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TEST PLAN 213 - REPORT

MODEL 867
SENTRY CHANGER
TRANSPORT PACKAGE
TEST RESULTS

Originator	S. Gresni	Date: 16 JUN 2015
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APPROVALS		
Engineering	S. Gresni	Date: 16 JUN 2015
Regulatory	[signature]	Date: 17 Jun 15
Quality Assurance	[signature]	Date: 17 Jun 15

TEST PLAN 213 - REPORT

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Rev0

June 15, 2015

Contents

Test Plan 213 - Report

Section 1 Introduction

This report documents the results of the Model 867 SENTRY source changer with the new shielded dust cover design tested and/or assessed to the normal conditions of transport (NCT) and hypothetical accident conditions (HAC) test requirements specified in Test Plan 213, the Code of Federal Regulations, 10 CFR Part 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(2009 Edition).

The family of SENTRY transport packages, consisting of the SENTRY 110 projector, SENTRY 330 projector, and Model 867 source changer, were all previously tested to and successfully passed the NCT and HAC test requirements under test plans 180 and 195. The previous testing shall be used to qualify the Model 867 with new dust cover design for package orientations and conditions not covered in this report.

In order to determine the cumulative effect on the Model 867 transport package, the HAC test evaluation is based on the sequential application of the tests specified in the order indicated in 10 CFR Part 71. See **section 5.2** for this assessment. Alternatively, if the test sequence had been performed in reverse order to the sequence identified in 10 CFR Part 71, with the puncture test performed before the 30-foot free drop, the damage indicates that there would be no change in the final assessment. See **section 5.3** for the reverse order assessment.

The thermal test portion of the HAC test sequence is not performed based on the condition of the test specimens after the 30-foot free drop and puncture tests. See **section 5.4** for this assessment.

The following HAC tests were not covered in the test plan and therefore not conducted.

- The ***crush test*** was not performed because it is not required since the heaviest Model 867 transport package weighs below 800 lbs which is less than the 1100 lbs. minimum weight limit for the test.
- The ***immersion – fissile material test*** is not required since the Model 867 package does not transport fissile material.
- The ***immersion – all packages test*** is not needed since the materials of construction used in the Model 867 transport package are impervious to water and are not structurally affected when immersed in water of at least 15 meters (50 feet).

Section 2 Construction and Condition of Test Specimens

2.1 Test Specimen Construction

The Model 867 transport package test specimen is constructed in accordance with QSA Global engineering drawings and Quality Assurance Program. The drawings and manufacturing documents accurately depict the design intent along with methods for building and verifying the finished product. See **Appendix C: Test Specimen Manufacturing Records** and **Appendix D: Test Specimen Inspection Records**.

The Model 867 is the source changer version of the SENTRY family of transport package. It has a maximum package weight of 780 pounds and a shielding capacity to transport 330 curies of cobalt-60 in either one of its two ports. The Model 867 package can be transported in either the basic (**Figure 2.1**) or standard configuration **(Figure 2.2** but with plastic inserts).

The basic configuration without the optional handling ribs represents the worst case test configuration for the failure modes and test orientation identified in **Sections 3.1 & 3.2**. Test specimen TP180J is built to the basic configuration shown in **Figure 2.1**. The test specimen weighs 666 pounds. All drop heights shall be adjusted higher to provide equivalent impact energy of a 780 pound package.

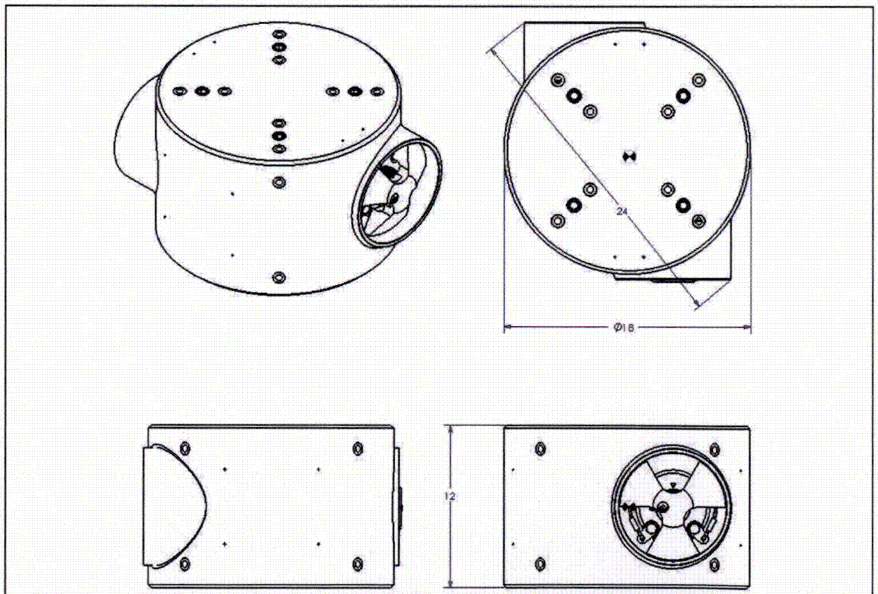


Figure 2.1: SENTRY Transport Package - Basic Configuration.

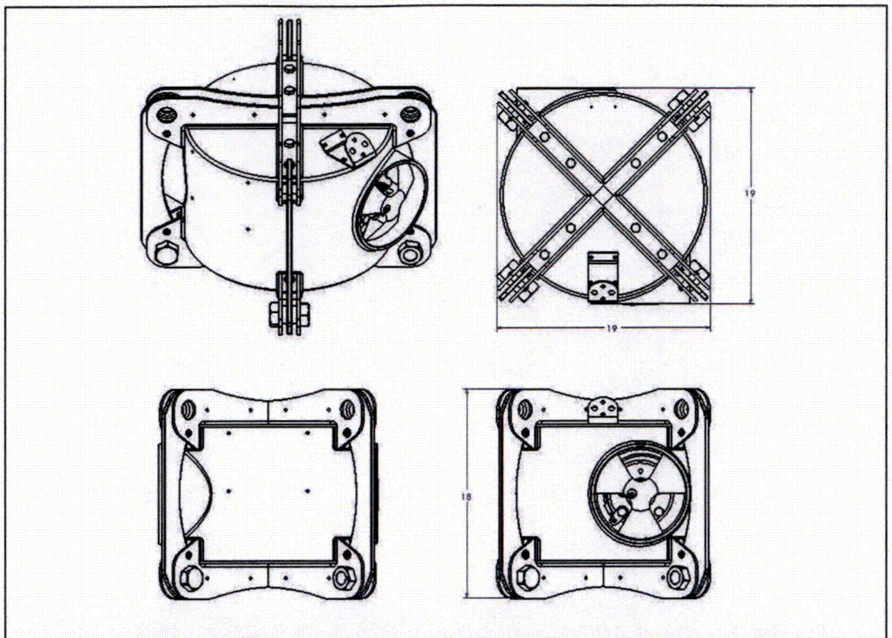


Figure 2.2: SENTRY Transport Package - Standard Configuration
NOTE: Plastic rib inserts not shown.

