or Calibration Certificate** |
| Drop Surface, Drawing No. T10122 | | |
| Puncture Billet, Drawing No. T10143 | | |
| Penetration Bar, Drawing No. T10129 | | |
| Thermometer | | |
| ***Record any additional tools used to facilitate the test and attach the appropriate inspection report or calibration certificates.*** | | |
| | | |
| | | |
| **Signature** | **Print Name** | **Date** |
| Engineering: | | |
| Regulatory: | | |
| Quality Assurance: | | |

## Compression Test Checklist

| | | |
|---|---|---|
| **Test:** | | |
| **Test Location:** | | |
| **Step** | **Data** | |
| 1. Record test specimen serial number: | | |
| 2. Record the test specimen weight: | | |
| 3. Record the ambient temperature (°C): | | Instrument S/N: |
| 4. Place the test specimen in its normal transport orientation. | | |
| 5. Record compression load (stack weight). | | |
| 6. Photograph set-up. | | |
| 7. Record the damage to the test specimen. Use a separate sheet and attach, if needed. | | |
| 8. Engineering, Regulatory Affairs and Quality Assurance make a preliminary assessment relative to 10 CFR 71. Record the assessment on a separate sheet and attach. | | |
| **Test witnessed by (Signature)** | **Print Name** | **Date** |
| Engineering: | | |
| Regulatory Affairs: | | |
| Quality Assurance: | | |

## Penetration Test Checklist

| Test: | | |
|---|---|---|
| **Test Location:** | | |
| **Step** | **Data** | |
| 1. Record test specimen serial number: | | |
| 2. Record the test specimen weight: | | |
| 3. Record the ambient temperature (°C): | | Instrument S/N: |
| 4. Identify target location on test specimen. | | |
| 5. Photograph set-up with penetration bar touching target location on test specimen. | | |
| 6. Lift penetration bar 40 inches from target location on test specimen to lowest point on penetration bar. | | |
| 7. Release the penetration bar. | | |
| 8. Photograph target location after impact. | | |
| 9. Record the damage to the test specimen. Use a separate sheet and attach, if needed. | | |
| 10. Engineering, Regulatory Affairs and Quality Assurance make a preliminary assessment relative to 10 CFR 71. Record the assessment on a separate sheet and attach. | | |
| **Test witnessed by (Signature)** | **Print Name** | **Date** |
| Engineering: | | |
| Regulatory Affairs: | | |
| Quality Assurance: | | |

## Free Drop & Puncture Test Checklist

| | | |
|---|---|---|
| **Test:** | | |
| **Test Location:** | | |
| **Step** | **Data** | |
| 1. Record test specimen serial number: | | |
| 2. Record the test specimen weight: | | |
| 3. Record the ambient temperature (°C): | | Instrument S/N: |
| 4. Identify set-up orientation figure: | | |
| 5. Record drop height. | | |
| 6. Photograph set-up in at least two perpendicular planes. | | |
| 7. Begin video recording of the test so that impact is recorded. | | |
| 8. Release the test specimen. | | |
| 9. Stop the video recorder. Ensure the point of impact and orientation specified in the plan has been achieved. | | |
| 10. Record the damage to the test specimen. Use a separate sheet and attach, if needed. | | |
| 11. Engineering, Regulatory Affairs and Quality Assurance make a preliminary assessment relative to 10 CFR 71. Record the assessment on a separate sheet and attach. | | |
| **Test witnessed by (Signature)** | **Print Name** | **Date** |
| Engineering: | | |
| Regulatory Affairs: | | |
| Quality Assurance: | | |

## Compression Test Data Sheet

| Test Unit Model/Serial No.: | Test: |
|---|---|
| Test Date: | Test Time: |

Describe the test orientation:

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

On-site test assessment:

- Was the test performed in accordance with 10 CFR 71, IAEA TS-R-1 1996, and this test plan? Yes or No.
- Does the test specimen meet the requirements of 10 CFR 71 and IAEA TS-R-1 1996 for this test? Yes or No.
- Should testing continue with this test specimen? Yes or No. If yes, next test: ____________________

**Engineering:** **Regulatory:** **QA:**

| Completed by: | Date: |
|---|---|

## Penetration Test Data Sheet

| | |
|---|---|
| Test Unit Model/Serial No.: | Test: |
| Test Date: | Test Time: |
| Describe the test orientation: | |
| Describe on-site inspection (damage, broken parts, etc.): | |

On-site test assessment:

- Was the test performed in accordance with 10 CFR 71, IAEA TS-R-1 1996, and this test plan? Yes or No.
- Does the test specimen meet the requirements of 10 CFR 71 and IAEA TS-R-1 1996 for this test? Yes or No.
- Should testing continue with this test specimen? Yes or No. If yes, next test: ____________________

**Engineering:** **Regulatory:** **QA:**

| | |
|---|---|
| Completed by: | Date: |

## Free Drop & Puncture Test Data Sheet

| | |
|---|---|
| Test Unit Model/Serial No.: | Test: |
| Test Date: | Test Time: |
| Describe drop orientation and drop height: | |
| Describe impact (location, rotation, etc.): | |
| Describe on-site inspection (damage, broken parts, etc.): | |
| On-site test assessment:<br>• Was the test performed in accordance with 10 CFR 71, IAEA TS-R-1 1996, and this test plan? **Yes or No.**<br>• Does the test specimen meet the requirements of 10 CFR 71 and IAEA TS-R-1 1996 for this test? **Yes or No.**<br>• Any changes to subsequent drop orientations needed to achieve maximum damage? Especially for the SENTRY 330 Standard, SENTRY 330 Special, and SENTRY Source Changer configurations. **Yes or No.** If yes, then identify and justify.<br>• Did sufficient damage occur at or on the rear-plate attachment area to warrant further drop testing the SENTRY 110 Projector – Basic configuration because of its thinner rear-plate? **Yes or No.**<br>• Should testing continue with this test specimen? **Yes or No.** If yes, next test: ____________________<br>• Will the test specimen pass the thermal test based on the accumulated damage assessment? **Yes or No**<br>**Engineering:** **Regulatory:** **QA:** | |
| Describe any post-test disassembly and inspection: | |
| Describe any change in source position (if possible): | |
| Describe results of radiography (if performed): | |
| Completed by: | Date: |