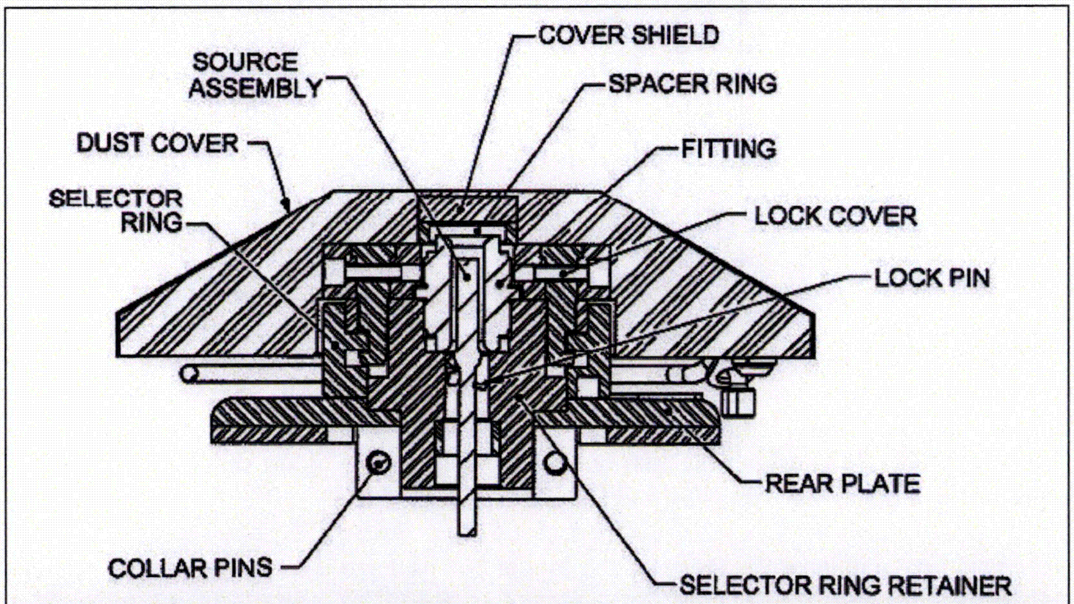


Figure 2.3 Model 867 New Dust Cover Design

Figure 2.3 shows the new dust cover design for the Model 867 source changer. The nomenclature used in **Figure 2.3** is referenced throughout this report.

The new dust cover design applies only to the Model 867 source changer and not the two projector versions of the SENTRY package. The new cover protrudes 0.3 inches beyond the welded port tube and the cover includes a disc shaped cover shield made from high density tungsten. The cover shield is needed to attenuate low energy Compton scatter emitting from the center of the port.

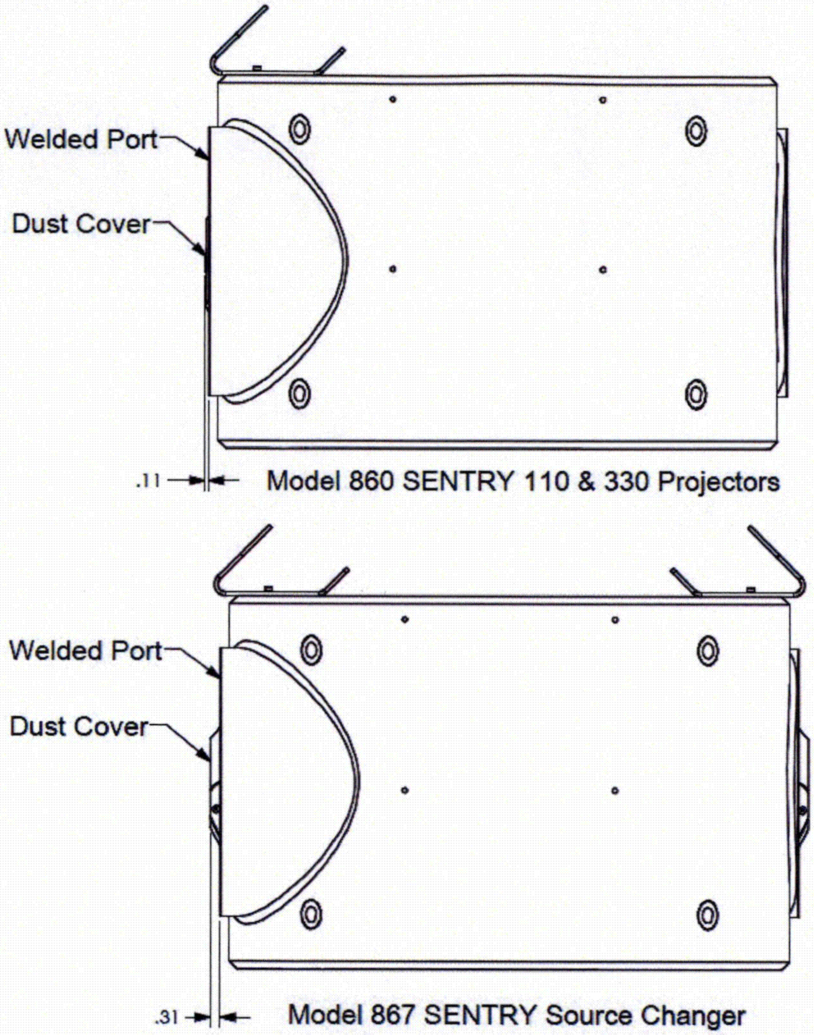


Figure 2.4 Previously tested Model 860 design versus new Model 867 Design

Figure 2.4 shows an additional 0.2 inches of dust cover protruding from the welded port in the new Model 867 design. The tests and assessments in this report shall focus on the effect this protrusion may have on NCT and HAC transport testing.

The primary containment system for the Model 867 package is the source capsule assembly which is permanently attached to the source assembly. The source capsules transported in the SENTRY Series of packages have been tested separately and demonstrated the ability to withstand the ANSI/ISO class 4 or 7MPa pressure test requirements. The secondary containment system, the transport package rear plate assembly and shield container, is open to the atmosphere and therefore in constant equilibrium with changing operating pressures.

The structural materials used in the construction Model 867 transport package retain their key mechanical and physical properties between -40°C (-40°F) and +38°C (+100°F). Therefore, the temperature of the test specimen did not need to be adjusted for the tests performed in test plan 213.

2.2 Test Specimen Modification

Other than including a simulated Model A424-13 source assembly in both ports, there were no other pre-test build modifications done to the test specimen. Build documentation is recorded on the temporary manufacturing instructions (TMI) for the test specimen. See **Appendix C: Test Specimen Manufacturing Records**

2.3 Test Specimen Pre-Test Shield Profile Measurements

Table 2.1 gives the maximum radiation measurements on and around the test specimen just before testing.

Two separate sets of measurements were taken, one with a Model A424-13 source assembly loaded into port "A" and then the same source loaded into port "B". The source activity at the time of measurement was 313.3 curies of cobalt-60. Direct measurements were factored up to correct for the 330 curie package capacity. The data given in **Table 2.1** is corrected for capacity and incorporate surface correction factors.

Table 2.1: Maximum Radiation Measurements Before Testing			
At Surface of Package		At 1 Meter from Surface of Package	
Port "A"	Port "B"	Port "A"	Port "B"
141 mR/h	179 mR/h	1.6 mR/h	2.9 mR/h

Section 3 Failure Modes and Test Orientations

3.1 Test Failure Modes

The test orientation, shown in **Figure 3.1,** targets one of the two welded ports and dust covers in an attempt to damage the package enough to cause an elevation in radiation measurements. The possible failures for this orientation considered under the required test conditions potentially leading to elevated radiation measurements on and around the transport package include the following:

1. Extreme displacement of the shield within the package enough to position the source in a much less shielded location.

2. Any release or loss of control of the source caused by either; damage to the rear plate assembly enough to allow the source to exit the package, loss of all rear plate hex bolts and/or detachment of the source capsule from the source assembly.

3. A significant rupture or opening in the exterior of the package leading to loss of foam protecting the shield during the thermal test.

3.2 Test Orientation

Figure 3.1 shows the planned test orientation for all drop tests. This orientation attempts to exploit the failure modes discussed in **Section 3.1** by targeting the features of the new dust cover design. The orientation for the puncture tests used the same orientation as the 4-foot & 30-foot drop tests as this continued to be the worst case orientation after the 4 & 30 foot drops damaged the test specimen.

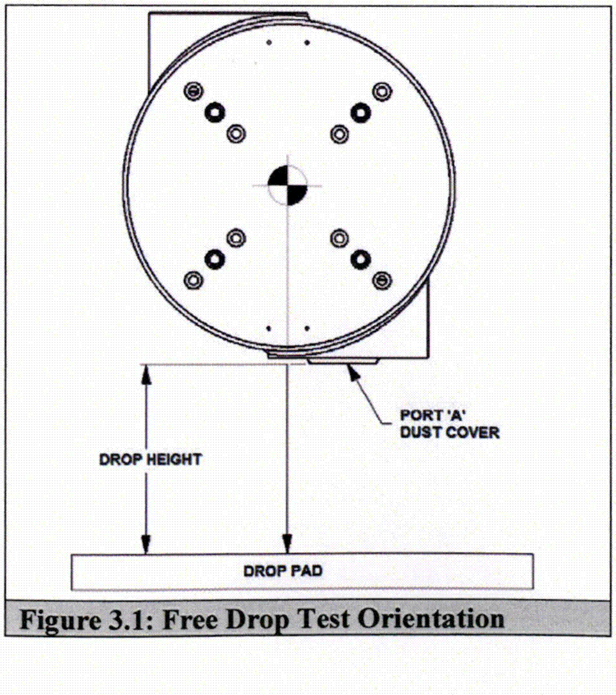


Figure 3.1: Free Drop Test Orientation

3.3 Free Drop Height Adjustment

The drop test heights specified in 10 CFR Part 71 were adjusted higher in all drop tests. The adjusted drop height allowed for future packages built heavier than the actual test specimens, but less than the maximum allowable weight specified for the transport package configuration, to demonstrate compliance with 10 CFR Part 71.

Test specimen TP180J, weighed 666 lbs. The maximum allowable transport package weight is 780 lbs. Therefore, the ratio for equivalent impact energy of a 780 pound package when related to the test specimen weighing only 666 pounds is 780/666 or 1.17.

All drop heights were factored up by 1.17 to provide the equivalent impact energy of the 780 pound transport package.

Section 4 Test Results

4.1 4-Foot (1.2-Meter) Drop Test Results

Test Specimen TP180J was dropped from 4.7 feet in the planned orientation - with port "A" facing downward towards the drop pad. See **Figures 4.1.1 & 4.1.2**.

<table>
<tr><th colspan="2">Table 4.1.2: Four Foot Free Drop Test Setup</th></tr>
<tr><td colspan="2">• No changes to the planned drop orientation.
• Test specimen weight = 666 lb (302 kg)
• Actual drop height = 4.7 ft. (1.4 m)
• Ambient temperature at time of test = 88°F (31°C)</td></tr>
<tr><td></td><td></td></tr>
<tr><td>Figure 4.1.1: Four foot drop setup – Side view</td><td>Figure 4.1.2: Four foot drop setup – End view</td></tr>
</table>

The specimen landed near the center of the essentially unyielding drop pad surface to impact directly onto the test specimen dust cover and welded port tube. After impact, the specimen bounced slightly and then rolled onto the opposite welded port "B" before coming to rest near the edge of the drop pad.

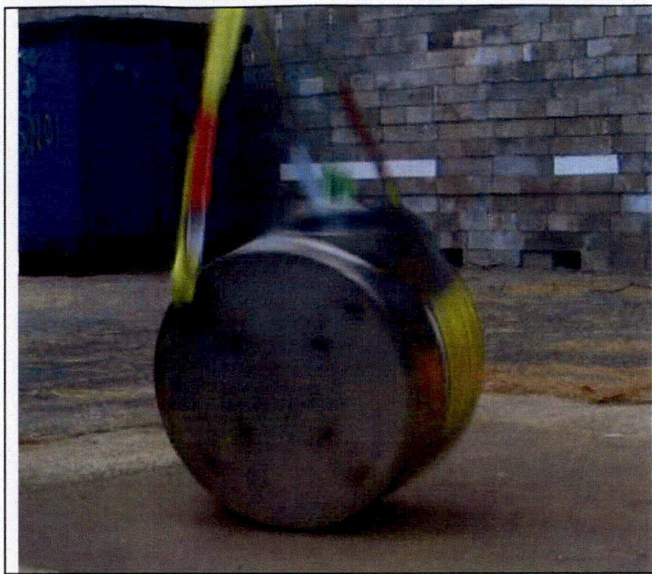


Figure 4.1.3: 4-foot drop impact – Side view.

Inspection of the specimen immediately after the drop found a rusty imprint of the drop pad surface on the outward facing surfaces of the plastic dust cover and also on the rim of the welded port tube of port "A". The welded port tube of port "B" was bent slightly inward towards the center of the port by about 0.5 inches. A small screw holding the dust cover storage bracket to the top surface of the specimen had broken off leaving the bracket with one remaining screw. The dust cover storage bracket and attachment screws provide no safety function to the package and are not considered important to safety.