## Test Inspection Data Sheet

| | |
|---|---|
| Test Specimen Serial No.: | Last Test Performed: |
| Describe and measure (if appropriate) any damage or broken parts, etc.: | |
| Describe and measure (if appropriate) any signs of permanent strain or deformation: | |
| Describe the condition of the simulated source wire assembly. | |
| Reassemble the package using a representative active source, making sure that the source position and the package configuration is the same as they were immediately after the last test.<br><br>Measure and record a radiation profile of each test specimen in accordance with QSA Global Work Instruction WI-Q-1806. | |
| Compare the pre-test dose levels with post-test dose levels at the surface of the package and at 1 meter from the surface of the package. | |
| Is a radiograph required to inspect for hidden component damage or failure? If radiography is performed, describe any damage or failures found. | |
| Completed by: | Date: |

## 2.12.2 Test Plan 180 Addendum dated 25 February 2010

| QSA GLOBAL | Document Number<br>**F-E-1808-1**<br>**Test Plan Cover Sheet** | Revision<br>0 |
|---|---|---|

# TEST PLAN 180
# ADDENDUM

## SENTRY – Model 860 Projectors & Model 867 Source Changer Type (B) Transport Package Tests

| | | |
|---|---|---|
| Originator | S. Gum | Date: 24 Feb 2010 |

| APPROVALS | | |
|---|---|---|
| Engineering | [signature] | Date: 25 Feb 10 |
| Regulatory | [signature] | Date: 25 Feb 10 |
| Quality Assurance | C. Rumfnan | Date: 25 Feb 2010 |
| | | |
| | | |

# TEST PLAN 180
## ADDENDUM

# SENTRY - MODEL 860 PROJECTORS & MODEL 867 SOURCE CHANGER TYPE (B) TRANSPORT PACKAGE TESTS

February 24, 2010

## Contents

# Test Plan No. 180 Addendum

## Section 1 Introduction

This addendum to test plan 180 outlines the approved changes to the hypothetical accident condition (HAC) tests prompted by the 4-foot free drop test results found during the normal conditions of transport tests conducted earlier. See Test Plan 180 – Report #1.

Except for the changes described herein, test plan 180 shall be followed as planned.

## Section 2 Normal Conditions of Transport Test Results

Test Plan 180 – Report #1 provides the results of the normal conditions of transport tests. Two orientations of the 4-foot free drop tests caused damage to components of the lock cover assembly. The roll pins used for attaching the cover pins were clearly sheared through allowing the dust cover with the lock cover attached to fall way from the rear plate assembly.

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. The lock cover acts as a spacer to reduce the damage of an impact to the end face of the source connector. 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. Once past the lock slide, the source wire would be free to move within the shield and potentially increase radiation levels if the source capsule were to move to the less shielded area at the front plate end of the package.

The 4-screws securing the selector ring retainer and ultimately, the source connector to the shield, were found to be slightly twisted after the 4-foot free drop tests in the same orientations causing damage to the lock cover. It was decided to redesign the selector ring retainer securing mechanism to ensure it remains intact and attached to the rear plate after the 30-foot free drop and puncture drop tests.

## Section 3 Design Changes to the SENTRY Package

There are two design changes to the SENTRY transport package as a result of the normal conditions of transport testing.

The first involves increasing the size and shape of the pins of the lock cover assembly. The roll pins went from a standard duty, 0.062 diameter pin to a heavy duty, 0.188 diameter pin. The cover pins were changed from a 0.28 diameter headless pin to a 0.38 diameter headed pin. The head prevents the pins from detaching from the rear plate in the event the roll pins were to fail. Figure 3.1 show the original lock cover design and Figure 3.2 shows the design with the current changes.

Security-Related Information Figure Withheld Under 10 CFR 2.390

Figure 3.1: Original Lock Cover Design.

Security-Related Information Figure Withheld Under 10 CFR 2.390

Figure 3.2: New Lock Cover Design.

The second change eliminates the 4-screws attaching the selector ring retainer to the rear plate assembly. If these 4-screws were to fail, the selector ring retainer would fall away from the package leaving the source unsecured.

The design change consists of lengthening the selector ring retainer enough to pass through and extend beyond the back-side of the rear plate where it gets clamped in place. Thick sections of the clamp engage into slots in the selector ring retainer preventing it from being pulled away from the rear plate. Once the assembly is attached to the package, it is confined within the mounting bore and cannot become detached unless the rear plate assembly mounting hardware is removed.

Security-Related Information
Figure Withheld Under 10 CFR
2.390

Figure 3.3: Original Rear Plate Assembly Design.

Security-Related Information
Figure Withheld Under 10 CFR
2.390

Figure 3.4: New Rear Plate Assembly Design.

## Section 4 Changes to the Puncture Drop Orientation

Test Plan 180 identifies the puncture drop orientations to be performed for each test specimen in the same orientation as to be conducted in the 30-foot free drop test. Based on the results of the normal conditions of transport tests, a change to the puncture drop orientation for test specimen TP180E is needed.

During the 4-foot free drop, the flat face drop orientation of test specimen TP180E produced the most severe damage to the lock cover and rear plate assemblies directly affecting the overall safety of the package. Any damage or failure occurring to the lock cover or rear plate assemblies from this orientation in the 30-foot free drop should be further exploited in the puncture drop test.

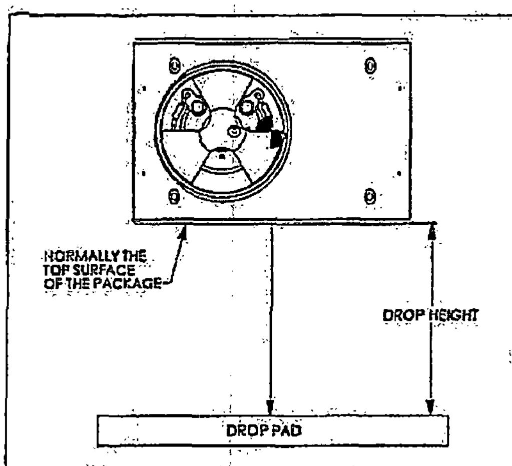



Figure 4.1. 30-foot free drop orientation for test specimen TP180E.

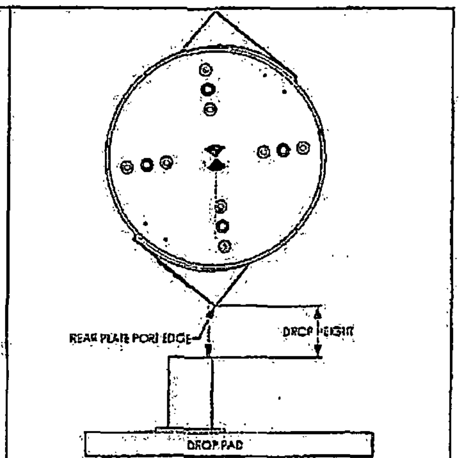



Figure 4.2 Puncture drop orientation for test specimen TP180E.