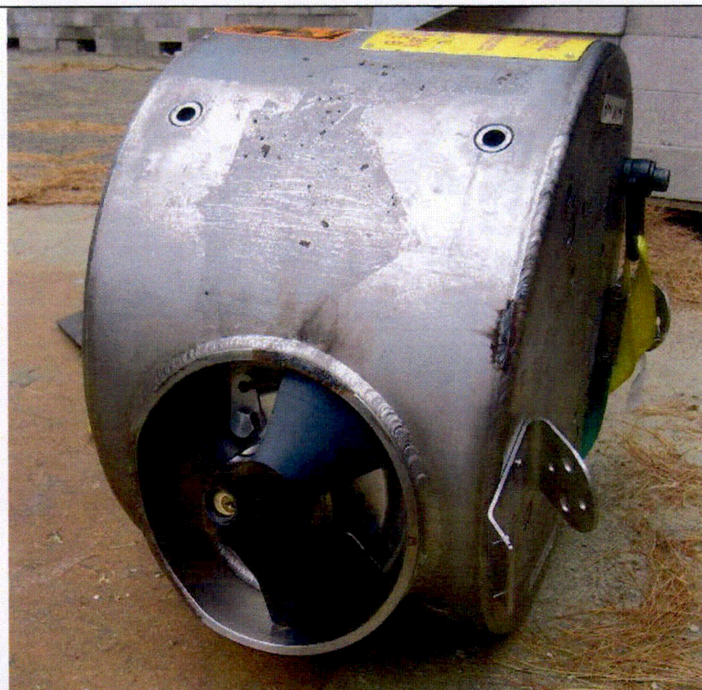


Figure 4.1.4: Port "A" – Immediately after drop.

Close examination of the specimen after removing both dust covers found no movement or damage to the source assembly or any of its locking features. No reduction in the safety of the package could be found.

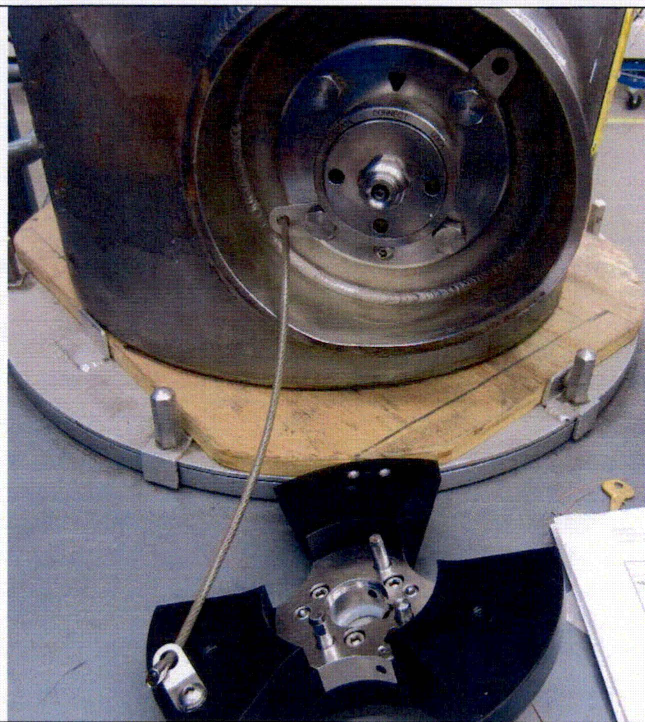


Figure 4.1.5: Port "A" - Close examination with dust cover removed

Below is a list of observations about the test specimen after the 4-foot drop test.

- Drop pad imprinted on dust cover and port "A" rim.
- Minor dent in top edge seam near port "A" about 2 inches long.
- Minor bend in port "A" tube toward tube center about 0.12 inches
- Minor bend in port "B" tube towards tube center about 0.50 inches.
- Dust cover bracket screw broke and missing.
- No movement or damage to source assembly.
- No damage to the rear plate or the rear plate attachment bolts.

Radiation measurements taken after the test were compared to measurements taken before the test and showed no substantial increase. **Table 4.1.1** gives the maximum radiation measurements before and after the 4-foot drop test.

A slight measurement difference can be attributed to a variation in the manual measurement technique and the accuracy of the measuring equipment (+/-10% for the E600 probe and meter). See **Appendix A: Radiation Profile Results** for the actual inspection data.

Table 4.1.1: Maximum Radiation Measurements Before & After 4-foot Drop

Taken	At Surface of Package		At 1 Meter from Surface of Package	
	Port "A"	Port "B"	Port "A"	Port "B"
Before	141 mR/h	179 mR/h	1.6 mR/h	2.9 mR/h
After	159 mR/h	180 mR/h	1.9 mR/h	1.3 mR/h

Based on the above test results, the Model 867 transport package satisfies the Normal conditions of transport test requirements of Test Plan 213, the Code of Federal Regulations, 10 CFR Part 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 (2009 Edition).

4.2 30-Foot (9-Meter) Drop Test Results

Test Specimen TP180J was dropped from 35 feet twice in the planned orientation - with port "A" facing downward towards the drop pad. The specimen rotated slightly during descent in the first drop and missed hitting port "A" face on, but appeared to hit port "A", to some extent, in the second drop.

Table 4.2.1: 1st Thirty Foot (9-Meter) Free Drop Test Setup	
• No changes to the planned drop orientation. • Test Specimen Weight = 666 lb (302 kg) • Actual Drop Height = 35 ft. (10.7 m) • Ambient temperature at time of test = 88°F (31°C)	
	
Figure 4.2.1: 1st Thirty foot drop setup – Side view	**Figure 4.2.2: 1st Thirty foot drop setup – End view**

In the first 30-foot drop, the specimen rotated slightly during descent and landed near the center of the essentially unyielding drop pad hitting the top edge of the welded body near port "A". **Figure 4.2.3** shows the point of impact on the specimen. After impact, the specimen bounced about 1-foot and then flipped twice before landing on the flat bottom surface of the welded body about 4-feet from the drop pad.

Inspection of the specimen immediately after the first drop found a rusty imprint of the drop pad surface at the welded edge seam between the cylinder and top surface of the body. The impact deformed the 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. The seam weld was sealed and completely intact.

A second 30-foot drop was performed to attempt to more completely impact port "A".

Figure 4.2.3: 1st Thirty foot drop damage.

In the second drop, the specimen again rotated during descent and landed near the center of the essentially unyielding drop pad. The point of impact appeared to miss again and hit the same edge surface hit in the first drop.

Table 4.2.2: 2nd Thirty Foot (9-Meter) Free Drop Test Setup

- No changes to the planned drop orientation.
- Test Specimen Weight = 666 lb (302 kg)
- Actual Drop Height = 35 ft. (10.7 m)
- Ambient temperature at time of test = 88°F (31°C)

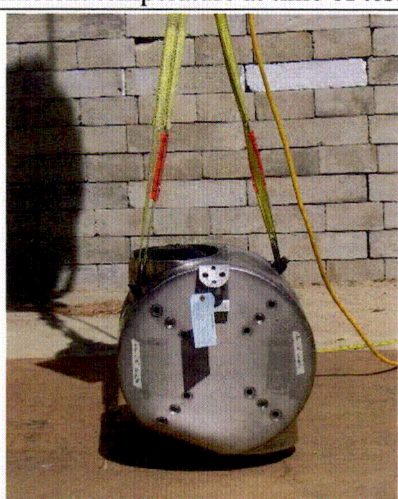


Figure 4.2.4: 2nd Thirty foot drop setup – Side view

Figure 4.2.5: 2nd Thirty foot drop setup – End view

Figure 4.2.6: 2nd Thirty foot drop impact – Side view.

Figure 4.2.7: 2nd Thirty foot drop impact – End view.

Figures 4.2.6 & 4.2.7 show the approximate moment of impact for the 2nd thirty foot drop test. After impact, the specimen bounced about 2-feet and then flipped before landing again on the flat bottom surface of the welded body about 2-feet from the drop pad against the brick retaining wall.

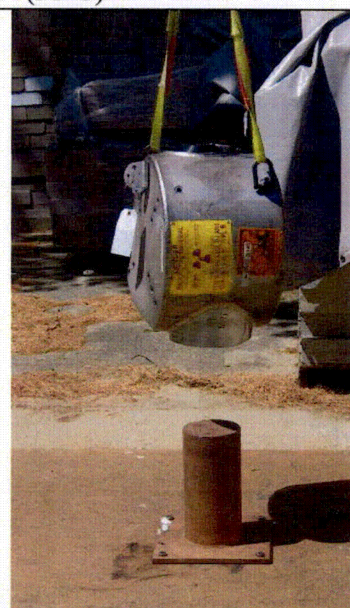
The edge seam dent from the first drop grew slightly in the second drop. The edge depression increased by about 1 inch inwards, and the top surface bulge grew about 1 inch outward. Again, the weld was sealed and completely intact.

A light rusty imprint of the drop pad surface could be seen on the outward facing surface of the port "A" dust cover. It appears the second impact was a glancing blow to the dust cover before hitting the edge seam again.

Figure 4.2.8: 2nd Thirty foot drop damage.

4.3 Puncture Drop Test Results

Test Specimen TP180J was dropped from 1-meter in the planned orientation - with port "A" facing downward towards the puncture billet mounted to the drop pad.

<table>
<tr><th colspan="2">Table 4.3.1: Puncture Drop Test Setup</th></tr>
<tr><td colspan="2">• No changes to the planned drop orientation.
• Test Specimen Weight = 666 lb (302 kg)
• Actual Drop Height = 3.9 ft. (1.2 m)
• Ambient temperature at time of test = 88°F (31°C)</td></tr>
<tr><td></td><td></td></tr>
<tr><td>Figure 4.3.1: Puncture drop setup – Side view</td><td>Figure 4.3.2: Puncture drop setup – End view</td></tr>
</table>

The specimen landed squarely on the top surface of the rigidly mounted puncture billet located at the center of the essentially unyielding drop pad. The plastic dust cover of the specimen hit directly onto the top of the billet. The port tube rim did not appear to contact the billet leaving the entire impact being fully applied to the plastic dust cover.

After impact, the specimen bounced up and flipped backwards hitting the side of the specimen on the billet again before landing on its side just off the drop pad. The orientation of the specimen immediately after the drop had the axis of both port tubes aligned horizontally relative to the drop pad surface with Port "A" at ground level and port "B" at the higher elevation by the parallel distance between the two ports. See **Figure 4.3.5** for the test specimen resting location and position immediately after the puncture drop.

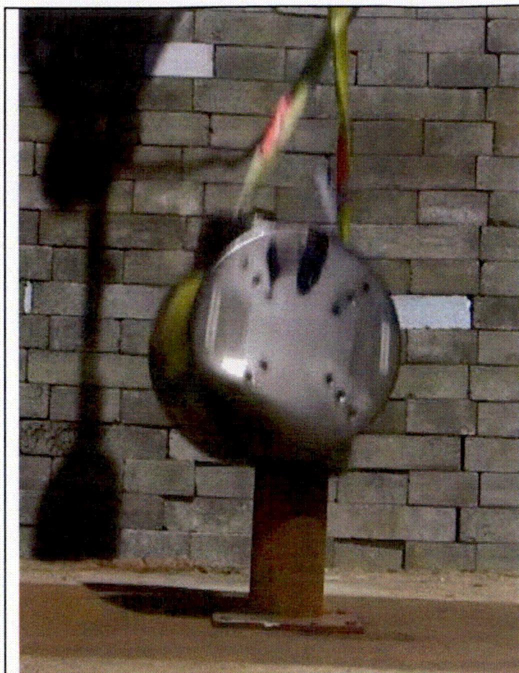


Figure 4.3.3: Puncture drop impact – Side view.

Figure 4.3.4: Puncture drop impact – End view.

Figure 4.3.5: Test specimen rest position after puncture drop.

A quick look at the specimen immediately after the drop found the plastic dust cover compressed into the port but without any significant damage. The brass plunger lock appeared

to be slightly deformed. See **Figure 4.3.6** for a close-up picture of Port "A" after the puncture test.

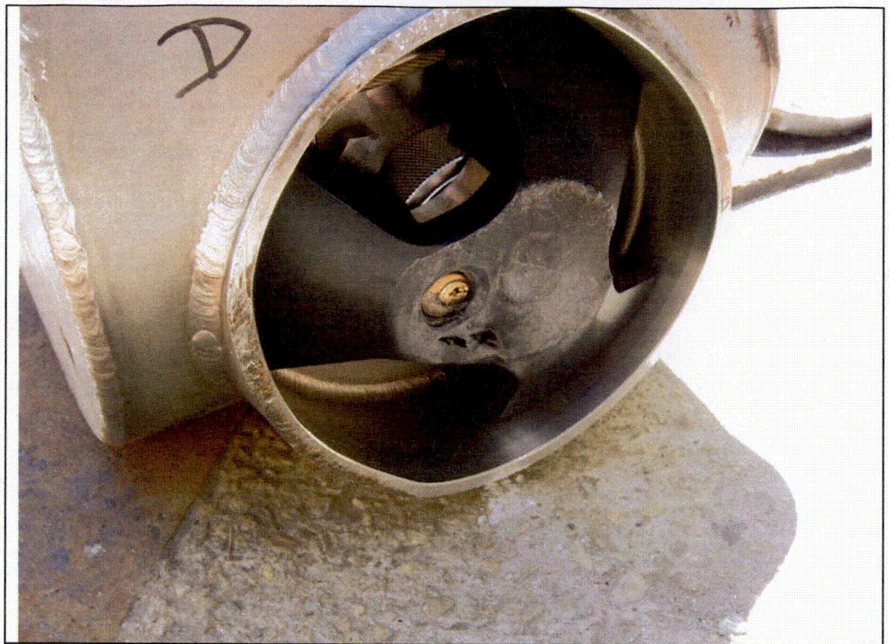


Figure 4.3.6: Damage after puncture drop.

4.4 Specimen Examination after Testing

The port "A" dust cover had to be cut in two pieces for removal from the specimen. The port "B" dust cover was completely intact and fully functional.