# Appendix

Test Specimen Manufacturing Records stored in network folders:

> \\GANYMEDE\Cad\2 Released Files (PDF)\Test Plans & Reports (TP)\TP180 SENTRY Transport Testing\Test Specimen Build\Inspection Records\Rear Plate & Lock Cover Change
>
> \\GANYMEDE\Cad\2 Released Files (PDF)\Test Plans & Reports (TP)\TP180 SENTRY Transport Testing\Test Specimen Build\Route Cards & TMIs\Rear Plate & Lock Cover Change

For:

- Lock Cover Assembly, 86023, with component parts.
- Rear Plate assemblies, 86080-110 & 86080-330 with component parts.

### 2.12.3 Test Plan 180 Report #1 dated 14 January 2010

| QSA GLOBAL | Document Number<br>**F-E-1808-1**<br>**Test Plan Cover Sheet** | Revision<br>0 |
|---|---|---|

# TEST PLAN 180 – REPORT #1

## SENTRY – MODEL 860 PROJECTORS & MODEL 867 SOURCE CHANGER

## NORMAL TRANSPORT PACKAGE TEST RESULTS

| | | | |
|---|---|---|---|
| Originator | S. Gemi | Date: | 6 JAN 2010 |

| APPROVALS | | | |
|---|---|---|---|
| Engineering | D. Kl | Date: | 14 Jan 10 |
| Regulatory | [signature] | Date: | 13 Jan 10 |
| Quality Assurance | C. Rongson | Date: | 13 Jan 10 |
| | | | |
| | | | |

# TEST PLAN 180 - REPORT #1

# SENTRY TRANSPORT PACKAGE

# NORMAL TRANSPORT TEST RESULTS

Rev0

Jan 4, 2010

# Contents

# Test Plan 180 - Report #1

## Section 1 Introduction

This report documents the partial test results of Test Plan 180 and covers only the normal transport tests performed on the SENTRY transport package. The results of the hypothetical accident condition tests of Test Plan 180 will be documented in a report at a later date.

The tests results confirm the SENTRY transport package passes the normal transport test requirements, but will require a design modification to the lock cover and rear plate Posilock mechanism to ensure the package will survive the hypothetical accident condition tests.

A weakness in the lock cover, part number 86023, (a sub assembly of the dust cover) and the rear plate Posilock mechanism, part number 86020-330, was discovered after the 1.2 meter (4-foot) free drop test. The lock cover attachment pins sheared off allowing the cover to fall away from the Posilock, leaving the Posilock and the female connector of the source wire assembly vulnerable to damage in subsequent tests. One of the functions of the cover is to protect the Posilock mechanism and connector during the puncture test after the 30-foot free drop test.

The four #10-32 socket head cap screws, part number SCR002, of the rear plate Posilock assembly were also found to be twisted slightly during the post-test examination. Based on this finding, it is believed, these screws could fail during the more severe 30-foot drop test. The function of the four screws is to hold the selector ring retainer to the package securing the source wire assembly in the shield.

All tests were conducted according Test Plan 180, the Code of Federal Regulations, 10 CFR Part 71.71, revised as of March 31, 1999 and criteria stated in the IAEA Regulations for the Safe Transport of Radioactive Material, No. TS-R-1 1996 Edition (Revised).

## Section 2 Construction and Condition of Test Specimens

All SENTRY transport package test specimens are constructed in accordance with QSA Global engineering drawings and Quality Assurance Program. The drawings and quality program accurately represent the intended design along with methods for manufacturing and verifying the finished product.

The five test specimens, serial numbers TP180A thru TP180E, were all built to the basic configuration shown in figure 2.1. The unprotected welded body of the basic configuration represents the worst case test configuration for all the possible failure modes identified in test plan 180.

The standard and/or special configurations with optional handling ribs were not tested because the ribs would provide additional impact absorption and therefore, not considered to be a worst case test condition. The additional weight of the ribs would be offset by the energy absorption the ribs supply upon impact in the 1.2 meter drop test.

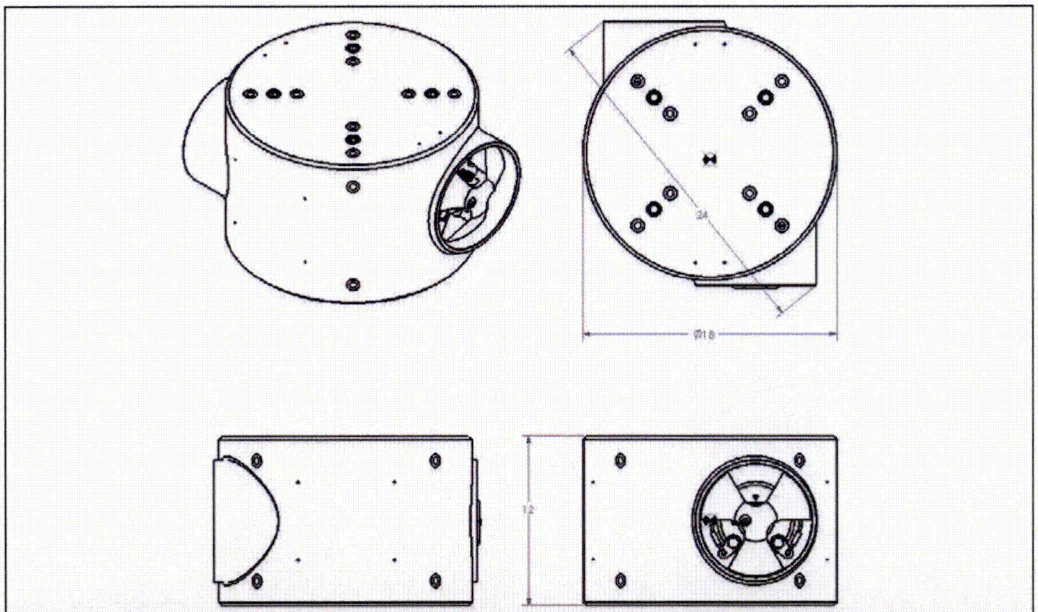


**Figure 2.1. SENTRY Transport Package – Basic Configuration.**

**Table 2.2. Test Specimen Manufacturing Documentation and Identification**

| Test Specimen Configuration | Drawing Number | TMI | Serial Number(s) |
|---|---|---|---|
| SENTRY 330 Projector – Basic | TP86015-330 | 189 | TP180A, TP180B, TP180C, TP180D, TP180E |

There were no significant changes to the test specimen build or construction as described in test plan 180. Any and all deviations and/or changes to the test specimens are recorded on the temporary manufacturing instructions (TMI) for each test specimen (See Appendix).

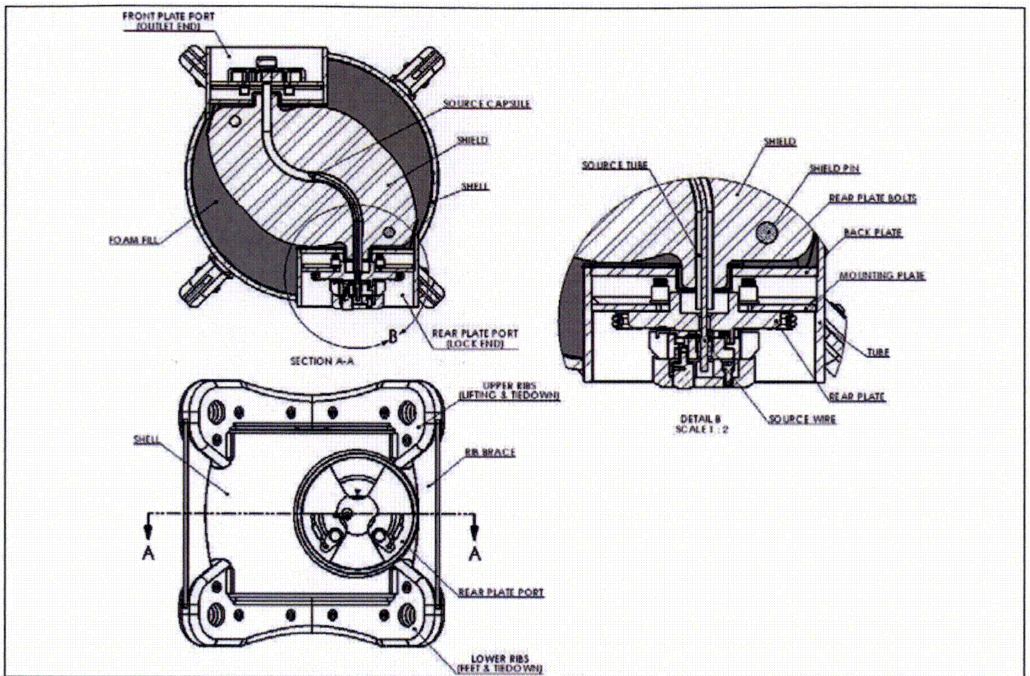



**Figure 2.3. SENTRY Transport Package Common Components Optional Handling Ribs Shown**

Figure 2.4 shows the rear-plate and Posilock assembly of the projector version of the SENTRY transport package. The features shown in figure 2.4 were targeted in the penetration bar and 1.2 meter drop tests.

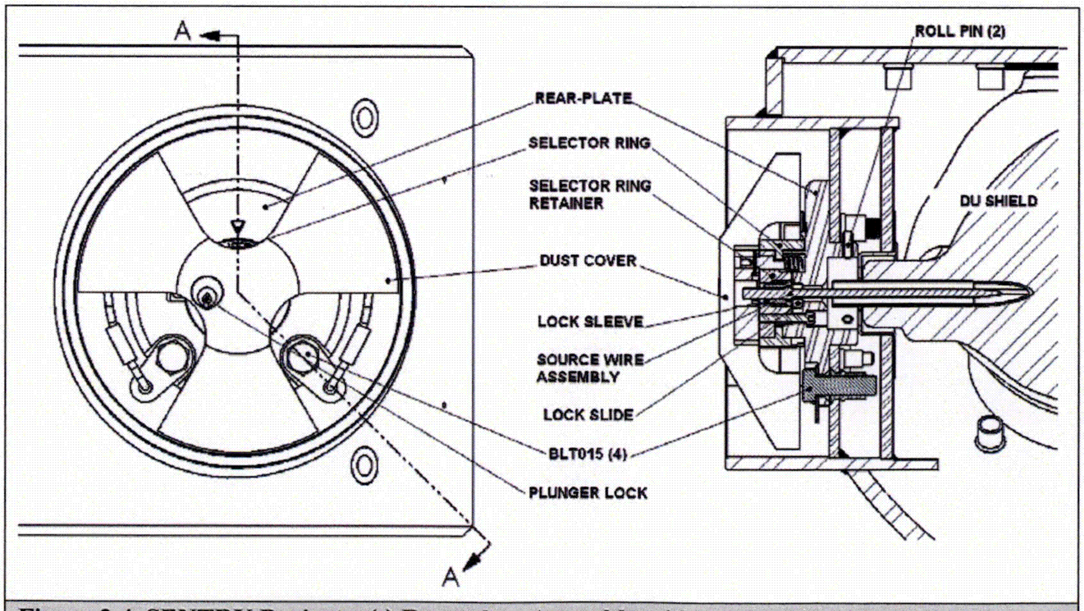



**Figure 2.4. SENTRY Projector(s) Rear-plate Assembly with source wire secured**

# Section 3 Regulatory Compliance

The SENTRY projector/transport package complies with the normal transport package test requirements of 10 CFR 71.71 and IAEA TS-R-1 1996 based on the successful completion of the tests and analysis described in this report.

The pass criteria for a successful normal transport test or analysis is identified 10 CFR part 71.43 paragraph (f). This paragraph states:

> "There should be no loss or dispersal of radioactive contents, no significant increase in external surface radiation levels and no substantial reduction in the effectiveness of the packaging.
>
> IAEA TS-R-1 1996 paragraph 646 stipulates the same criteria except that it also requires that the loss of shielding integrity should not result in more than a 20% increase in the radiation level at any external surface of the package."

## *3.1 Free Drop Height Adjustment*

The free drop test heights specified in 10 CFR Part 71 are adjusted higher to allow for SENTRY transport packages built heavier than the test specimen but less than the maximum package weight. The actual test specimens weigh less than the maximum weight specified on the top level assembly drawing.

Table 3.1 shows the adjusted free drop height based on the actual test specimen weight compared to the maximum transport package weight. The adjusted heights provide impact energy equal to or greater than the maximum transport package weight if dropped at the 10 CFR Part 71 specified drop height.