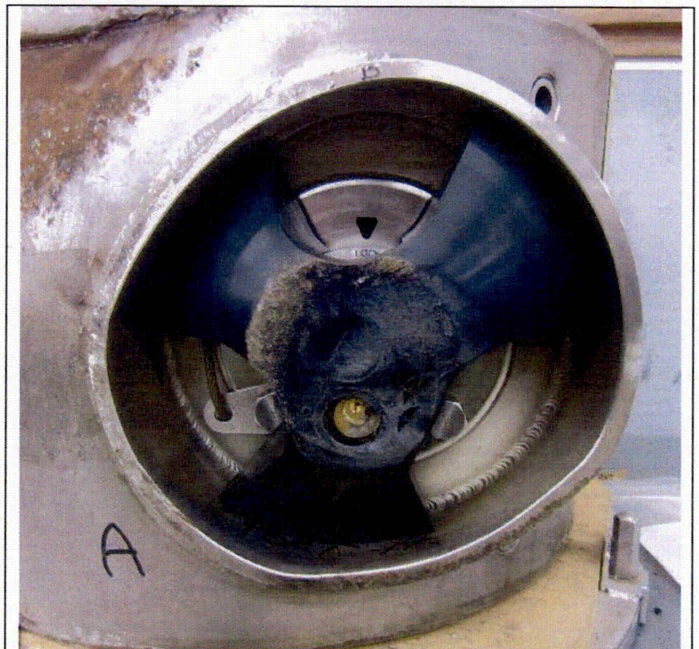


Figure 4.4.1: Port "A" after puncture drop.

Examination of the port "A" cover revealed the spacer ring had crushed axially but remained in the cover. The cover shield was intact and also remained in the cover. The cover shield did show an impact ring giving evidence it contacted the tungsten fitting during the test sequence.

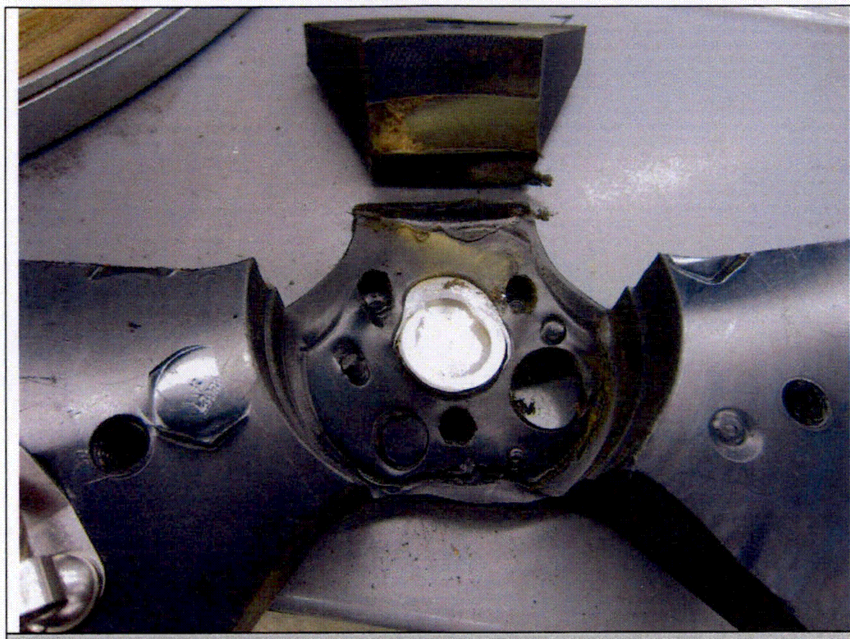


Figure 4.4.2: Cut dust cover with crushed (white) spacer.

The brass lock was damaged enough to prevent key insertion. The brass lock was drilled out to remove the lock cover. The lock cover was completely intact and remained in place. The rear plate assembly continued to secure and lock the source assembly in its fully shielded position within the package.

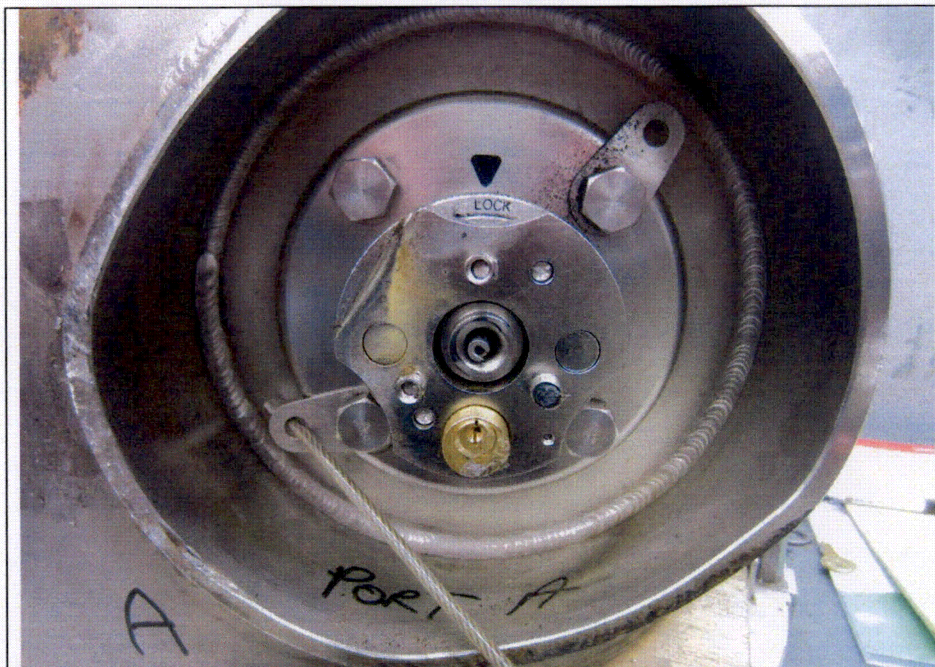


Figure 4.4.3: Lock assembly intact and functional – except brass lock.

The selector ring turned freely to enable the lock cover to be removed and to access the tungsten fitting. The fitting was undamaged and unscrewed from the selector ring retainer without issue.

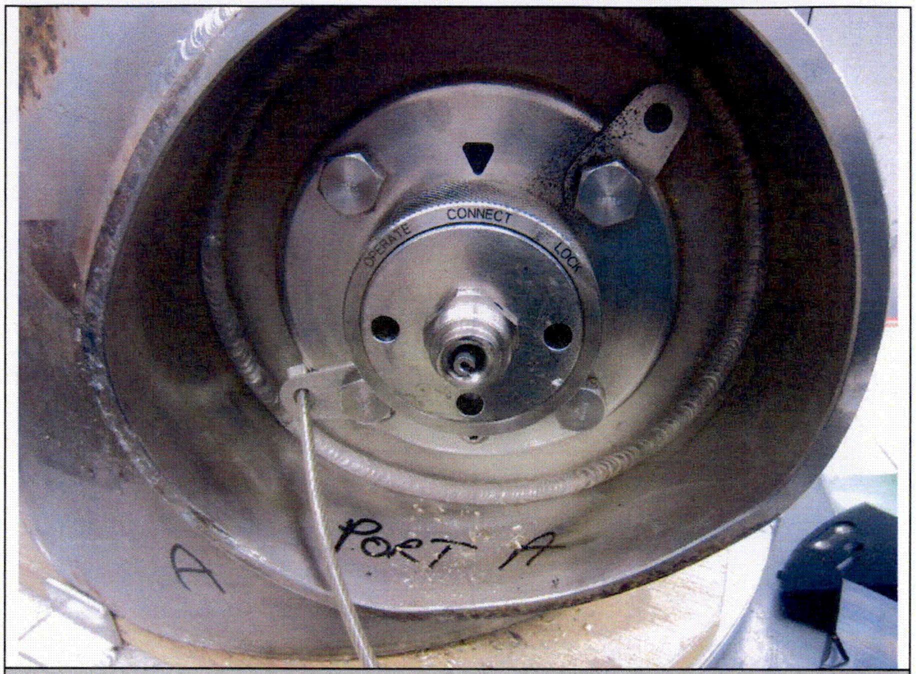


Figure 4.4.4: Tungsten Fitting undamaged and functional

The source assembly connector remained in its pre-test location and undamaged.