**Table 3.1. Test Specimen 1.2 Meter Free Drop Height Adjustment**

| Test Specimen | Actual Test Specimen Weight (Lbs) | Maximum Transport Package Weight (Lbs) | 1.2 Meter (4-foot) Adjusted Height | |
|---|---|---|---|---|
| | | | (Meters) | (Feet) |
| TP180A | 655 | 780 | 1.5 | 4.9 |
| TP180B | 656 | 780 | 1.5 | 4.9 |
| TP180C | 652 | 780 | 1.5 | 4.9 |
| TP180D | 657 | 780 | 1.5 | 4.9 |
| TP180E | 659 | 780 | 1.5 | 4.9 |

# Section 4 Test Results

## 4.1 Compression Test

### 4.1.1 Compression Test Requirement

The compression test subjects the transport package to a uniformly applied compressive load to the top and bottom of the package in the position in which the package would normally be transported for 24 hours. The compressive load must be equivalent to either 5 times the weight of the package or 2 pounds per square inch (PSI) times the vertically projected surface area of the package, whichever is greater.

The maximum package weight is 780 pounds per table 3.1. Five times the maximum package weight is equal to 3900 pounds. The total vertically projected surface area of the package is 255 square inches. This area times 2 PSI is equal to 510 pounds. Therefore, 3900 pounds is larger and will be used as the applied load for the test.

### 4.1.2 Compression Test Analysis

The SENTRY transport package is a vertically oriented, 18 inch diameter by 12 inch long, cylindrical tube capped at both ends. The tube and both end caps are 0.38 inch thick type 304 or 304L stainless steel. The minimum yield strength for type 304 or 304L stainless steel material is 30,000 PSI.

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, 20 square inches, into the applied load, 3900 pounds. The resulting compressive stress on the tube's cross section is 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). The calculated factor of safety is 154. A factor of safety of 154 indicates the package is sufficiently strong enough to support the 3900 pound load for an indefinite period of time.

The slenderness ratio of a 12 inch long by 18 inch diameter hollow cylinder establishes the package as a short column. Therefore, for a short column, the strength limit of the tube material determines failure and bucking failure is not a concern.

### 4.1.3 Compression Test Assessment

The compression test was analyzed in accordance with Test plan 180, 10 CFR 71.71, and IAEA TS-R-1 1996. A preliminary evaluation of the specimen relative to the requirements of 10 CFR 71 and IAEA TS-R-1 1996 confirms the package meets the test requirement. The testing shall continue to the penetration test.

## 4.2 Penetration Test

### 4.2.1 Penetration Test Requirement

This test drops a vertically oriented, solid steel, cylindrical bar from a height of 1 m (40 in) onto the exposed surface of the package that is most vulnerable to puncture.

The bar has a diameter of 3.2 cm (1.25 in) with a hemispherical end and a mass of 6 kg (13 lbs). The long axis of the cylinder must be perpendicular to the package surface. The most vulnerable exposed surface of the package is the plunger lock of the rear plate dust cover. Therefore, the plunger lock is the target for the test.

### 4.2.2 Penetration Test Results

Since all SENTRY dust cover assemblies are essentially identical, only 1 penetration test is performed to determine compliance to this test requirement. Test specimen, serial number TP180A, was used for the test. Figure 4.4.1 shows the orientation of the test specimen, figure 4.4.2 shows the penetration bar contacting the brass plunger lock of the black trefoil dust cover, and figure 4.4.3 shows the damage caused by the dropped bar.

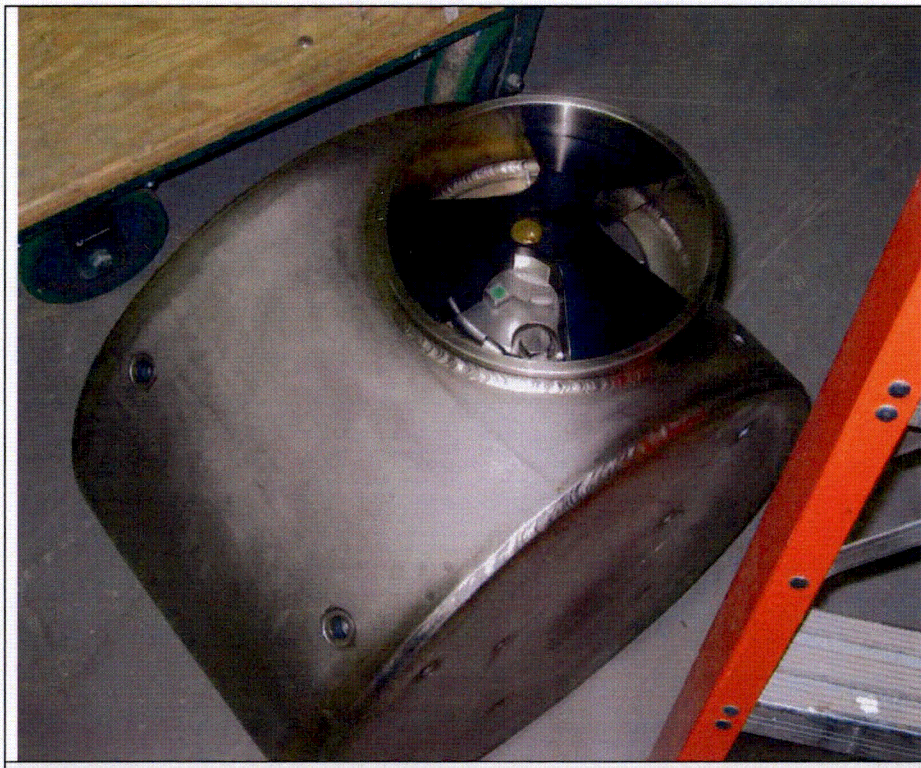


Figure 4.4.1 shows the orientation of test specimen for penetration test.

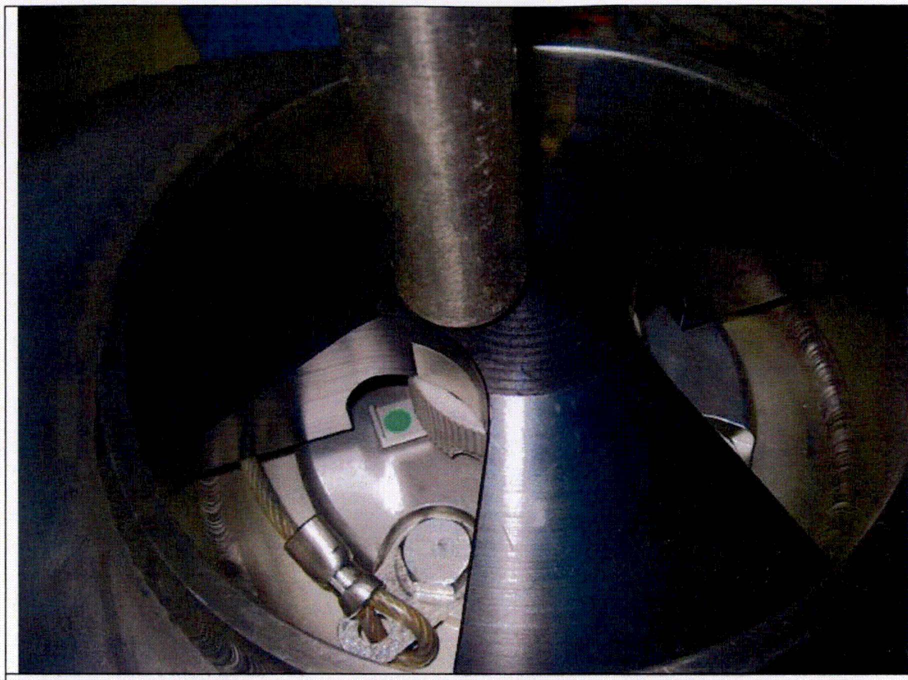


Figure 4.4.2 shows the penetration bar contacting the brass plunger lock.

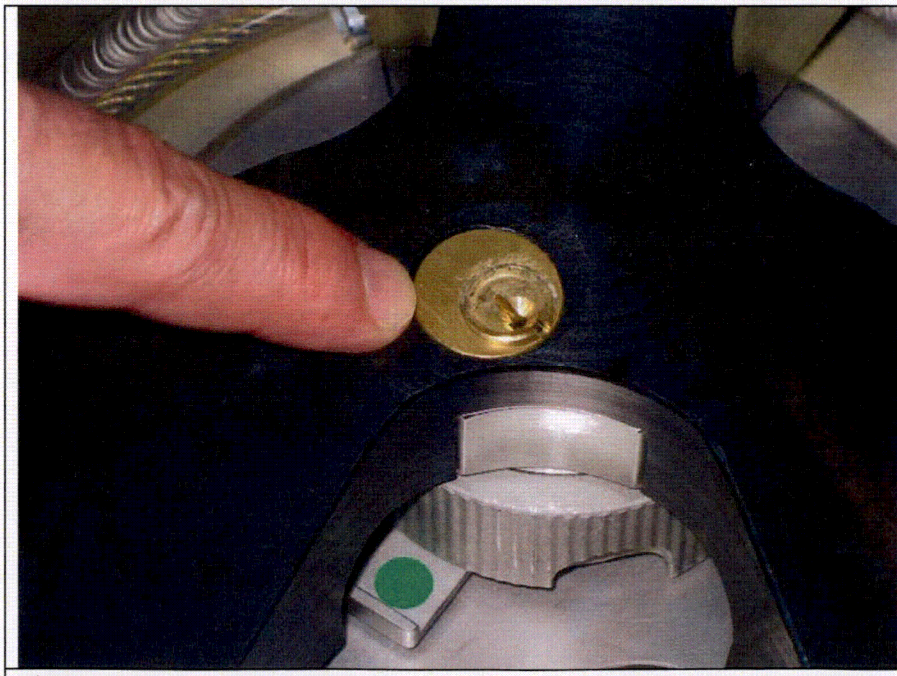


Figure 4.4.3 shows the damage caused by the penetration test.

### *4.2.3 Penetration Test Assessment*

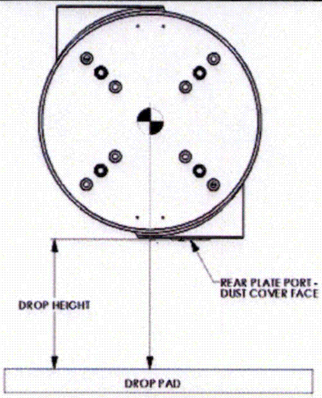
The penetration test was executed in accordance with Test plan 180, 10 CFR 71.71, and IAEA TS-R-1 1996. A preliminary evaluation of the specimen relative to the requirements of 10 CFR 71 and IAEA TS-R-1 1996 confirms the package meets the test requirement. The damage was not sufficient enough to prevent further testing. So, testing shall continue on to the 1.2 meter free drop test.

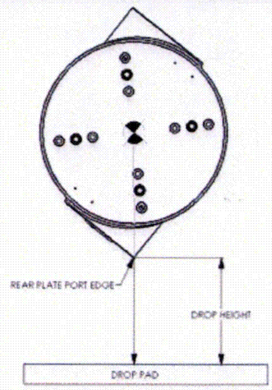
## 4.3 1.2 Meter Free Drop Test

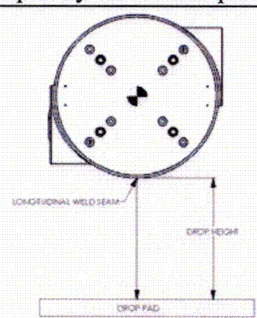
### 4.3.1 1.2 Meter Free Drop Test Requirement

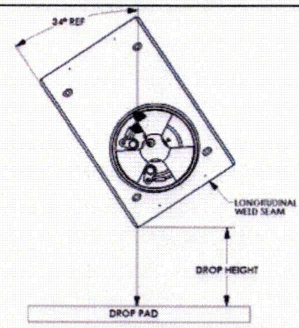
The 1.2 meter free drop test subjects the test specimen to a free drop of at least 1.2 meters (4 feet) onto a rigid, essentially unyielding surface. The orientation of the test specimen during the drop shall be the most unfavourable relative to the failure modes identified in test plan 180.