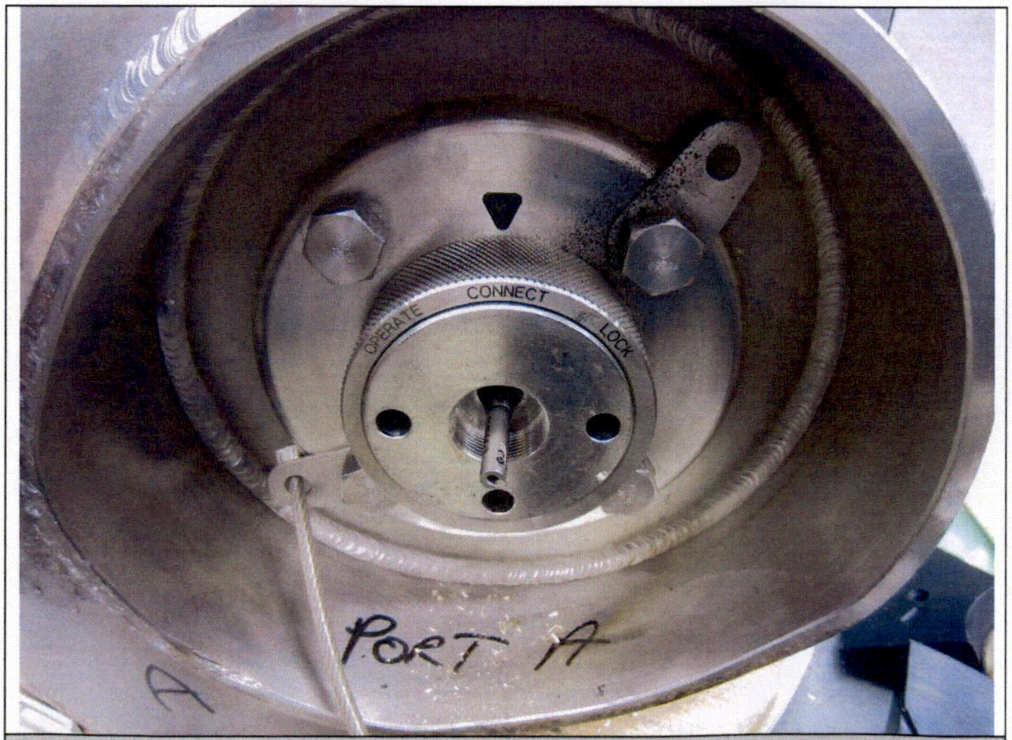


Figure 4.4.5: Source Assembly unaffected by testing.

Radiation measurements were taken without the benefit of the dust cover with cover shield because the cover would melt or burn away in the thermal test. The radiation measurements taken after the hypothetical accident condition sequence are given in Table 4.4. The higher 1-meter values are a result of the measurement taken without the plastic cover and cover shield in the ports.

Table 4.4: Maximum Radiation Measurements After HAC Test Sequence	
At 1 Meter from Surface of Package	
Port "A"	Port "B"
5.4 mR/h	4.6 mR/h

Section 5 Test Assessments

5.1 4-Foot Free Drop Test Assessment

The test results confirm the Model 867 transport package complies with the normal transport test requirements of 10 CFR part 71 and IAEA TS-R-1 (2009 Edition). The test resulted in 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.

5.2 30-Foot Free Drop & Puncture Test Assessment

The 30-foot free drop and puncture tests were both performed in accordance with test plan 213, 10 CFR 71, and IAEA TS-R-1 (2009 Edition).

A direct hit to the dust cover and welded port could not be obtained in any of the two 30-foot drop tests conducted under this plan and also the two 30-foot drops conducted under test plan 180 (TP180A).

In both the 4-foot drop and 1-meter puncture drops, the fall distances were short enough to prevent any appreciable specimen rotation - allowing a direct hit in both cases.

The previous test results from test plan 180 and the results in this report shall be used to assess the ability of the Model 867 package with the new plastic dust cover to meet the HAC test requirements of 10 CFR part 71 and IAEA TS-R-1 (2009 Edition).

The assessment shall consider each of the possible failure modes given here and in **section 3.1**:

- Substantial Shield Displacement
- Package Shell Rupture
- Source Release or Loss of Control

Substantial Shield Displacement

All radiation measurements taken before and after test plan 180 and this plan in any test orientation confirms the shield **does not** shift or move enough to result in radiation levels at or above 1-rem/hr at a meter from the surface of the package. In fact, the post HAC test radiation measurements in all the tests indicate levels acceptable for normal transport.

The thicker plastic dust cover material will provide slightly more impact absorption compared to the old design when hit directly on the dust cover. This will result in similar radiation measurements as previous test results.

Based on the above, the Model 867 with new dust cover design will not cause any substantial shield displacement and will therefore continue to meet the NCT and HAC test requirements of 10 CFR Part 71.

Package Shell Rupture

There is no evidence of a rupture to the Model 867 outer shell in any current and previous NCT and HAC test results. The tough austenitic stainless steel material gives the shell the ability to withstand large plastic deformations without rupture even when dropped multiple times on the same location.

Based on the above, the Model 867 with new dust cover design will not cause a shell rupture of the package and will therefore continue to meet the NCT and HAC test requirements of 10 CFR Part 71.

Source Release or Loss of Source Control

There are two possible failure modes to consider for causing a source release or a loss of source control. These are:

1. Failure of the rear plate attachment system to the extent the rear plate assembly becomes detached from the package.

2. Failure of the two lock pins within the rear plate assembly enough to allow the source assembly to fall from the package in a post-puncture drop or thermal test orientation.

<u>Rear Plate Attachment System</u>

The new Model 867 dust cover protruding 0.3 inches beyond the welded port may induce some deformation to the package from a direct hit in the 30-foot drop, but the deformation will not cause failure of the rear plate attachment system and its ability to secure the source in its shielded position.

The rear plate attachment system relies on material toughness and redundancy to keep the rear plate attached to the package. The system consists of the four hex bolts, a single security screw, the two collar pins, a lock and nut collar, and the rear plate itself.

Any deformation or shock load to the rear plate would need to cause failure of all four hex bolts, the security screw, and the two collar pins to allow the rear plate assembly to fall away from the package. The two collar pins are protected from shear and bending by their location inside the welded port behind the mounting plate. So even if all bolts and screws failed, the rear plate assembly would remain attached by the collar pins.