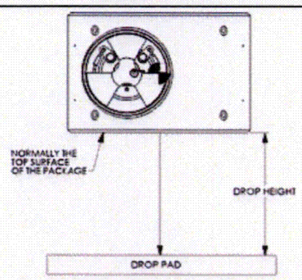
### 4.3.2 1.2 Meter Free Drop Test Orientation Review

<table>
<tr><th colspan="2">Table 4.4.2 Free Drop Test Orientation Review</th></tr>
<tr>
<td>

Test Specimen: TP180A<br>Hit squarely on the rear plate port.</td>
<td>

Test Specimen: TP180B<br>Hit the edge of the rear plate port.</td>
</tr>
<tr>
<td>

Test Specimen: TP180C<br>Hit on the side of the shell directly on the seam weld.</td>
<td>

Test Specimen: TP180D<br>Hit on the edge of the shell directly on the seam weld.</td>
</tr>
<tr>
<td>

Test Specimen: TP180E<br>Hit squarely on the top surface of the welded body.</td>
<td></td>
</tr>
</table>

### 4.3.3 1.2 Meter Free Drop Test Results

#### 4.3.3.1 1.2 Meter Free Drop Test – TP180A Results

| Test Specimen TP180A Test Setup - 1.2 Meter Free Drop Test | |
|---|---|
| Changes to the planned drop orientation. | None |
| Test Specimen Weight | 655 pounds |
| Actual Drop Height | 4 feet and 9 inches (57 inches) |
| Temperature during test | 51 F |


Figure 4.4.3.1.A. Side View Orientation

Figure 4.4.3.1.B. End View Orientation

| Test Specimen TP180A Damage Report - 1.2 Meter Free Drop Test | |
|---|---|
| The black plastic dust cover compressed slightly into 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. Could not unlock source wire for examination. The source location within the package did not change. Therefore, there is no expected change in the external radiation dose levels of the package. | |
| Pre-test source location dimension | 6-5/8 inches |
| Post-test source location dimension | 6-5/8 inches |

Figure 4.4.3.1.C. Dust cover and port tube damage.

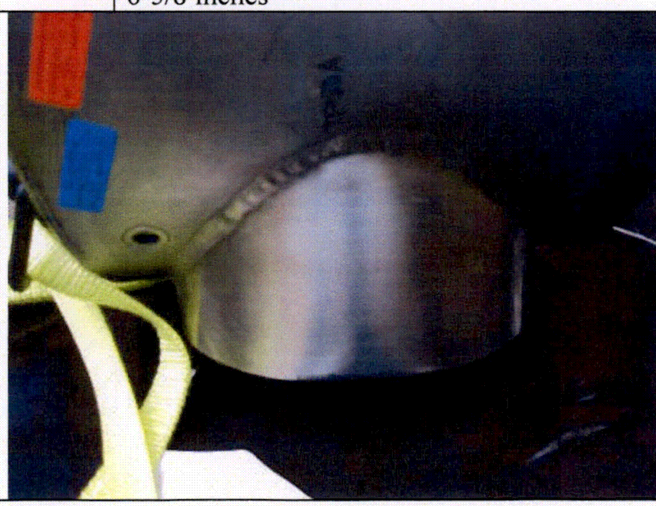


Figure 4.4.3.1.D. Close-up of the bent port tube.

### 4.3.3.2 1.2 Meter Free Drop Test – TP180B Results

| Test Specimen TP180B Test Setup - 1.2 Meter Free Drop Test | |
|---|---|
| Changes to the planned drop orientation. | None |
| Test Specimen Weight | 656 pounds |
| Actual Drop Height | 4 feet and 9 inches (57 inches) |
| Temperature during test | 51 F |


Figure 4.4.3.2.A. Side View Orientation

Figure 4.4.3.2.B. End View Orientation

| Test Specimen TP180B Damage Report - 1.2 Meter Free Drop Test | |
|---|---|
| The welded port tube bent in towards the dust cover by about 1 inch. No damage was found on the simulated source wire and/or rear plate attachment bolts. The source location within the package appears to have changed slightly. A post-test radiation profile inspection shows no change in the external radiation dose levels of the package. | |
| Pre-test source location dimension | 6-5/8 inches |
| Post-test source location dimension | 6-1/2 inches |

Figure 4.4.3.2.C. Port tube damage.

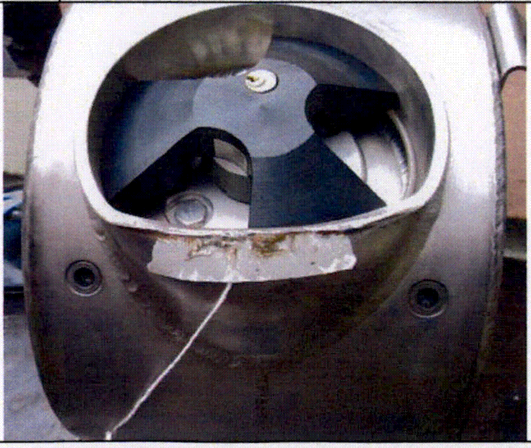


Figure 4.4.3.2.D. Close-up of the bent port tube.

#### 4.3.3.3 1.2 Meter Free Drop Test – TP180C Results

| Test Specimen TP180C Test Setup - 1.2 Meter Free Drop Test | |
|---|---|
| Changes to the planned drop orientation. | None |
| Test Specimen Weight | 652 pounds |
| Actual Drop Height | 4 feet and 9 inches (57 inches) |
| Temperature during test | 52 F |


Figure 4.4.3.3.A. Side View Orientation

Figure 4.4.3.3.B. End View Orientation

| Test Specimen TP180C Damage Report - 1.2 Meter Free Drop Test | |
|---|---|
| The longitudinal seam of the welded body shows minor deformation. No break in weld seam. No damage was found on the simulated source wire and/or rear plate attachment bolts. The source location within the package did not change. Therefore, there is no expected change in the external radiation dose levels of the package. | |
| Pre-test source location dimension | 6-5/8 inches |
| Post-test source location dimension | 6-5/8 inches |


Figure 4.4.3.3.C. Dent to weld seam.


Figure 4.4.3.3.D. Close-up of the weld seam.

### 4.3.3.4 1.2 Meter Free Drop Test – TP180D Results

| Test Specimen TP180D Test Setup - 1.2 Meter Free Drop Test | |
|---|---|
| Changes to the planned drop orientation. | None |
| Test Specimen Weight | 657 pounds |
| Actual Drop Height | 4 feet and 9 inches (57 inches) |
| Temperature during test | 51 F |

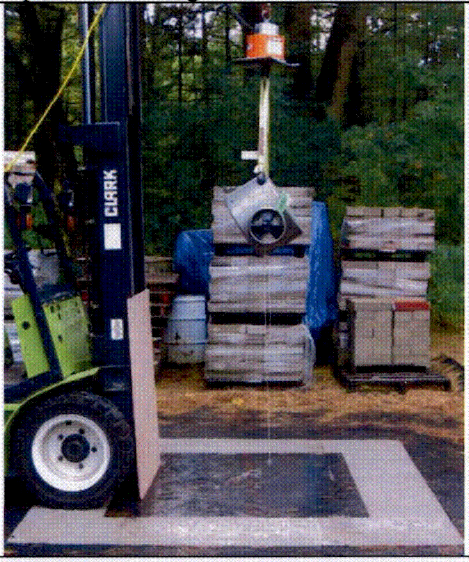



Figure 4.4.3.4.A. Side View Orientation

Figure 4.4.3.4.B. End View Orientation

| Test Specimen TP180D Damage Report - 1.2 Meter Free Drop Test | |
|---|---|
| The end seam of the welded body shows slight deformation. No break in the weld seam. No damage was found on the simulated source wire and/or rear plate attachment bolts. The source location within the package did not change. Therefore, there is no expected change in the external radiation dose levels of the package. | |
| Pre-test source location dimension | 6-5/8 inches |
| Post-test source location dimension | 6-5/8 inches |

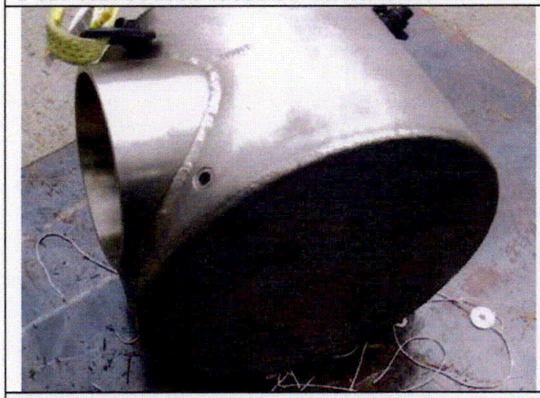


Figure 4.4.3.4.C. Dent to weld seam.

Figure 4.4.3.4.D. Close-up of the weld seam.

### *4.3.3.5 1.2 Meter Free Drop Test – TP180E Results*

| Test Specimen TP180E Test Setup - 1.2 Meter Free Drop Test | |
|---|---|
| Changes to the planned drop orientation. | None |
| Test Specimen Weight | 659 pounds |
| Actual Drop Height | 4 feet and 9 inches (57 inches) |
| Temperature during test | 51 F |


Figure 4.4.3.5.A. Side View Orientation

Figure 4.4.3.5.B. End View Orientation

| Test Specimen TP180E Damage Report - 1.2 Meter Free Drop Test | |
|---|---|
| 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 Posilock after the test reveals a slight twisting of the #10-32 screws holding the selector ring retainer to the assembly. No other damage was found on the welded body, simulated source wire and/or rear plate attachment bolts. The source location within the package appears to have changed slightly. A post-test radiation profile inspection shows no change in the external radiation dose levels of the package. | |
| Pre-test source location dimension | 6-5/8 inches |
| Post-test source location dimension | 6-1/2 inches |

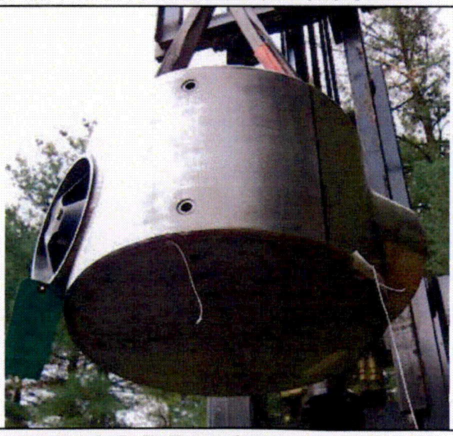


Figure 4.4.3.5.C. Post drop view of impact surface (bottom). Note – the black plastic dust cover is intact at this point in the test.

Figure 4.4.3.5.D. The black plastic dust cover fell away from the rear plate assembly when unit was moved after the test. The roll pins holding the lock pins failed in shear.

#### *4.3.4 1.2 Meter Free Drop Test Assessment*

The 1.2 meter free drop test was performed in accordance with test plan 180, 10 CFR 71, IAEA TS-R-1 1996.

After the 1.2 meter free drop test, all test specimens continued to successfully meet the normal transport requirements of 10 CFR 71 and IAEA TS-R-1 1996. There was no loss or dispersal of radioactive contents, no significant increase in external surface radiation levels and no substantial reduction in the effectiveness of the packaging. There was no loss of shielding integrity resulting in more than a 20% increase in the radiation level at any external surface of the package.

Since the orientation of test specimen TP180E caused the roll pins of the lock cover to shear allowing the dust cover to fall away from the package and the #10-32 screws holding the selector ring retainer appeared to have a slight twist, these features will require a modification to increase the robustness of these items in order to successfully meet the hypothetical accident condition test requirements of 10 CFR 71, IAEA TS-R-1 1996. Once redesigned, only 1.2 meter free drop test in the orientation of test specimen TP180E needs to be repeated.

#### *4.3.5 Testing the other SENTRY Configurations*

Based on the assessments given for each SENTRY configuration below, the compression, penetration, and 1.2 meter free drop tests do not need to be performed for these other SENTRY configurations.

##### *4.3.5.1 SENTRY 330 or 110 Projector - Standard Configuration*

The compression, penetration, and 1.2 meter free drop tests do not need to be performed on this configuration because failure of the handling ribs would not affect the radiation safety of the package. Dose levels would not increase, the contents would not be released, and the overall effectiveness of the package would not be compromised.

##### *4.3.5.2 SENTRY 330 or 110 Projector - Special Configuration*

The compression, penetration, and 1.2 meter free drop tests do not need to be performed on this configuration because failure of the handling ribs without the plastic inserts would not affect the radiation safety of the package. Dose levels would not increase, the contents would not be released, and the overall effectiveness of the package would not be compromised.

##### *4.3.5.3 SENTRY 330 or 110 Projector - Alternate Configuration*

The compression, penetration, and 1.2 meter free drop tests do not need to be performed on this configuration because no test orientation affected the rear plate assembly enough to reduce the radiation safety of the package. Dose levels would not increase, the contents would not be released, and the overall effectiveness of the package would not be compromised.

##### *4.3.5.4 SENTRY Source Changer - Standard Configuration*

The compression, penetration, and 1.2 meter free drop tests do not need to be performed on this configuration because no test orientation affected the rear plate assembly enough to reduce the radiation safety of the package. Dose levels would not increase, the contents would not be released, and the overall effectiveness of the package would not be compromised.