Any oblique angle hit to the dust cover would cause the lock and nut collars to bind in the mounting plate hole at their assembled location preventing the rear plate assembly detachment.

The austenitic stainless steel rear plate has already demonstrated its ability to remain intact and attached to the package after having undergone severe plastic deformation. The results of test plan 180, specimen TP180B gives evidence of the rear plate attachment system to remain intact after having undergone substantial damage.

Based on the above, the Model 867 with new dust cover design will not cause failure to the rear plate attachment system and will therefore continue to meet the NCT and HAC test requirements of 10 CFR Part 71.

Rear Plate Lock Pins

The two lock pins capture the helical windings on the cable of the flexible source assembly. The pins are made of high strength steel and are protected in the robust selector ring retainer. The selector ring retainer is essentially a 2.25 diameter pipe with a 0.88 inch thick wall made of austenitic stainless steel.

The lock pin forks extend into the center hole of the selector ring retainer to grip the source assembly cable. Since the lock pins are well protected in the selector ring retainer, the source assembly is the only other component capable of applying an impact load to the lock pin forks. An impact load can only be applied by the source assembly when the end of the source assembly connector is hit. The connector end is flush or below the outside end of the fitting. In order for the impact to be transmitted to the connector, the fitting would need to crush towards the lock pins. The fitting crush distance would equal the potential maximum fork deflection. The high compressive strength of the tungsten fitting along with the continued protection of the welded port tube as explained below will keep the lock pins intact and the source locked in place after the 30-foot and 1-meter puncture drops.

Damage to the lock pins from a 30-foot drop can be evaluated by comparing the damage sustained in the 4-foot drop to damage produced in the 1-meter puncture drop.

The 4-foot drop resulted in a direct hit to the dust cover outer surface and also the outward facing end of the welded port tube. In the 4-foot drop, damage to the dust cover and rear plate components were superficial and left all source securing features unaffected by the drop. The impact marks on the outward facing surface of the welded port tube proves the welded port had been recruited to absorb impact energy.

The 1-meter puncture drop also resulted in a direct hit to the dust cover, but with no contact with the welded port tube. In the 1-meter puncture drop, the damage to the dust cover was substantial resulting in a crushed spacer ring and an impact mark appearing on the cover shield from the fitting.

This damage comparison indicates the welded port tube would continue to provide sufficient impact protection to prevent failure of the rear plate lock pins and will therefore continue to allow the Model 867 with new dust cover design to meet the NCT and HAC test requirements of 10 CFR Part 71.

Based on the assessment above and after the 30-foot free drop and puncture test, the Model 867 meets the hypothetical accident conditions transport requirements of 10 CFR 71 and IAEA TS-R-1 (2009 Edition). Based on the assessment and after the tests, there was:

- No loss or dispersal of radioactive material or contents.
- No external radiation dose rate exceeding 10-mSv/h (1-rem/h) at 1 m (40 in) from the external surface of the package.
- No escape of other radioactive material exceeding a total amount A_2 in 1 week.

5.3 Reverse Sequence 30-Foot Free Drop & Puncture Assessment

If we were to reverse the test sequence and perform the puncture test before the 30-foot free drop, the Model 867 transport package would continue to meet the HAC requirements of 10 CFR Part 71 and also IAEA TS-R-1 (2009 Edition). The results show the puncture test does not damage the rear plate assembly and its attachment system enough to elevate radiation levels on and around the package or to allow the release or dispersal of the radioactive material.

For the sake of argument, let's say the puncture bar completely sheared off the lock cover along with the dust cover and additionally sheared off the fitting and the source connector in the process. The helical cable windings would remain attached to the lock pins because it is well protected in the selector ring retainer. This continued attachment would keep the source secure and shielded.

If the package was then dropped from 30-feet (after puncture damage), the recessed rear plate assembly, now without the dust cover, would be protected from an impact in any orientation by the welded port. Therefore the components of the rear plate assembly would not be damaged enough to cause elevated radiation levels on and around the package or to allow the release or dispersal of the radioactive material.

This allows the Model 867 transport package to successfully meet the hypothetical accident conditions transport test requirements of IAEA TS-R-1 (2009 Edition).

5.4 Thermal Test Assessment

Review of the damage to all test specimens after the drop tests suggest the fire test would have no affect on the radiation measurements taken after the drop tests. The reasons for this can be justified based on the condition of the test specimen after the drop tests and the properties of the materials used to secure and shield the source within the specimen.

5.4.1 Condition of Test Specimens before Thermal Test

- The internal structure for supporting the DU shield is intact and fully functional. The structure consists of the depleted uranium shield, the stainless steel welded shell body, the titanium shield locating pins, the stainless steel welded port tubes, and the stainless steel rear mounting plates with stainless steel rivet nuts. A copper barrier exists between all stainless steel components and the DU shield.

- The test results showed no unintentional openings in the welded shell body to allow the polyurethane foam, filling the void between the DU shield and shell

body, to fall away from the package in a thermal test. The polyurethane foam provides thermal insulation and blocks air flow around the shield protecting it from oxidizing during the thermal test.

- The source assembly is intact, undamaged and secure in the shielded position.

- The rear plate assembly continues to secure the source assembly to the package in its shielded position. The securing components of the rear plate assembly consists of the stainless steel rear plate, stainless steel lock slide, tungsten sleeve, stainless steel selector ring retainer, stainless steel nut & lock collars, four stainless steel ½-13 hex bolts, and one stainless steel 5/16-18 security screw.

- The dust cover would burn or melt away in the thermal test and also remove the cover shield with it. Radiation measurements were taken after the puncture test without the benefit of the dust cover and cover shield. The post-puncture test measurements confirm the Model 867 dose levels at 1-meter from the package surface is less than 1-rem/hr without the dust cover and cover shield.

5.4.2 Material Properties at Elevated Temperatures

- The melting temperature for all materials (depleted uranium, stainless steel, tungsten, and titanium) of the structure, rear plate assembly and source assembly is above the thermal test temperature of 800°C.

- The thermal expansion for all materials of the structure is less than the design clearance allowed for assembly.

- The stainless steel and titanium components of the structure, rear plate assembly and source assembly have about 30% and 60% of their room temperature strength at 800°C, respectively.

  The load condition during the thermal test is for the structure to support the static weight of the shield in suspension. The dynamic impact nature of the drop tests subjects the structure to a force over 100 times the static weight of the shield. This suggests 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.

Section 6 Final Test Assessment

The test results confirm the Model 867 transport package complies with the NCT and HAC test requirements of 10 CFR Part 71 and IAEA TS-R-1 (2009 Edition).

The test resulted in 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 after the 4-foot drop and did not show external radiation dose rates exceeding 10-

mSv/h (1-rem/h) at 1 m (40 in) from the external surface of the package after being subjected to and assessed to the HAC test sequence identified in 10 CFR Part 71.

The results and assessments in this report confirm the Model 867 transport package in any of its described configurations meet the hypothetical accident conditions test requirements of test plan 213, 10 CFR Part 71, and IAEA TS-R-1 (2009 Edition).